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PART II—NONMETALS

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CONTENTS.

[The dates of publication of the separate chapters are given in parentheses.]

	Page.
Thorium, zirconium, and rare-earth minerals, by W. T. Schaller (Sept. 1, 1920)	1
Fuel briquetting, by F. G. Tryon (Aug. 13, 1920)	33
Lithium minerals, by Herbert Insley (Aug. 12, 1920)	37
Peat, by K. W. Cottrell (Oct. 14, 1920)	41
Sodium compounds, by R. C. Wells (Nov. 16, 1920)	47
Potash, by W. B. Hicks and M. R. Nourse (Dec. 8, 1920)	77
Strontium, by G. W. Stose (Dec. 9, 1920)	95
Gypsum, by R. W. Stone (Dec. 28, 1920)	99
Mineral waters, by A. J. Ellis (Jan. 21, 1921)	115
Sand and gravel, by R. W. Stone (Jan. 5, 1921)	151
Gems and precious stones, by B. H. Stoddard (Feb. 2, 1921)	165
Foreign graphite, by A. H. Redfield (Feb. 5, 1921)	181
Phosphate rock, by R. W. Stone (Feb. 25, 1921)	211
Magnesite, by C. G. Yale and R. W. Stone (Mar. 7, 1921)	227
Sand-lime brick, by Jefferson Middleton (Mar. 5, 1921)	237
Salt, bromine, and calcium chloride, by Herbert Insley (Mar. 26, 1921)	239
Fuller's earth, by Jefferson Middleton (Mar. 9, 1921)	257
Talc and soapstone, by J. S. Diller (Apr. 14, 1921)	265
Mica, by Herbert Insley (Mar. 28, 1921)	269
Asphalt and related bitumens, by K. W. Cottrell (July 18, 1921)	279
Asbestos, by J. S. Diller (May 14, 1921)	299
Graphite, by L. M. Beach (July 19, 1921)	309
Concrete stone and concrete blocks, by G. F. Loughlin and M. E. McCaslin (July 27, 1921)	325
Barytes and barium products, by G. W. Stose (July 28, 1921)	335
Fluorspar and cryolite, by H. W. Davis (July 20, 1921)	349
Slate, by G. F. Loughlin and A. T. Coons (July 29, 1921)	369
Feldspar, by L. M. Beach (Aug. 12, 1921)	377
Silica, by L. M. Beach (Aug. 27, 1921)	379
Abrasive materials, by L. M. Beach and A. T. Coons (Sept. 16, 1921)	381
Cement, by E. F. Burchard (Sept. 21, 1921)	387
Lime, by G. F. Loughlin and A. T. Coons (Oct. 6, 1921)	405
Stone, by G. F. Loughlin and A. T. Coons (Oct. 18, 1921)	419
Artificial gas and by-products in 1917–18, by R. S. McBride (Nov. 16, 1921)	457
Natural-gas gasoline, by E. G. Sievers (Dec. 7, 1921)	519
Sulphur and pyrites, by P. S. Smith (Apr. 29, 1922)	535
Index	547

ILLUSTRATIONS.

	Page.
FIGURE 1. Production of fuel briquets, 1907–1919, in the Eastern, Central, and Pacific Coast States, and in the United States	33
2. Graph showing production of graphite in principal countries, 1910–1919	183
3. Map showing location of graphite deposits in Austria and Czecho-Slovakia	187
4. Map showing location of graphite deposits in Chosen	198
5. Map showing location of graphite deposits in French Indo-China	200
6. Map showing location of graphite deposits in New Zealand	207
7. Diagram showing production (sales), consumption, imports, and exports of salt, 1900–1919, in short tons	240

		Page.
Figure 8.	Diagram showing quantity, value, and average price per pound of bromine produced annually in the United States, 1890-1919....	252
9.	Diagram showing production, total value, and average value per ton of fuller's earth from 1895 to 1919..........	259
10.	Diagram showing percentages of pavements of different types in American cities..........	296
11.	Section from Cerro del Temporal across Roosevelt reservoir and by the American Ores & Asbestos Co.'s mine to the summit of Coon Creek Butte, in the Sierra Ancha, Ariz..........	301
12.	Diagram showing production of crystalline graphite in the United States, 1900-1919, and in Alabama, 1913-1919..........	311
13.	Diagram showing production of manufactured graphite in the United States from inception of the industry in 1897 to 1919, inclusive..........	313
14.	Diagram showing production of graphite in principal countries, 1910-1919..........	317
15.	Map showing location of graphite mines and mills in Chester County, Pa..........	318
16.	Diagram showing production of fluorspar in the United States, 1883-1919, and imports, 1910-1919..........	354
17.	Curve showing average prices per ton of fluorspar at the mines in the United States, 1883-1919..........	355
18.	Artificial gas sold in the United States, 1898-1918..........	462
19.	Artificial gas sold per plant in the United States, 1898-1918......	476
20.	Artificial gas sold per capita in the United States, 1898-1918.....	480
21.	Average price of artificial gas sold in the United States, 1898-1918.	482
22.	Quantity and value of natural-gas gasoline produced in the United States, 1911-1919..........	522
23.	Natural-gas gasoline produced in the United States, by States, 1911-1919..........	523

Note.—Owing to the long delay in obtaining some of the figures for the chapters on petroleum, natural gas, coal, coke, and clay-working industries it has been decided to omit these chapters from this volume and to include complete statistics in the volumes for 1920 or 1921. Certain figures on these subjects are given in the summary at the beginning of Part I of Mineral Resources for 1919.

MINERAL RESOURCES OF THE UNITED STATES, 1919—PART II.

THORIUM, ZIRCONIUM, AND RARE-EARTH MINERALS.

By Waldemar T. Schaller.

INTRODUCTION.

The production of thorium, zirconium, and rare-earth minerals is of relatively small consequence, the combined value of the domestic product and of the imports of both crude minerals and manufactured salts never having amounted to half a million dollars in any one year. The value of the finished products, as sold, is of course much greater. These minerals, when found, usually cause some excitement to the prospector and miner and there seems to be a rather widespread misunderstanding as to their market value. The fact that monazite and zircon and many of the other thorium or zirconium bearing minerals are much heavier than ordinary minerals at once gives them a much higher value in the uninformed prospector's mind than is warranted. The value of monazite depends altogether on its content of thorium oxide, which can be determined only by a careful chemical analysis. A large deposit of monazite, if its thorium content is too low, would be absolutely worthless. Zirconium has been shrouded in a good deal of mystery, the element being supposed to have properties so phenomenal that any deposit of zircon is of great value. The facts that the metal zirconium can be extracted from zircon, the silicate of zirconium, only with great difficulty and expense and that the foreign deposits of the natural oxide of zirconium are large enough to supply the entire demand make the value of any domestic deposit of zircon doubtful.

This report aims to set forth the world relations as well as the domestic resources of these minerals so that the intending producer can readily understand the situation before undertaking development work.

The present report is essentially a reprint of the reports for 1916, copies of which are no longer available for distribution. The figures of production have been brought up to date as far as possible, the text has been slightly revised, and additional available information has been added.

THORIUM MINERALS.

CONDITION OF INDUSTRY.

The oxide of thorium, or thoria (ThO_2), glows intensely when heated and is therefore used in making incandescent mantles for gas lights. Thoria is obtained by ignition of the nitrate, the thorium salt that is handled on the market. After a thorium mineral is mined and shipped, two factors chiefly determine its value—the quantity and the ease of extraction of the thoria contained in the mineral. Obviously, then, a mineral corresponding in composition to thoria would be the most valuable, and the mineral thorianite, which has this composition, is in fact the most valuable of such minerals. The only known commercial deposits of thorianite, those of Ceylon, have been worked out, and although several other minerals high in thoria (thorite, auerlite, and others) have been mined to a small extent, only a single mineral, monazite, has been found in quantities sufficient to yield a continuous production for many years.

The domestic deposits of monazite sand, the only thorium mineral produced in this country, are described in several papers, listed in the bibliography given on pages 16–18. This bibliography also includes papers describing foreign localities as well as those treating in general of monazite and the monazite industry. The conditions of the monazite sand industry throughout the world are stated in a quantitative way rather than in a descriptive way, so that the intending producer of domestic sand can see what he would have to compete with and, from the qualities of his own sand, can judge for himself whether he can profitably undertake the production of his particular lot of sand. The monazite-sand industry in the United States was prosperous at the beginning of this century and continued so until about 1910, after which the production ceased entirely for several years. Some sand has been mined and marketed since 1914, but the industry has in no way regained its prosperity of a decade or two ago.

The United States, Brazil, and India have produced practically all the monazite consumed. Several other countries have yielded small quantities, but relatively their production has been insignificant. Some of these deposits, at present idle, may prove to be of value if the price of thorium nitrate continues to advance.

Monazite was found in the Carolinas in 1879, and the placer deposits there were first worked about 1886. The next year the mineral was shipped and more or less has been mined and shipped ever since. The quantity produced in the United States reached its maximum in 1895. In this year monazite sand from the rich coastal deposits of Brazil entered the market and in the next few years the domestic production fell to almost nothing, the combined total for 1896 and 1897 being valued at about $3,500. Increased demand soon caused a revival in the domestic output, which in 1905 again approached the maximum. From 1893 to 1910, inclusive, there was a large production of monazite in this country; from 1911 to the present time the production has been small, notwithstanding the increased consumption of thorium nitrate.

To what is this decline in the domestic production due? A comparison of the figures of production and imports in the table on page

4 shows that the decline in the price of manufactured thorium nitrate has been accompanied by a marked decline in the domestic production of the crude mineral; that this decline in domestic production has been accompanied by an increase in the imports of crude mineral from foreign countries; and that this increase of imports of crude mineral has, in turn, been accompanied by a steady decrease in the quantity of manufactured thorium nitrate imported. In short, the cheapness of manufactured thorium nitrate in 1910 permitted it to be imported at a price lower than the cost of manufacture from domestic monazite sand; but since thorium nitrate has been manufactured profitably in this country from imported monazite sand the imports of the manufactured salt declined until, in 1918, none was imported, whereas more than 50 tons was imported annually prior to 1915. Thus, by reason of its cheapness and of its higher content of thoria, foreign crude monazite has practically put an end both to the domestic production of monazite sand and to the importation of thorium nitrate.

The mineral monazite is widespread in its occurrence throughout the world, but forms only a very small fraction of 1 per cent of the rock (gneiss, pegmatite, etc.) containing it. On decomposition of the rock, the monazite and other resistant minerals are not attacked chemically, but remain behind unaltered, and, being much heavier than the products of decomposition, are gradually but slowly concentrated in the residue from the broken-down rock. Locally, river waters will effect a concentration of the heavy minerals into monazite-bearing river sands and gravels. If the ocean encroaches on an area of such decomposed rock, the selective action of the sea waves will still further concentrate the heavier minerals. Seacoast deposits of sand, therefore, contain monazite in higher natural concentration and cover larger areas than river-bed deposits. Even if the percentage of thoria in monazite were constant (which it is not; see pp. 12–13 for analyses), seacoast monazite sands would contain more thoria than river-bed sands on account of their greater content of monazite.

The cheapness of labor in Brazil and India, the two great monazite-producing countries of the world, and the relatively low cost of ocean transportation are further facts which enter into any consideration of the mining of domestic monazite. A third factor is the higher percentage of thoria in the foreign monazite sand. That from Brazil averages about 6 per cent of thoria, that from India about 9 per cent, whereas that from this country, according to the published analyses, averages only 4 to 5 per cent (p. 12). Any project to revive the mining of domestic monazite sand must, therefore, consider at least three essential features—the market price of thorium nitrate, the cheapness of imported foreign monazite sand, and the percentage of thoria in the sand.

PRODUCTION AND IMPORTS.

A statement of the production of monazite sand in the United States is given in the subjoined table. To domestic production are added for comparison the imports of monazite sand, the imports of thorium nitrate, and the price per pound of thorium nitrate. A comparison of domestic production with imports and prices shows that the domestic production declined as the imports of sand increased, and also that the imports of thorium nitrate were affected by both the domestic production and the imports of foreign sand. So much sand was imported in 1916 and 1917 that only about half a ton of thorium nitrate was brought in each year, the thorium nitrate used in the manufacture of incandescent mantles being prepared in this country from imported sand. In 1918 no thorium nitrate was imported.

The statistics of imports given here and elsewhere in this report are furnished by the Bureau of Foreign and Domestic Commerce, Department of Commerce

Monazite sand produced in the United States, 1893–1919, and monazite sand and thorium nitrate imported for consumption, 1901–1919.

Year.	Monazite sand produced in the United States.		Imports of monazite sand.		Imports of thorium nitrate.		Price per pound of thorium nitrate.[a]
	Quantity (pounds).	Value.	Quantity (pounds).	Value.	Quantity (pounds).	Value.	
1887	(b)	(b)					[c] $500.00
1893	130,000	$7,600					
1894	546,855	36,193					[d] 221.00
1895	1,573,000	137,150					[d] 58.00
1896	[e] 30,000	1,500					[d] 14.00
1897	44,000	1,980					[f] 7.00
1898	250,776	13,542					[d] 4.00
1899	350,000	20,000					[f] 3.40
1900	908,000	48,805					[f] 3.20
1901	748,736	59,262			(g)	(g)	
1902	802,000	64,160		$12	(g)	(g)	[i] 4.00
1903	862,000	64,630			64,520	$232,155	5.86
1904	744,999	84,838			58,655	249,904	5.98
1905	1,344,418	162,308			52,378	269,504	6.53
1906	846,175	152,312			40,090	139,929	3.78
1907	547,948	65,754			51,441	152,666	4.29
1908	422,646	50,718			65,289	173,239	4.70
1909	541,931	65,032	69,988	8,324	127,833	236,057	3.87
1910	99,301	12,006	453,554	39,699	124,808	219,615	3.10
1911			705,149	60,542	121,111	238,841	3.00
1912			556,959	47,334	117,485	225,386	3.00
1913			817,810	65,848	119,044	230,628	2.73
1914			770,842	61,595	101,927	239,376	2.98
1915	[j] 36,000	3,600	1,873,971	161,456	67,247	170,268	[k] 4.50
1916	37,872	3,400	2,436,197	188,383	909	3,884	[l] 6.25
1917	22,000	1,760	5,828,270	355,017	1,188	2,359	[m] 8.00
1918			2,994,515	204,661			[n] 8.00
1919	(o)	(o)	632,568	48,768	3,307	5,250	[p] 3.75

[a] The first prices given are only approximate. The prices after 1898 are an average for the year and may likewise be only approximate.
[b] A production of 24,000 pounds in 1887 was reported as having been shipped from Brindletown Creek, Burke County, N. C., but no value was reported, and no other production was reported until 1893.
[c] In 1888 thorium nitrate was quoted at approximately $500 a pound. Pratt, J. H., Zircon, monazite, and other minerals, etc.: North Carolina Geol. Econ. Survey Bull. 25, p. 35, 1916.
[d] Molinari, Ettore, General and industrial inorganic chemistry, p. 402, 1912.
[e] Production (exports) of Brazilian monazite sand began in 1895.
[f] Kithil, K. L., Monazite, thorium, and mesothorium: Bur. Mines Tech. Paper 110, p. 28, 1915.
[g] The figures for the fiscal year 1901 are 12,986 pounds, valued at $41,663, and for the fiscal year 1902 they are 10,480 pounds, valued at $34,310. The imports of thorium nitrate do not include the imports of manufactured gas mantles.
[h] Includes thorite.
[i] The prices for 1902 to 1914, inclusive, are taken from the report by Kithil cited above. An average price was taken for those years in which a variation was shown.
[j] The figures of production for 1915 were not received until after publication of the Summary of Mineral Production of the United States for 1915.
[k] The prices for 1915 ranged from $3.75 to $6.
[l] The prices for 1916 ranged from $4.75 to $8.50.
[m] The prices for 1917 ranged from $7.00 to $8.00.
[n] The prices for 1918 ranged from $8.00 to $8.25.
[o] Only one producer. Figures can not be revealed.
[p] The prices for 1919 ranged from $3.75 to $8.00 The figures for 1915 to 1919 were kindly furnished by Dr. Hugo Lieber, 23 East Twenty-sixth Street, New York City.

Thorium oxide and other salts and scrap mantles imported, 1909–1919.

Year.	Thorium oxide and other salts.		Scrap mantles.	
	Quantity (pounds).	Value.	Quantity. (pounds).	Value.
1909	17,549	$19,596		$3,926
1910	5,234	8,500		2,194
1911				3,227
1912				1,822
1913	1,763	2,694	12,107	434
1914	763	1,687	52,473	3,099
1915	139	349		
1916	4,099	9,487		
1917	11	293		
1918	28	124		
1919				

The duty on imported monazite sand was 6 cents a pound in 1902; on August 6, 1909, the duty was changed to 4 cents a pound; in July, 1913, the duty became 25 per cent ad valorem. Imported thorium nitrate paid 25 per cent duty from 1901 to 1908, 40 per cent in 1909 and until July, 1913, when the duty was changed back to 25 per cent. Thorium oxide and other salts paid 40 per cent until 1913, when the duty was reduced to 25 per cent. Scrap mantles, or mantle ashes, paid 40 per cent duty until October 4, 1913; since then the duty has been 10 per cent.

WORLD'S PRODUCTION.

The production of monazite sand in the United States, Brazil, and India is given in the following table, both in short tons and in metric tons. These three countries have produced practically all the thorium minerals that have been utilized in the manufacture of thorium nitrate. The monazite and thorite produced in Norway, combined with the very small production in other countries, averages less than 0.1 per cent.

World's production of monazite sand, 1893–1919.

Year.	United States.		Brazil.		India.		Total.		Percentage production of the United States.
	Short tons.	Metric tons.	Short tons.	Metric tons.	Short tons.	Metric tons.	Short tons.	Metric tons.	
1893	65	59					65	59	100
1894	273	248					273	248	100
1895	787	714	3,307	3,000			4,094	3,714	19
1896	15	14	192	174			207	188	7
1897	22	20	249	226			271	246	8
1898	125	114	2,149	1,949			2,274	2,063	5
1899	175	159	2,932	2,659			3,107	2,818	6
1900	454	412	1,633	1,481			2,087	1,893	22
1901	374	339	1,811	1,643			2,185	1,982	17
1902	401	364	1,328	1,204			1,729	1,568	23
1903	431	391	3,636	3,298			4,067	3,689	11
1904	372	337	5,357	4,860			5,729	5,197	6
1905	672	610	4,891	4,436			5,563	5,046	12
1906	423	384	4,797	4,351			5,220	4,735	8
1907	274	249	4,891	4,436			5,165	4,685	5
1908	211	191	5,473	4,965			5,684	5,156	4
1909	271	246	7,121	6,459			7,392	6,705	4
1910	50	45	5,994	5,438			6,044	5,483	(a)
1911			4,064	3,687	932	845	4,996	4,532	
1912			3,746	3,398	1,271	1,153	5,017	4,551	
1913			[b] 1,584	[b] 1,436	1,383	1,255	2,967	2,691	
1914			[c] 661	[c] 600	1,328	1,204	1,989	1,804	
1915	18	16	[c] 484	[c] 439	1,241	1,126	1,743	1,581	1
1916	19	17			1,448	1,314	1,467	1,331	1
1917	11	10	1,252	1,136	2,173	1,971	3,436	3,117	(a)
1918			551	500	2,371	2,151	2,922	2,651	
1919	(d)	(d)	(e)	(e)	(e)	(e)	(e)	(e)	

[a] Less than 1 per cent.
[b] To France, Germany, and the United States.
[c] All to the United States.
[d] Only one producer. Figures can not be revealed.
[e] Figures not available.

LOCALITIES.

UNITED STATES.

The workable deposits of monazite sand in the United States are in North Carolina, South Carolina, and Idaho. In North Carolina deposits of commercial value have been found in Alexander, Burke, Catawba, Caldwell, Cleveland, Gaston, Iredell, Lincoln, McDowell, Polk, and Rutherford counties; in South Carolina in Anderson, Cherokee, Greenville, Laurens, Oconee, Pickens, and Spartanburg counties. The Idaho deposits are around Centerville, Boise County.

These domestic deposits have been repeatedly described and are well summarized in Bulletin 25 of the North Carolina Geological and Economic Survey (1916) and therefore need not be discussed here. No reports of production from the Idaho field have been received in recent years, and the production from the Carolinas has in recent years been very small.

Samples of monazite sand from a locality near Jacksonville, Fla., have been received from several persons. It is reported that a company has undertaken extensive development work at this locality. (See under zircon, p. 19.)

BRAZIL.

The deposits of monazite sand in Brazil lie along the coast of the States of Bahia, Espirito Santo, and Rio de Janeiro, from Maranhao, in Bahia, south to the State of Rio de Janeiro. Deposits occur also in the sandy beds of rivers of the interior. The following localities along the coast are given by Gottschalk:[1]

Praia Massanduba, near Cape Frio, deposits of titaniferous iron containing some monazite; Macaha, 45 miles farther north, a small deposit; at the foot of the Cliffs of Siry, 30 miles north of the southern frontier of the State of Espirito Santo, a reputedly rich bed; at Maratayso Praia, 2 miles farther north, a poor bed; at the foot of Mount Aga, at Piuma, just south of Benevente, two beds not far apart; at Ubu, 4 miles north of Benevente, a better deposit; 2 miles north, at Maimba, and 2 miles farther north, at Miahype, Federal beds with extensive private marginal deposits. Miahype is considered by some persons one of the richest beds in Brazil. Four miles north of this come the southernmost of the Guarapary beds—Rastinga, Canto de Riacho, Praia de Diogo, etc. Nothing occurs for 15 miles northward till Ponto da Fructa and Victoria. Eighteen miles north of Victoria is a deposit at Nova Almeida, and 20 miles farther one at Regencia, described as particularly large. Seventy miles farther north are the Sao Matheus beds. It is said that certain beds still farther north—those of Padro, in the State of Bahia, are constantly being renewed by the wave action of extremely high tides beating upon the clay cliffs. Two other beds in the State of Bahia are mentioned—one at the mouth of the Cahy River and another just north of the River Carahyba. It is said that neither is important.

The coast sands were originally rich enough to be shipped as found, but in later years these rich natural concentrations have been worked out and the sand is now artificially concentrated before being shipped, so as to contain at least 85 per cent of monazite.

The interior deposits are in the sandy beds of rivers of the States of Minas Geraes, Espirito Santo, and Rio de Janeiro. The formation is similar to that of the Carolinas, the stream sands and bottom lands containing about the same proportion (0.3 per cent) of monazite. Locally some of the deposits are much richer.

The production of monazite sand in Brazil, as based on the exports, is reported to be as follows:

Monazite sand produced (exported) in Brazil, 1895–1919.

Year.	Quantity (short tons).	Value.	Average value per ton.	Year.	Quantity (short tons).	Value.	Average value per ton.
1895	3,307	....	....	1908	5,473	$551,744	$101
1896	192	....	....	1909	7,121	704,387	99
1897	249	$21,602	$87	1910	5,994	620,605	104
1898	2,149	92,775	43	1911	4,064	540,688	133
1899	2,932	....	....	1912	3,746	528,614	141
1900	1,633	165,412	101	1913	1,584	186,520	118
1901	1,811	165,154	91	1914	661	79,068	120
1902	1,328	261,141	197	1915	484	56,358	117
1903	3,636	360,797	99	1916	....	....	....
1904	5,357	529,597	99	1917	1,252	(a)	....
1905	4,891	486,835	99	1918	551	(a)	....
1906	4,797	478,961	100	1919	(a)	(a)	....
1907	4,891	486,066	99				

[a] Figures not available.

Monazite sand exported from Brazil, 1910–1919, in short tons.

By States.

State.	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919
Bahia	757	614	1,347	......	......	......	......	......	......	......
Espirito Santo	1,322	2,272	2,250	1,574	661	484	......	......	......	......
Rio de Janeiro	3,915	1,178	149	10	......	......	......	......	......	......
	5,994	4,064	3,746	1,584	661	484	......	[a] 1,252	[a] 551	......

[a] Source, by States, unknown.

[1] Gottschalk, A. L. M., Brazilian monazite sands lie in coastal strip: Min. and Eng. World, May 15, 1915.

Monazite sand exported from Brazil, 1910–1919, in short tons—Continued.

By destinations.

Destination.	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919
Germany	2,906	2,083	2,043	282	......	......	......	......	......	......
France	1,864	1,209	1,041	858	......	......	......	......	......	......
United States	1,213	772	661	441	661	484	......	......	......	......
Italy	11	......	......	......	......	......	......	......	......	......
Great Britain	......	......	1	3	......	......	......	......	......	......
	5,994	4,064	3,746	1,584	661	484	......	a1,252	a551	......

a Destination unknown.

INDIA.

Travancore.—Monazite is widely distributed over the State of Travancore, in the extreme southwestern part of India. The rocks are essentially gneisses and intruded pegmatites. Many of the soils and river sands show monazite, but only in certain naturally concentrated deposits near the seacoast are the deposits of commercial size. The selective action of the sea waves has led to local concentrations of large quantities of monazite in the sands. The monazite sand is further concentrated by artificial means and, until the war, was exported to Germany. The deposits were discovered by a German prospector in 1909, and work was begun by the London Cosmopolitan Mining Corporation in 1911, since when there has been a steady production.

The following description of the deposits is taken from an article on "Monazite in southern India," in the Mining Journal (London), for August 10, 1912:

Hitherto the chief localities for the mineral monazite have been Brazil and Carolina in the United States of America. It is not unlikely that in the near future southern India will be a serious competitor in the market. The chief locality, one may say almost the only locality, is the native State of Travancore, forming the extreme southern portion of the Presidency of Madras, and separated from British India by the range of hills known as the Western Ghauts.

The deposits brought into public notice in 1909 by Mr. C. W. Schomberg, of the London Cosmopolitan Mining Corporation, occur along the coast on the east and the west, and are somewhat extensive. Starting on the eastern side, north of the Vattokotta Fort, the mineral occurs in isolated patches, but these are not extensive, being confined to brooks and small areas on the shore. The first deposit, which is fairly rich is about a mile south of the fort, and about 3 miles north of Cape Comorin. The extent, however, is small, being not more than 5 acres. The sand is very fine in texture, the monazite contents rising to sometimes 20 per cent, though the average is much less, depending on the waves. The associated minerals are ilmenite, garnet, zircon, rutile, and a certain amount of quartz. Going southward, immediately north of the Cape, is another deposit, somewhat more extensive but still of the same character as the previous one. These two deposits, together with the periodical accretion due to the action of waves, will yield a few thousand tons of monazite.

Turning to the west coast, the southernmost deposit is an extensive one, running from Kadiapatnam north of Muttam to the seaport of Colachel, for nearly 4 miles in length; the breadth varies from half a mile to a quarter and less. The extreme southern portion is very rich in monazite, the percentage rising to nearly 50 or more. The depth of the deposit is not known; probably it is not much, as one often sees bosses of granites, gneisses, and charnockites rising above. Possibly the deposit is laid in the hollows formed by these rocks. It is estimated by the Geological Survey of India that this contains at least 1,800 tons; this is a low estimate, as it is expected that this patch will last at least 20 years, the output being 1,200 tons a year. This deposit gains considerable importance, being easily worked at and being so near the port Colachel.

Northward there is not any patch of monazite sand till we come to about 8 miles south of Trevandrum, the capital of the State. Here it is about a mile long, but it is only a few yards in breadth, and the sand is not very rich either. The next deposit of any importance is the one a little north of Anjengo, passing by Warkala to near Edava. The sand is rich generally, but in certain parts it is extremely poor. Farther north there is a deposit of some extent near Quilon. All these deposits are flat coastal deposits, not differing from other parts in other respects. In all these monazite is associated with ilemnite usually, but invariably garnet, rutile, and zircon, with a varying amount of quartz, and broken shells are present.

The mineral found in these deposits has been traced by Mr. E. Masillamani, the State geologist, to the pegmatites, which are everywhere seen to cut through the gneisses, granulites, charnokites, and other igneous rocks. In these the mineral is usually in intimate association with ilmenite, but he has pointed out that this is not invariably so, as instances are known where ilmenite is entirely absent, giving way to mica; in fact, the pegmatite becomes a mica-monazite pegmatite, the other constituents, quartz and feldspar, being insignificant. Again, the mineral is seen in close intimacy with graphite. Some specimens of graphite are fittingly described as being charged with monazite. Dr. Derby, of Rio de Janeiro, is of opinion that graphite almost always contains monazite or rutile included in it. The pegmatites by decomposition set free monazite, which is carried by streams to the seashore. Hence it is but natural that small pocket deposits should be found inland; but these are insignificant. All around the coast are found a series of grits and sandstones, locally known as the Warkalli beds; these also occasionally contain monazite, which was necessarily derived from the decomposition of the pegmatites.

The production of monazite sand in Travancore, India, began in 1911, and until the war the sand was exported to Hamburg, Germany. Since then increasing imports have been brought to this country.

Monazite sand produced (exported) in Travancore, India, 1911–1919.

Year.	Quantity (short tons).	Value.	Average value per ton.	Year.	Quantity (short tons).	Value.	Average value per ton.
1911	932	$117,010	$126	1916	1,448	$183,535	$127
1912	1,271	201,566	159	1917	2,173	274,904	127
1913	1,383	204,451	148	1918	2,371	286,243	121
1914	1,328	201,527	152	1919	(a)	(a)	....
1915	1,241	161,753	130				

a Figures not available.

It has been estimated that the Travancore field will yield ultimately at least about 2,000,000 tons. As this estimate is based on a 10 per cent monazite content of the sand to a depth of only 2 feet, it is probably much too low, as in many places such sand extends to ten times that depth.

Mysore.—Monazite occurs in Mysore, but no naturally concentrated deposits of value have been found.[2] Monazite from decomposed pegmatite carried only 2.25 per cent of thoria.

OTHER LOCALITIES.

Malay Peninsula.—In the Malay Peninsula the alluvial deposits of tin ore contain varying proportions of monazite in the "amang," the residue of heavy minerals, supposed to be worthless, separated from the alluvial tin ores. This monazite, in a pure state, has yielded on analysis of different samples, 5.30, 8.38, and 8.7 per cent, respectively, of thoria, and is therefore a valuable by-product. The different constituents of the alluvial tin deposits can be separated

[2] Smeeth, W. F., and Iyengar, P. S., Mineral resources of Mysore: Mysore State Dept. Mines and Geology Bull. 7, pp. 191–192, 1916.

by a combination of hydraulic, mechanical, and electromagnetic processes. So far as known there has been no commercial production from this field.

Burma.—Monazite sand from 28 localities in Mergui and Tavoy, in Tenasserim, Lower Burma, averaged only 0.18 per cent of thoria (ThO_2).

Ceylon.—Monazite has been found at many places in Ceylon and a beach deposit was worked in 1918, about 20 tons of monazite being separated and made ready for shipment to England.

Australia.—Certain alluvial deposits in Western Australia contain abundant monazite, tin ore, and the rare-earth minerals fergusonite, euxenite, and gadolinite. The monazite from Cooglegong is in small pebbles of an average weight of about one-fiftieth of an ounce. A sample of the sand contained 80 per cent of monazite and yielded 3.46 per cent of thoria. The monazite sand from the residue obtained by resluicing low-grade alluvial tin ore contained 26 per cent of monazite. The individual pebbles of monazite yielded a little more than 5 per cent of thoria.

In the New England region, New South Wales, monazite of low thoria content (0.35 to 4.12 per cent) is a frequent associate of the tin and tungsten deposits.

Monazite of very low thoria content (0.2 per cent) is abundant in corundum-mica schist in the Flinders Range, between Mount Pitt and Mount Painter, South Australia.

Norway.—The pegmatites of southern Norway contain large crystals and masses of monazite, which are saved by the feldspar miners and sold as a by-product of the quarries. It has been stated that the annual quantity of monazite so obtained and sold has never been more than a ton for any one year.

Africa.—A few occurrences have yielded monazite with a thoria content of 8 per cent, but the only known deposit of possible commercial size, about 60 miles northeast of Pretoria, has monazite containing only 4 per cent of thoria.

USES.

The thorium extracted from thorium minerals is used in the form of nitrate in the manufacture of incandescent gas mantles. The fabric of the mantles is made of cotton, ramie fiber, or artificial silk; this fabric is impregnated with a solution of thorium nitrate, which is then dried and burnt off. The resulting thoria, when heated, emits an intense white light. A mixture of 99 per cent of thoria with about 1 per cent of ceria gives the brightest light. From 250 to 500 mantles are produced from 1 pound of thorium nitrate. The world's annual consumption of incandescent gas mantles is about a third of a billion. A small quantity of thoria mixed with a little ceria is being used as the illuminating material in certain searchlights and automobile headlights. Thorium compounds form a portion of some magnesium flashlight powders, and the metal thorium, with other rare-earth metals, is alloyed with tungsten, making very ductile filaments for electric lamps.

Several other products are obtained from the monazite sand, but only a very slight use has been found for them. From the monazite itself thousands of tons of cerium, lanthanum, neodymium, and praseodymium oxides have been prepared. Uranium, radium, and mesothorium are also present in monazite. Mesothorium has uses similar to those of radium, and although the percentage of mesothorium in monazite is exceedingly small, its very high value might pay for its recovery as a by-product. It has been estimated that 1 ton of monazite containing 5 per cent of thoria will yield about 2.5 milligrams of mesothorium. A small quantity of cerium nitrate is added to the thorium nitrate used in the gas mantles. Some cerium is used in pyrophoric alloys, and a little, as oxalate, is used in medicine. The neodymium and praseodymium salts form the basis of the indelible brand placed upon the gas mantles.

SOURCES OF THORIUM.

RELATIVE IMPORTANCE.

Monazite sand has furnished more than 99 per cent of the crude material from which thoria has been obtained. Several other thorium minerals have been produced, however, and although the total output of them is small they are much richer in thorium than monazite and would prove of very great value if found in deposits of commercial size. In addition to the minerals thorite, thorianite, auerlite, and several others, broken or scrap mantles, which consist essentially of thoria, are valuable, as the thoria can be changed to the nitrate form and used over again. From 1910 to 1914, inclusive, scrap mantles valued at $14,702 were imported into this country.

MONAZITE.

GENERAL DESCRIPTION.

Monazite is essentially a phosphate of cerium, lanthanum, and didymium, including small and varying quantities of thorium, silicon, and other elements. The mineral is yellow, varying in shade and tint from a light greenish yellow to dark honey-brown; it is somewhat translucent to opaque, and it is characterized by a resinous or greasy luster. It shows no distinct cleavage, and is brittle, breaking with an uneven fracture. In the original rock it may show sharp edges and plane crystal faces, but as found in sand it is in rounded grains, intimately mixed with other heavy and resistant minerals, the most abundant of which are zircon, magnetite, ilmenite, and garnet.

The monazite sands as found usually have to be concentrated, as the sands of this country usually carry less than 50 per cent of monazite.

ANALYSES.

A compilation of analyses of the mineral monazite—that is, the pure, selected mineral—has been made to serve as a basis for comparison of the value of monazite from different localities. The percentage of thoria present in the sand from which this monazite was selected can be obtained by multiplying the percentage of thoria in the pure mineral by the percentage of monazite in the sand.

Analyses of samples of monazite from the United States.

	1	2	3	4	5	6	7
ThO_2	6.49	1.48	1.22	1.43	2.32	1.19	7.00
Ce_2O_3	31.38	37.26	} 54.03	{ 32.93	} a 65.32	c 61.77	{ 34.50
$(La,Di,Yt)_2O_3$	30.88	31.60		b 25.54			28.80
P_2O_5	29.28	29.32	23.43	18.38	28.16	26.05	26.00
SiO_2	1.40	.32	1.60	6.40	3.20	1.45	2.00
ZrO_2	....	....	3.25	....	....	....	.70
TiO_2	....	....	....	4.67	.61	1.40	.90
Fe_2O_3	....	....	5.58	7.83	....	.65	....
Al_2O_3	....	....	2.49	1.62	....	.15	....
CaO	....	....	....	1.20	....	....	.70
H_2O	.20	.17	....	....	....	....	....
Miscellaneous	....	....	c 7.74	....	....	d 6.39	....
	99.63	100.15	99.34	100.00	99.61	99.05	100.60

[a] Including ZrO_2 and BeO.
[b] Including ZrO_2, BeO, and Ta_2O_5.
[c] Including 4.12 per cent $(Cb, Ta)_2O_5$ and 3.62 per cent FeO.
[d] Ta_2O_5.

1. Sand from Brindletown district, Burke County, N. C. Penfield, S. L., Am. Jour. Sci., 3d ser., vol. 24, p. 252, 1882.
2. Alexander County, N. C., 3 miles east of the hiddenite mine. Penfield, S. L., and Sperry, E. S., Am. Jour. Sci., 3d ser., vol. 36, pp. 317–331, 1888.
3. "Carolina." (Probably Belwood, N. C.) Monazite separated from sand containing 78.39 per cent monazite. Tschernik, G. P., Acad. Imp. Sci. St. Petersburg Bull., vol. 2, pp. 243–254, 1908.
4. Monazite sand from Burke, N. C. Not pure monazite. Glaser, C., Estimation of thoria; chemical analysis of monazite sand: Am. Chem. Soc. Jour., vol. 18, pp. 782–793, 1896.
5. Nearly pure monazite, from Shelby, N. C. Idem.
6. Nearly pure monazite, from Belwood, N. C. Idem.
7. From South Carolina. Tschernik, G. P., op. cit.

A rather high percentage of thoria in North Carolina monazite is reported by Kress and Metzger,[3] who give the thoria content for four selected samples of monazite as 7.49–8.07, 5.57–5.79, 6.10–6.40, and 5.72–5.99 per cent. Monazite from Madison County, N. C., is stated to carry 5.06 per cent of thoria.

Analyses of samples of monazite from Brazil.

	1	2	3	4	5	6
ThO_2	9.23	10.05	1.09	6.06	6.50	6.49
Ce_2O_3	31.21	32.14	32.46	} 62.92	62.10	{ 31.28
$(La, Di)_2O_3$	....	25.99	36.02			30.88
P_2O_5	28.36	25.51	29.18	28.50	28.46	29.28
SiO_2	10.14	2.63	....	.75	.64	1.40
ZrO_2	5.74	.60	....	....	....	....
TiO_2	2.62	....	....	....	....	....
Fe_2O_3	4.22	1.79	.61	.97	1.50	....
Al_2O_3	.32	.84	....	.10	.08	....
CaO	1.11	.20	.10	.21	.30	....
H_2O	....	.92	....	.38	.64	.20
Ta_2O_5	1.16	....	....	....	....	....
	94.11	100.67	99.46	99.89	100.22	99.53

1. Monazite from river bed, in large pieces weighing as much as 2 pounds; derived from pegmatite Southern Serra dos Aymores, Espirito Santo. Freise, F., Zeitschr. prakt. Geologie, vol. 18, pp. 123–124, 1910.
2. From river sands of Rio Paraguassir in Bahia, Bandeiro do Mello. Hussak, E., and Reitinger, J., Zeitschr. Kryst. Min., vol. 37, pp. 550–579, 1903.
3. Sand from Bandeirinha, near Diamantina, Mines Geraes. Idem.
4. Espirito Santo. Johnstone, S. J., Soc. Chem. Industry Jour., vol. 33, pp. 55–59, 1914.
5. Alcobaca, Borhia. Idem.
6. Brazilian monazite. Analysis furnished by F. H. Lee. Gottschalk, A. L. M., Min. and Eng. World, May 15, 1915.

[3] Kress, O., and Metzger, F. J., Does thorium exist as thorium silicate in monazite?: Am. Chem. Soc. Jour., vol. 31, pp. 640–652, 1909.

Analyses of samples of monazite from India and Ceylon.[a]

	1	2	3	4	5	6
ThO_2	10.22	8.65	10.75	10.29	9.49	7.90
Ce_2O_3	31.90	61.73	26.71	27.37	27.15	56.50
$(La, Di)_2O_3$	28.46		31.52	32.27	33.52	
P_2O_5	26.82	26.50	24.61	27.67	26.12	26.80
SiO_2	.90	1.00	2.47	1.03	1.67	1.92
Fe_2O_3	1.50	1.09	1.09	.81	.87	1.40
Al_2O_3	.17	.12	.70	.17	.17	.13
CaO	.20	.13	.85	.41	.45	.27
H_2O	.46	.45	.93	.20	.48	2.20
U_3O_8	......	......	......	......	......	2.66
	100.63	99.67	99.63	100.22	99.92	99.78

[a] Johnstone, S. J., Monazites from some new localities: Jour. Chem. Industry, vol. 33, pp. 55-59, 1914.

1. Sand from Travancore, India.
2. Isolated from a concentrate from Travancore, India.
3. From sand from Niriellaganga, Ceylon.
4. Monazite pebble from Ratnapura, Ceylon.
5. Monazite pebble from Muladiwanella Durayakanda, Gilimale, Ceylon.
6. Washed from pegmatite containing 100 grams monazite per metric ton (0.01 per cent) from Rifle Range Stream, Moon Plains, Ceylon: Imp. Inst. Bull., vol. 14, p. 349, 1916.

Analyses of samples of monazite from the Malay Peninsula and Australia.

	1	2	3	4	5	6
ThO_2	8.38	3.40	3.53	9.41	5.03	3.80
Ce_2O_3	25.46	33.74	66.45	62.82	33.06	31.10
$(La, Di)_2O_3$	35.52	33.44			30.35	34.30
P_2O_5	23.92	26.58	27.87	23.71	26.70	26.89
SiO_2	.92	1.45	1.08	2.20	1.22	1.96
Fe_2O_3	2.78	.65	.64	1.13	2.21	.42
Al_2O_3	.84	.03	.07		.44	.64
CaO	.61	.33	.17	.29	[a]1.11	.34
H_2O	1.28	.94	.52	.94	.59	.58
	99.71	100.56	100.33	100.50	100.71	100.03

[a] CaO, 0.90; MgO, 0.21.

1. Concentrated monazite from the Sempang tin Co., Pahang. Occurrence of monazite in the tin-bearing alluvium of the Malay Peninsula: Imp. Inst. Bull., vol. 4, pp. 301-309, 1906.
2. Isolated from concentrate, Puchong, Babi, River Kenring, Perak. Johnstone, S. J., Monazites from some new localities: Jour. Chem. Industry, vol. 33, pp. 55-59, 1914.
3. Isolated from concentrate, Kulim, Kedah. Idem.
4. Kelantan. Idem.
5. Forty pebbles from Moolyella, Western Australia. Simpson, E. S., The occurrence of monazite at Cooglegong and Moolyella: Western Australia Geol. Survey Bull. 48, 1913.
6. Single crystal from Cooglegong, Western Australia. Idem.

PERCENTAGE OF THORIA IN MONAZITE SANDS.

Monazite sands contain many other minerals besides monazite, chiefly zircon, ilmenite, garnet, magnetite, and quartz, but also cassiterite, xenotime, rutile, columbite, tantalite, andalusite, etc. The value of the monazite sand depends on the percentage of the mineral monazite, and the sands as found are further concentrated to contain at least 90 per cent of the pure mineral.

Recent figures giving the percentage of thoria in monazite sand from the United States are not available, but older analyses of sand containing about two-thirds monazite report the following percentages of thoria (ThO_2) in the sand from North Carolina: 0.13, 0.18, 0.23, 0.26, 0.29, 0.40, 1.27, 1.75, 1.93, 2.15, 2.25, 2.48, 3.40, 4.84, 5.11, 5.19, 5.87, 6.26, 6.30, 6.54, the average of these 18 analyses being 2.60 per cent. A sample from Brindletown, N. C., analyzed by W. F. Hillebrand, contained 4.3 per cent of thoria.

Artificially concentrated monazite sand from the Centerville region, Idaho, yielded from 2.41 to 4.60 per cent of thoria. Another analysis gave 5.2 per cent for the pure mineral, or 4.94 per cent ThO_2 for a 95 per cent sand. Monazite sand from the Musselshell district, Idaho, containing 31.8 per cent of monazite gave 0.88 per cent of thoria, and sand containing 55.36 per cent of monazite gave 1.85 per cent of thoria. A sample from Placerville, Idaho, contained 1.2 per cent of thoria. Sand from Bighole River in Beaverhead County, Mont., containing 65 per cent of monazite, gave 1.69 per cent of thoria.

The Brazilian sand, from the seacoast, as marketed, is stated to run about 92 per cent of monazite and to contain from 5 to 7 per cent of thoria or an average content of 6.3 per cent. The inland deposits are said to be slightly lower in their thoria content than the seacoast sand, and to run from 4 to 5.7 per cent of thoria.

The India sand, as found, carries as much as 46 per cent of monazite, the remainder being chiefly ilmenite and zircon. A somewhat concentrated sample of the sand, as marketed in London, contained 62 per cent of monazite, 26 per cent of ilmenite (chiefly), and 11 per cent of zircon (chiefly), and yielded from 5 to 6 per cent of thoria. A concentrated sample (90.5 per cent of monazite) yielded 8.87 per cent of thoria. Samples of magnetically separated sand (from 90 to 100 per cent pure) yielded, respectively, 4.8, 6.0, 8.5, 8.65, 8.70, 8.7, 8.87, 9.2, 10.08, and 10.22 per cent of thoria. This India sand, as marketed in the United States, runs 90 per cent of monazite and yields 9 per cent of thoria.

The monazite from Ceylon, not produced on a commercial scale, is also rich in thoria. Sand with 48 per cent of monazite yielded 4.15 per cent of thoria, another with 96 per cent of monazite yielded 8.39 per cent of thoria. Artificial concentrations from pegmatite, with from 45 to 87 per cent of monazite, yielded from 5 to 7.3 per cent of thoria.

The Malayan sands are unique in their high content of cassiterite, which ranges up to 65 per cent. The monazite in these sands runs from 1 to 58 per cent.

THORITE.

The silicate of thorium, or thorite, is usually massive and disseminated through the pegmatite rock in irregular, compact masses. Rarely crystals, similar in shape to those of zircon, are found. Thorite is more or less opaque and of a dark-brown or black color, with a glassy luster and shell-like fracture. The luster of the altered forms is more resinous or greasy. Very rarely clear crystals are found, and these are of a yellow or orange color and are known as orangite. The mineral, as found, is generally impure and contains considerable water. The formula of the mineral ($ThSiO_4$) calls for 81.5 per cent of ThO_2, but this value is not reached by the mineral as found. Analyses have shown the following percentages of thoria (ThO_2): 49, 50, 52, 57, 58, 59, 66, 69, 71, 72, 73, and 74.

Thorite has been found at numerous places, but has been produced in small quantities for consumption only in Norway and in Ceylon. The mineral occurs with feldspar in the syenite pegmatites on the islands of the Langesunder Fjord, in southern Norway. Some masses of the mineral weighed more than 2 pounds. When first found, a pound of thorite brought about $49, so, that it paid to collect the isolated masses from the feldspar quarries. The entire pegmatite, on being sampled, yielded only a small fraction of 1 per cent for its thorite content, so that the entire pegmatite could not be crushed and worked, only the portions rich in thorite being exploited for that mineral. The development of the Brazilian and Carolina deposits of monazite stopped thorite mining in Norway. No figures of production of thorite from Norway are available, but it has been stated that the production of monazite, found with the thorite as large, individual crystals and masses, probably did not exceed 2,000 pounds in any one year. In 1905 a total of 112 pounds of thorite, valued at $97, and in 1907 a total of 447 pounds, valued at $146, were exported from Ceylon.

AUERLITE.

Auerlite is a dull yellowish-white to reddish mineral, closely related to thorite. It was found at the Freeman zircon mine near Zirconia, Henderson County, N. C. In composition it is essentially a silicate of thorium containing 70 per cent of ThO_2. Several pounds has been obtained, and it is thought that a considerable output could be produced by further exploitation.

THORIANITE.

A black mineral from the gem washings of Ceylon, found to be very rich in thoria and consisting chiefly of that oxide, with a little uranium, was named thorianite. Its analyses and relations to uraninite indicate that it has the formula ThO_2, being probably isomorphous with uraninite (UO_2). Consequently the natural occurrences of the mineral show slight and varying amounts of uranium oxide, the percentages of thorium oxide reported in the analyses of thorianite being 59, 62, 63, 65, 67, 71, 72, 74, 76, 77, 79, and 93.

Thorianite has been reported from the United States, Madagascar, and Russia, as well as from Ceylon, but only in Ceylon has it been produced commercially.

In 1904 thorianite was discovered in the refuse from gem washings near Belangoda, Ceylon. The high percentage of thoria in the mineral gave it sufficient commercial value to induce considerable exploration for deposits of the mineral. The rich placer deposits were soon exhausted, and after 1907 production of thorianite on a commercial scale practically ceased, except in the year 1911. It is considered improbable that new placer deposits rich enough to be worked will be found in Ceylon. The richness of the detrital deposits that have been worked was due not to the richness of the pegmatites, but to the large aggregate area of thorianite-bearing pegmatite outcrops. Attempts to exploit the thorianite-bearing pegmatites have all failed, as the percentage of thorium mineral in the pegmatite, from 0.001 to 0.003, is too small. An unusually rich pegmatite, which contained segregations of thorianite, yielded an average of 6 pounds of thorianite to the ton (0.3 per cent); other samples yielded 8 ounces of thorianite to the ton (0.025 per cent); and another pegmatite averaged only half an ounce to the ton (0.0016 per cent).

Thorianite produced in Ceylon, 1904–1911.

Year.	Quantity.	Value.	Average price per pound.	Year.	Quantity.	Value.	Average price per pound.
	Pounds.				*Pounds.*		
1904	a 3,000	a $3,000		1908	178	a $274	
1905	20,049	24,333	$1.23	1909	224	a 345	
1906	5,825	8,030	1.38	1910			
1907	1,000	1,541	1.54	1911	8,818	60,393	$6.85

a Estimated.

When first found thorianite was valued at about a dollar a pound. The value soon increased, and in 1911, the last year of recorded production, it was nearly $7 a pound. To-day the mineral is quoted at about $7 a pound, or $12 a pound of contained thoria.

The mineral has been identified in the black slimes from a gold placer deposit on River Boshagoch, Transbaikal, Siberia.[4] The accompanying monazite contained 8.2 per cent of thoria.

OTHER MINERALS.

A number of other minerals contain thoria in large proportion, and deposits of such minerals would have a very great value. Thorogummite from Texas contains 41 per cent of thoria; that from Wodgina, Western Australia, 24 per cent. Mackintoshite from Texas carries 45 per cent, and that from Wodgina 25 per cent. Pilbarite from Wodgina has 31 per cent of thoria. Other black or blackish-brown heavy minerals with a greasy or pitchlike luster, such as fergusonite, zirkelite, uraninite, yttrochrasite, and yttrialite, are likely to contain small quantities of thoria.

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ZIRCONIUM MINERALS.

ZIRCON.

Two minerals containing zirconium have been produced on a commercial scale—zircon, the silicate of zirconium, and baddeleyite, the oxide of zirconium. Zircon is a colorless to yellow, red, brown, gray, or green mineral, generally in small, well-defined square prisms. It occurs in many rocks—the crystalline limestones and schists, gneiss, granite, pegmatite, and the sedimentary rocks. The mineral is very widespread in its occurrence but is found at only a few places in commercial deposits. In North Carolina some of the pegmatites contained enough zircon to warrant their development; at other places only the concentrated sedimentary zircon-sand deposits have been worked.

Zircon contains about 33 per cent of silica and 67 per cent of zirconia, the oxide of zirconium. Iron is a common impurity, but many other elements have been found in zircon, especially in the so-called altered varieties.

BADDELEYITE.

The oxide of zirconium mineralogically known as baddeleyite or brazilite has been found in quantity only in Brazil, although it has been identified in Ceylon, Sweden, Italy, and Montana.

In the trade the name baddeleyite seems to be restricted to the variety in distinct crystals, whereas the term brazilite is applied to the fibrous, botryoidal, or columnar forms. The trade name zirkite is used to designate the commercial ore of zirconia, the ore being a mixture of baddeleyite or brazilite, zircon, and a supposed new unnamed silicate of zirconium. Zirkite contains from about 70 to 94 per cent of zirconium oxide, and the following analyses show how the composition of the commercial ore varies:

Analyses of zirkite.

	1	2	3	4	5	6	7	8	9	10	11
ZrO_2	93.18	81.75	86.57	85.93	82.00	85.01	71.88	94.12	88.40	74.48	68.93
SiO_2	1.94	15.49	2.50	9.35	11.38	9.63	25.31	2.41	5.89	14.08	26.30
TiO_2	.69	.50	1.43	1.84	.36	1.52	.63	.98	3.12	1.35	.60
Fe_2O_3	2.76	1.06	5.29	1.93	2.08	3.57	.43	3.22	4.07	10.26	3.59
Al_2O_3	.64	.85	1.00	.36	.62	....	.15	....	....	....	....
MnO	Trace.	Trace.	....	....	....	....	....	....	....	....	....
H_2O	.47	.63	3.32	1.56	3.35	....	1.56	....	....	....	.80
	99.68	100.28	100.11	100.97	99.79	99.73	99.96	100.73	101.48	100.17	100.22

1. Slate-gray fava (waterworn pebble resembling a bean). Specific gravity 5.245.
2. Light-brown fava. Specific gravity 4.850.
3–6. Hard lump ore.
7. Gray porous ore.
8. Glassy variety.
9. Stony variety.
10. Pebbles.
11. Commercial variety

Analyses of purer samples of baddeleyite gave the following results:

Analyses of baddeleyite.

	1	2	3
ZrO_2	97.19	98.90	96.52
SiO_2	.48	.19	.70
TiO_2	.48	....	....
Fe_2O_3	.92	.82	.41
Al_2O_3	.40	....	.43
CaO	....	.06	.55
MnO	Trace.	....	....
MgO	....	....	.10
Alkalies	....	....	.42
H_2O	.38	.28	.39
	99.85	100.25	99.52

1. Botryoidal, from Brazil. Specific gravity 5.533.
2. From Ceylon. Specific gravity 5.72 to 6.025.
3. From Jacupirangi, Brazil. Specific gravity 5.006.

OCCURRENCE.

UNITED STATES.

NORTH CAROLINA.

The only locality (except possibly Pablo Beach, Fla.) in the United States which has produced zircon is in Henderson County, N. C. Near Tuxedo (formerly called Zirconia) a pegmatite dike, about 100 feet wide and striking N. 50° E., cuts through the pre-Cambrian gneisses of the region and has been traced for a mile and a half. The upper part of the pegmatite is kaolinized and disintegrated to a depth of 40 feet or more. Zircon crystals are present in abundance in certain parts of the pegmatite but are not uniformly distributed throughout the dike. They are gray in color and show both the prism and pyramid about equally developed. They average in size from about an eighth to a quarter of an inch. They can be readily washed from the decomposed pegmatite or from the unaltered crushed rock.

Two places have been worked on this pegmatite dike—the Freeman mine, near the southwest end of the dike, and the Jones mine, near the northeast end. The first shipment of zircon was made in 1888. The demand for zircon soon declined, and for many years there was no production. The last attempted mining of these deposits was done in 1911, when about a ton and a half was obtained and shipped. The writer visited the place in 1918 and found zircon crystals present in a large part of the dike, but there were also large exposures where no zircon could be seen. Several specimens of the zircon-bearing pegmatite were collected and sampled and showed a content of about 3 per cent of zircon. These were selected specimens, however, and do not represent the general pegmatite rock, though their zircon content may approach that of picked portions of the pegmatite. The locality could probably produce many thousand tons of zircon if the cost of operations were not considered. The entire recorded production of zircon from this locality is slightly less than 40 tons.

Many brownish pyramidal crystals of zircon, the largest 3 inches in diameter, have been found loose in the soil near New Sterling, Iredell County, N. C., but nothing is known of the size of the deposit.

FLORIDA.

A portion of the beach sands of the eastern coast of Florida, east of Jacksonville, contains an appreciable quantity of heavy minerals such as ilmenite, rutile, zircon, and monazite. A particular stretch of beach about 20 miles long, extending southward from Little Talbot Island, north of St. Johns River outlet, to a point within a short distance of St. Augustine Inlet, has been exploited for its content of these minerals. The most intensive investigation was undertaken at about the middle of this field, a few miles south of San Pablo and about 20 miles east and southeast of Jacksonville.

The beach sands have an average width of about 500 feet and a depth of 8 feet. Behind the beach proper are sand dunes 12 feet high and 200 feet wide. The heavy minerals named, together with garnet, kyanite, epidote, and staurolite, are not uniformly distributed through the sand but are concentrated in a strip about 70 feet wide and 2½ feet thick, which has been traced for nearly 4 miles. In this richer portion the heavy minerals constitute about 16 per cent of the quartz sand. About 10 per cent of the heavy minerals is zircon, which forms from 1 to 2 per cent of the entire concentrated strip of sand. It has been estimated that this locality could yield between 3,000 and 4,000 short tons of zircon sand, at least 90 per cent pure.

Although an output of a few tons of zircon is reported from this locality, the producers have not been willing to furnish any information regarding production to the United States Geological Survey.

VIRGINIA.

A bed of zirconiferous sandstone is exposed about 3 miles west of Ashland, Va. The bed does not crop out as a continuous ledge, but is represented on the surface by isolated flat fragments or boulders, only a few of which are as much as a foot long. The largest boulder seen [5] measures 26 by 15 by 10 inches; the average diameter of the boulders is about 4 to 6 inches. These isolated fragments and boulders are found in the clay, gravel, or sand soil for about a mile north and south and about 500 feet east and west. The vertical thickness of the zone containing these boulders does not seem to be more than a few feet, although there is almost no evidence on this point. The zirconiferous boulders seen on the surface would not weigh altogether more than several hundred tons.

The zirconiferous boulders occur at the "fall line," or junction of the coastal sediments and the igneous rocks of the Piedmont, which are less than a mile west. The hard brownish boulders are held to represent a local cementation of a soft sandy bed which was found in the lower part of a well 14 feet deep near the home of Benjamin Wright, three-eighths of a mile southwest of the Shelton home, where these hardened surface boulders occur in greatest numbers. The sand in Mr. Wright's well contained 13 per cent of zircon. The hardened boulders found on the surface for a distance of nearly a mile showed a greatly varying content of zircon, the maximum being 30 per cent.

The compact sandstone contains much ilmenite and quartz and smaller quantities of rutile, staurolite, kyanite, feldspar, and other minerals. All of it is cemented by brown limonite. The density of the sandstone is a good indication of its zircon content, for the pieces very poor in zircon weigh perceptibly less than those rich in zircon. A collection of 24 samples of the brown boulders from the northernmost exposure contained only 0.5 per cent of zircon; 7

[5] Now in the United States National Museum, Washington, D. C.

samples from another place yielded 3 per cent of zircon; 19 samples from another place gave 12 per cent of zircon; a compact brown boulder near Mr. Wright's house contained 25 per cent of zircon; and the average content of 32 pieces of fine-grained sandstone from the Shelton farm contained 25 per cent of zircon. On the other hand, 17 samples of coarse-grained sandstone from the Shelton farm, similar in appearance to the fine-grained material except in the size of its particles, averaged only 1 per cent of zircon.

Ten samples of the clay dirt collected from the well on the Shelton farm, at 2-foot vertical intervals, contained zircon from a trace to nearly 0.5 per cent. Only three of the samples yielded more than 0.1 per cent of zircon, and five of the samples had less than 0.03 per cent.

The occurence was thoroughly tested in 1912 by G. L. English, who sunk a number of pits on the Shelton farm. In one of these pits a solid bed of the zirconiferous sandstone was found 7 feet below the surface; in the other pits only isolated fragments of the hardened sandstone were found. There seems to be very little evidence of the existence of a continuous bed of this sandstone, short lenses a few feet in length seeming to be the general feature. Most of these lenses have been broken up into isolated fragments and boulders, and there is almost no evidence of a continuous bed of this particular rock. Moreover, the diverse character and zircon content of the boulders, as found, shows that only a part of the deposit contains enough zircon to be considered a possible source of that mineral.

The very evidently stratified character of the boulders, many of which have a distinctly layered structure, indicates that the local cementation extended for horizontal distances of about 10 feet or more. The problem of the presence or absence of a distinct well-defined bed a mile long can be solved only by a detailed study of the region, involving the sinking of numerous pits.

NEW JERSEY.

Several localities in northern New Jersey, especially in Sussex County, have been reported to contain zircon-bearing ores and rocks, and an investigation of the deposits was undertaken to test their availability as a source of zircon. It has been concluded that if the demand for zircon should become imperative and if the mineral must be had at any cost, then several hundred tons could be obtained from northern New Jersey, but the locality does not offer any inducement as a commercial field.

The zircon-bearing rocks are of two general types—the hard, compact magnetite iron-ore rock and the quartz-feldspar pegmatites. The iron-ore rock contains, besides magnetite, chiefly pyrite, quartz, and various silicate minerals. The very tough rock would have to be finely crushed, the heavy minerals concentrated, and the zircon then separated from the other heavy minerals. These iron-ore deposits are indicated by old abandoned shafts, either full of water or filled up with dirt, and the present timbering is so rotten as to be a source of great danger. Some of these mines have not been worked for 40 to 100 years. In many of the mines the main part of the magnetite-ore body has probably been extracted.

Specimens from the Williams mine were collected from the surface and from the old dumps, as no ore could be examined in place. At least half a dozen timbered shafts once afforded entrance to the mine. It has not been worked for over 40 years, and the shafts are full of water and numerous pits are caved in. The old workings were said to be deep and extensive. Twenty different specimens of the magnetite ore averaged 0.2 per cent of zircon; ten specimens of the country rock with but little magnetite averaged 0.07 per cent of zircon.

Very little ore could be seen at the Green mines, where a dozen old shafts and pits, full of water or caved in, constitute the surface openings. The magnetite ore is said to have been pockety in nature and is now practically worked out. The "pepper and salt" Pochuck gneiss yielded on an average about 0.1 per cent of zircon.

The old Wawayanda mine is half a mile south of the Green mines. Two filled-in pits were found, and the samples of the rocks collected did not show any indication of the presence of zircon.

A visit was also paid to some of the similar old iron-ore mines across the New York State border, with essentially similar results. Specimens of magnetite ore and of the inclosing rocks were collected from the old O'Neil, Clove, and Forshee mines, south of Monroe, Orange County, N. Y. They gave a zircon content ranging from a trace to 0.16 per cent. The statement that these iron ores near the New Jersey-New York State line could be considered as potential zircon ore is not borne out by the facts.

Some of the pegmatites of northern New Jersey are much richer in zircon, but it is extremely doubtful if their zircon content will ever be utilized. The most promising pegmatite is that of the old Woods mine, about half a mile southeast of Stockholm, N. J. At least four shafts, now filled in, were made in a pegmatite dike about 10 feet wide and exposed for more than 100 feet. The pegmatite rock is composed of quartz, feldspar, magnetite, and zircon. There is too little magnetite in the rock to be worked as an iron ore. The shafts are said to have been dug long ago—maybe over 100 years. No ore is known ever to have been shipped away. The rock is richer in zircon than any other rock seen in this region. Some selected parts of the dike may carry as much as 5 per cent of zircon, but an average sample of 20 specimens of selected zirconiferous rock yielded only 1.53 per cent of zircon. The rock in the shaft at one end is much richer in zircon than the rock at the other end of the line of shafts. An average sample of 10 specimens collected across the exposed dike at 1-foot intervals, contained 0.92 per cent of zircon. The pegmatite rock is hard and unaltered and would have to be crushed before any zircon could be obtained. The total quantity of zircon obtainable from this locality would not amount to more than a few hundred tons, and the expense would prohibit commercial exploitation.

OKLAHOMA.

A pegmatite dike with many scattered zircon crystals occurs near the south edge of the Wichita National Forest, Wichita Mountains, about 7 miles northwest of Cash, Okla. The zircon crystals reach a maximum size of nearly an inch, though most of them are much smaller. They are simple pyramids with the prism faces nearly absent. Most of the crystals are deep reddish brown, but a few are yellowish to nearly colorless.

An investigation of the deposit seemed to indicate that only a very small quantity of zircon could be obtained, as the zircon-rich portion of the pegmatite was of slight extent.

BRAZIL.

The deposits of the natural oxide of zirconium, or zirconia, in Brazil are described as follows by H. C. Meyer:[6]

The deposits of zirconia are in the Caldas region, which lies partly in the State of Minas Geraes and partly in the State of Sao Paulo, approximately 130 miles north of the city of Sao Paulo. It is a mountainous plateau, the main elevation of which is about 3,600 feet. The surface is undulating, presenting differences in level of from 300 to 600 feet. The whole area is bounded on all sides by ridges rising abruptly from 600 to 1,200 feet above the general level and forming a roughly elliptical inclosure with a major axis of approximately 20 miles in length and a minor axis of 15 miles. This peculiar arrangement of the higher ridges is very significant when coupled with the fact that the predominant rock of the plateau is a phonolite and the presence of highly mineralized thermal water of considerable medicinal value.

No thorough geological survey has been made of this area with a view to determining the origin of the zirconia. The character of the ore, however, and the formation seems to point to pneumatolitic agencies. A careful study of the relationship of the large masses of coarsely crystalline nephelite syenite in this area, with pronounced segregations of eudialyte, might throw some light upon this subject.

Zirconia ore can be roughly divided into two classes:

First, alluvial pebbles ranging in size from one-half inch to 3 inches in diameter, generally carrying about 90 per cent to 93 per cent zirconium oxide. These pebbles, known as "favas" and having a specific gravity ranging from 4.8 to 5.2, are found along small stream beds and on the talus slopes of low ridges.

Second, zirconia ore proper, or zirkite, which ranges in shade from a light gray to a blue-black, the lighter colored material carrying a higher percentage of zirconium silicate, as evidenced by analysis, which in some cases shows a minimum of 73 per cent zirconium oxide. The blue-black ore generally carries from 80 per cent to 85 per cent zirconium oxide. By careful sorting, however, a uniform grade carrying about 80 per cent is produced. Prior to the investigations of Derby and Lee, this ore was considered identical with baddeleyite. It has now been shown, however, that it is a mechanical mixture of three minerals, namely, brazilite, zircon, and a new and unnamed zirconium silicate carrying about 75 per cent zirconium oxide. This new mineral has the same crystal form as zircon (67 per cent ZrO_2) but is readily soluble in hydrofluoric acid, while zircon is not affected, this being a characteristic differential test. The finely powdered mineral, on being treated with a weak solution of hydrofluoric acid, leaves a residue of minute, perfect pyramidal crystals of zircon, the brazilite and new zirconium silicate going into solution. Several large outcrops of the ore occur on the extreme westerly edge of the plateau, one or two isolated boulders weighing as much as 30 tons. No extensive development work has yet been attempted, although several crosscuts have been run to determine the width of the vein, and a few shallow prospect holes to determine the depth, but seemingly, through indifference of the owners, this development work was not completed. Owing to the hardness of the ore, it is almost impossible to drill holes for explosives, and in handling large masses it is found necessary to resort to the primitive methods employed by the emery miners of Naxos. A large fire is built against an exposed face of the ore and kept burning for several hours, at the end of which time water is thrown upon the ore, which produces fracturing of the mass, permitting it to be sledged into pieces easily handled by one man. In some of the deposits the ore occurs in the form of gravel and large pebbles embedded in a reddish clay matrix greatly resembling a boulder clay. This is mined by open-cut methods. The clayey mass, on being exposed to the tropical sun and air, readily dries, and the zirconia can then be separated from the clay matrix by a coarse screen. Before shipment, it is thoroughly washed to remove the small percentage of ferruginous matter still adhering.

Most of the mines are many miles from the railroad. Horses for other than saddle purposes are practically unknown, and the ore is transported to the railroad station by

[6] Meyer, H. C., Brazilian zirkite deposits: Monthly Prices, Foote Mineral Co., November, 1916, pp. 29–31.

ox carts carrying about 1 ton each. These carts are of the most primitive character, having large, solid, wooden wheels some 4 feet in diameter and 6 inches in thickness. From 10 to 15 yoke of oxen (20 to 30 oxen) are generally required for each cart, owing to the mountainous roads.

This very cursory examination of the zirconia deposits makes it unsafe to venture any conjecture as to the quantity of ore available. Suffice it to say, however, that the deposits have been traced for a distance of 15 miles between Cascata and Caldas and, if surface indications are of any significance, are of vast extent.

USES.

Metallic zirconium has not so far found any practical uses, although several have been suggested. An alloy with iron, ferrozirconium, has found an application in the steel industry. A zirconium steel is said to be particularly suited for armor plates, armor-piercing projectiles, and bullet-proof metal.[7] An alloy consisting of 65 per cent of zirconium, 26 per cent of iron, 7.7 per cent of aluminum, and 0.12 per cent of titanium is said to be highly resistant to chemicals, to be malleable, and to make good filaments for incandescent lamps.

The name "cooperite" has been given to a new patented alloy of zirconium and nickel. This new alloy, free from iron and carbon, has a bright silvery luster and is resistant to acids and alkalis. It is stated to be the best known alloy for use in the manufacture of edge tools of all descriptions, mainly machine tools for milling cutters and cast tools for lathe and plane use. Milling cutters and intricate tools of all descriptions may be cast from this alloy in such forms as to require only a minor grinding operation for finishing. Cooperite remains liquid for some time before solidifying, and intricate machine tools can be easily cast from this alloy. The heat conductivity is higher than for other high-speed metals and the cutting efficiency of the tools is therefore increased. The hardness can be varied by changing the proportions of the constituent metals. An alloy of 2 to 10 per cent of zirconium and the remainder nickel is said to make a fine cutting edge. With 16 to 30 per cent of zirconium and the remainder of nickel or cobalt, the hardness is increased. The melting point and tensile strength are decreased as the proportion of zirconium increases. The addition of molybdenum raises the melting point. It is claimed that cooperite is self-hardening and no tempering or other treatment is necessary except a slight finishing operation.

Another patented high-speed cutting alloy has the preferred composition: Nickel, 86.4 per cent; aluminum, 6 per cent; silicon, 6 per cent; zirconium, 1.5 per cent; carbon, 0.1 per cent. The zirconium content may vary from 0.5 to 2 per cent. Where silicon and aluminum are present in proper proportion, an excess of zirconium is without benefit. Another zirconium steel contains 3.15 per cent of nickel, 1.8 per cent of zirconium, 0.88 per cent of silicon, 0.75 per cent of manganese, 0.36 per cent of carbon, 0.03 per cent of sulphur, and 0.018 per cent of phosphorus. Less than 1 per cent of zirconium is enough to increase greatly the tenacity and strength of a sound steel casting. The zirconium is added in the form of alloys with 10 to 35 per cent of zirconium. An alloy of zirconium 56 per cent, iron 26 per cent, aluminum 9 per cent, and titanium 9 per cent is said to be nonoxidizable, not readily fusible, and suitable as a substitute for platinum.

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[7] Iron Age, May 3, 1917, p. 1073.

The incandescence of zirconium oxide, when heated, has led to its use in certain mantles, glowers, and lights. It was first used in the Drummond light to replace lime, and as early as 1830 an attempt was made to use zirconia buttons, heated to incandescence, for lighting the streets of Paris. In 1885 an incandescent gas mantle, composed chiefly of zirconia, was patented, but only a few years later the zirconia was replaced by thoria. About 1900 zirconia was used in the Nernst glower. At present only a very small quantity is used for lighting purposes. The oxide is used as an opacifier in the enamel industry, and small quantities (from 0.1 to 2.5 per cent) have been added to fused silica ware. The oxide makes a nonpoisonous, nondiscoloring white paint of permanency and good covering power, which is not affected by hydrogen sulphide, by acids, or by alkalies. The oxide also finds application in the making of X-ray pictures, and it has been suggested for use as a polishing powder. The finely divided zirconium oxide is incorporated with rubber before vulcanization so as to increase the toughness and tensile strength and to accelerate the vulcanization. Compounds have been used for weighting silk, and the carbide and other compounds, which are very hard, have been suggested as abrasives. Crystals of zircon, when clear and large enough, have been used as gem stones, being known as hyacinth when red, jacinth when yellow, and jargon when white. The pale-brown zircons from Ceylon, when decolorized by heat, are known as Matara diamonds.

The chief use of zirconium minerals, at present, is as a refractory material, the linear coefficient of expansion of pure fused zirconia (ZrO_2) being 0.00000084. Material made of fused zirconia can, therefore, be subjected to sudden changes of temperature without breaking. Because of the heat-resisting properties and resistance to fluxes and slags, zirconia would seem to be very suitable material for the manufacture of refractory bricks.

On this subject Meyer [8] says:

> In manufacturing refractory ware such as crucibles, muffles, combustion tubes, resistance cores, etc., from zirconia, it must always be borne in mind that the material has a very low thermal conductivity. Hence, the walls of the crucible or other shape must be considerably thinner than would be the case if other refractory bodies were used. Owing to the high tensile strength of articles made from zirconia when properly bonded and burnt at a sufficiently high temperature, it is possible to manufacture such ware without unusual danger of breakage through handling. Another important consideration in the use of zirconia is its resistance to fluxes and slags. Various patents have been secured, both in this country and abroad, covering the manufacture of refractory vessels from zirconia, for which are claimed remarkable heat-resisting properties. In one instance the pure oxide is mixed with 3 per cent to 10 per cent of magnesia, using starch, phosphoric acid, gelatinous zirconium hydroxide, or borates as binders. The ware is fired in an electric furnace at a temperature ranging from 2,000 to 2,300° C., thus producing a body which is practically impervious to all liquids and unaffected by strong acids or alkali fusions. Owing to the extremely low coefficient of expansion, such ware can be subjected to very sudden changes of temperature, in this way resembling fused silica, but, unlike the latter, is not subject to devitrification. Prior to 1915 no extensive research work had been done in America on the production of pure zirconium oxide on a commercial scale, but the inability to secure the product from abroad has spurred American investigators to develop commercial processes, so that there is every promise that an oxide running 98 per cent to 99 per cent ZrO_2 will in time be placed on the market at a price in the neighborhood of 60 cents per pound in ton lots. In the preparation of the pure oxide, it is

[8] Meyer, H. C., The industrial applications of zirconium: Mineral Foote-Notes, Foote Mineral Co., March, 1917, pp. 5–8.

extremely important that it be practically iron, titania, and silica free. Iron is particularly objectionable, as it acts as a flux. A very high grade commercially pure zirconium oxide gives the following analysis:

ZrO_2	99.91
TiO_2	.04
Fe_2O_3	.01
Al_2O_3	.01
SiO_2	.02
	99.99

A recent European patent covers the use of zirconium oxide as a surfacing material for silica, bauxite, or other refractory bricks and products. It is claimed by this process that a thin layer of zirconium oxide, with a suitable binder, renders the coated article highly resistant to slag corrosion. * * * The proper selection of a binder is a very important consideration in the manufacture of bricks and other ware from zirkite. Phosphoric acid, sodium silicate, and lime were tried but with indifferent success, and in many cases it was clearly apparent that such bonds were absolutely detrimental, causing serious fluxing and softening of the zirkite at comparatively low temperatures. In the manufacture of zirkite bricks in standard shapes, about 5 per cent of a highly refractory clay has been found a satisfactory bond, although a water-ground zirkite has been used as a cementing or bonding material, thus obviating the necessity of introducing binder having a lower melting point than the zirkite. American fire-brick manufacturers, however, have been unable to produce zirkite bricks on a commercial scale, owing to their inability to burn them at high enough temperatures to secure the maximum shrinkage. Most attempts to burn these bricks have been made in silica brick kilns, but with indifferent success. The future for zirkite in refractory bricks is very promising. The work along this line has been highly developed on the Continent and actual tests made on a Martin-Siemens furnace using a zirconia-lined hearth, show that after four months of continuous operation at high temperatures, the hearth was still in good condition and would serve at least four months longer before renewal. Careful statistics compiled from these tests show a saving of about 50 per cent in actual maintenance costs in favor of the zirconia lining over an ordinary refractory lining such as is generally used. No allowance was made for increased production and higher efficiency. The initial cost of zirconia lining is rather high as compared, for example, with magnesite brick, but it is more than offset by its higher melting point, marked resistance to corrosion, low thermal conductivity, and low coefficient of expansion.

The investigations of Dr. Charles Morris Johnson during the past few years have resulted in the manufacture of laboratory ware made from zirkite mixed with other refractory bodies. Zirkite filtering crucibles, muffles, combustion tubes, combustion boats, pyrometer protection tubes and Kipp generators with replaceable units are now on the market at prices comparing favorably with like articles manufactured from German porcelain or fused silica. Zirkite combustion tubes have been reported running in steel testing laboratories for as long a period as three months, being used constantly night and day. Owing to the composition of these tubes they are not attacked by basic substances, do not devitrify, and are gas-tight up to temperatures of 1,000° C.

With regard to zirkite Meyer [9] says:

The year 1918 witnessed an unprecedented demand for zirkite—the commonly accepted trade name for native zirconium oxide. The total amount of zirkite imported during 1918 was approximately 1,600 gross tons. This ore carries from 75 per cent to 80 per cent of zirconium dioxide. During the first quarter the demand for the ore was mainly for refractory purposes, as it has been shown to be of great value for electric-furnace linings, as well as for other purposes where a refractory having a low coefficient of expansion, high melting point, and maximum resistance to slag corrosion is demanded. It had been known prior to our entry into the war that the Germans had develped remarkable zirconium steel, which was claimed to be superior to vanadium, chromium, molybdenum, tungsten, or nickel steel. The demand for light armor plate on tanks, airplanes, and other equipment compelled the Government to investigate the possibilities of all steel-hardening elements for such purposes, and it was ultimately decided that zirconium was the best suited for the requirements of

[9] Meyer, H. C., Uncommon ores and metals: Eng. and Min. Jour., vol. 107, p. 125, 1919.

the War Department. Owing to the absence of any authoritative technical data on the production and uses of ferrozirconium, many difficulties were encountered, but ultimately, through the efforts of several large manufacturers of ferroalloys, a ferrozirconium suitable for the production of zirconium steel was evolved. Ferrozirconium, as now offered to the trade, carries approximately 30 per cent to 36 per cent of zirconium metal and sells for $4 to $4.50 per pound of contained metal, depending on the quantity demanded. It is not to be supposed that ferrozirconium will supplant ferrotungsten, ferrochromium, or ferrovanadium, but it seems evident that it will be largely in demand for certain purposes for which these other ferroalloys are not entirely satisfactory.

Lump metallurgical zirkite sold for 5 cents to 7 cents and ground for 6 cents to 8 cents per pound, depending on quantity. Zirkite cement for chemical purposes and as a bond for zirkite refractories sold at 8 cents to 10 cents per pound according to the quantity demanded.

The demand for zirkite bricks was active throughout 1918, increasing toward the closing months. All the standard brick shapes required by the trade are now available, and the use of this new basic refractory is well past the experimental stage. A standard 9-inch zirkite "straight" weighs approximately 12 pounds and sells in carload lots at prices comparing favorably with magnesite brick, when life and efficiency are considered.

PRODUCTION.

The early output of zircon in Norway and in North Carolina was used in the manufacture of incandescent gas mantles. Thoria and ceria have now entirely replaced zirconia in the manufacture of such mantles. The only zirconium mineral produced in the United States is zircon, almost all of which came from North Carolina. The zirconium minerals produced and exported from Brazil consist of the silicate, zircon, and the oxide, baddeleyite.

Zirconium minerals produced, 1902–1919.[a]

Year.	United States.		Brazil.			Year.	United States.		Brazil.		
	Quantity (short tons).	Value.	Quantity. Metric tons.	Quantity. Equivalent in short tons.	Value.		Quantity (short tons).	Value.	Quantity. Metric tons.	Quantity. Equivalent in short tons.	Value.
1902....	([b])	([b])	11	12	$3,947	1911....	[e] 1½	$802	41	45	$16,169
1903....	1½	$570	6	7	1,947	1912....	....	....	39	43	14,772
1904....	½	200	8	9	3,935	1913....	....	....	1,015	1,119	54,767
1905....	4	1,600	16	18	5,506	1914....	....	....	215	237	14,903
1906....	[c] ½	248	24	26	5,041	1915....	....	....	7	8	2,915
1907....	([d])	46	34	38	8,756	1916....	....	....	94	104	16,647
1908....	....	....	249	275	15,151	1917....	....	....	([f])	([f])	([f])
1909....	1	250	106	117	11,838	1918....	....	....	([f])	([f])	([f])
1910....	....	....	116	128	23,271	1919....	....	....	([f])	([f])	([f])

[a] In addition to the quantities and values given in this table, zircon has been produced in very small quantity in different countries, including the United States, because of its value as a gem. The actual figures of production of gem zircon are not available.

[b] It is reported that 1,000 pounds was mined in 1869 and 26 tons in 1883. No value was reported for these quantities. Dr. J. H. Pratt reports a production of 1 ton, valued at $380, in 1902. (Zircon, monazite, and other minerals, etc.: North Carolina Geol. Econ. Survey Bull. 25, p. 19, 1916.)

[c] The exact quantity is 1,100 pounds.

[d] 204 pounds.

[e] The exact quantity is 3,208 pounds.

[f] Figures not available.

IMPORTS.

The small imports of zirconium ore were not separately reported before July 1, 1918. For the six-month period, July to December, 1918, the imports of zirconium ore entered for consumption, as reported by the Bureau of Foreign and Domestic Commerce, Department of Commerce, amounted to 3,216,659 pounds (1,608 short tons), valued at $77,250, an average value of $48 a ton. In 1919 the imports amounted to 11,023 pounds, valued at $332.

RARE-EARTH MINERALS.

INTRODUCTION.

The term "rare earths" is variously interpreted [10] by different authors. As used in this report it excludes thorium and zirconium. The rare-earth elements are cerium, yttrium, lanthanum, neodymium, praseodymium, scandium, dysprosium, europium, samarium, terbium, ytterbium or neoytterbium, lutecium, celtium, erbium, holmium, and thulium. The elemental character of some of these minerals is still in doubt, and a number of additional names, such as victorium and decipium, have been proposed for what the authors believed to be new and additional elements. Their chemistry is an exceedingly difficult study; and the status of many of them may undergo considerable revision.

At present only a very few of these rare earths find any practical uses. Industrial chemistry is making such immense strides, however, that it is well not to ignore from the practical side those chemical elements which to-day seem to be only chemical curiosities.

CERIUM.

OCCURRENCE.

Cerium is found in many minerals, the most abundant of which are monazite, allanite, and cerite. Other minerals of very rare occurrence which contain high percentages of cerium are: Beckelith, britholite, caryocerite, erdmannite, freyalite, johnstrupite, melanocerite, mosandrite, rinkite, steenstrupine, thulite, tritomite, tscheffkinite, aeschynite, churchite, rhabdophanite, ancylite, bastnaesite, cordylite, parisite, weibyeite, fluocerite, tysonite, yttrocerite, samarskite, fergusonite, and euxenite. When the industrial uses of cerium were discovered a demand for allanite arose, and a large deposit of this mineral was found in Virginia. The mineral monazite, however, is more abundant than all the others combined, and, as thousands of tons of monazite are mined annually, it seems that the value of any deposit of minerals, considered solely on its cerium content, is very doubtful and will remain doubtful for a long time to come.

Monazite is mined for its content of thorium which is the basis of the incandescent gas mantles; the cerium and other rare earths in monazite are by-products obtained in large quantities. The total output of monazite which has been mined in the world to date is

[10] The term "earth" is applied to certain metallic oxides which were formerly regarded as elementary bodies, as Y_2O_3, Er_2O_3, La_2O_3, and names ending in "a" are often used in designating them, as yttria, erbia, lanthana. The ending "um" designates the element, as yttrium, erbium, lanthanum. (Browning, P. E., Introduction to the rarer elements, 2d ed., p. 35, 1908.)

about 88,000 tons. About a quarter of this is ceria, the oxide of cerium, so that it is evident that a very large supply of ceria is already on the market. The rare earth residues obtained from monazite in the process of extracting the thoria consist of about 45 per cent of ceria, 25 per cent of lanthania, 15 per cent of didymia, the remainder being composed chiefly of yttria and samaria.

USES.

Cerium finds a number of applications, but the total quantity consumed is only a small fraction of the total quantity produced. The incandescent mantles contain about 1 per cent of ceria, as it has been found that a mixture of 99 parts of thoria and 1 part of ceria gives the brightest illumination.

The metals of the cerium group (cerium, lanthanum, neodymium, and praseodymium) when scratched throw off glowing particles. This property is not lost in alloys, and as the cerium metals are too soft to be used alone they are alloyed with harder and commoner metals such as iron, tin, and zinc. These alloys possess the necessary strength, hardness, and brittleness to permit of their use in lighting devices. These alloys with the cerium metals have been given various names, such as pyrophoric alloy, spark-giving alloy, cer, lanthan, ferrocerium, cerium alloy, cerium-iron alloy, cerium-mixed metal, sparking metal, ignition stone, firestone, erd-metal, misch-metal, and Auer-metal. Kunheim metal is a similar alloy of the cerium group metals with magnesium and aluminum. One brand of cerium-mixed metal consists of approximately 50 per cent of cerium, 45 per cent of lanthanum, neodymium, and praseodymium, and 1 per cent of iron. Another alloy contains 71.2 per cent of cerium, 27.8 per cent of other rare earths, 0.43 per cent of iron, and 0.38 per cent of silicon.

The pure mixed metal, being too soft, is alloyed with about 30 per cent of iron to make the commercial sparking metal, which, as used, is in the form of small strips or "flints," of varying lengths, either round or rectangular. The commonest form is a round piece about one-eighth of an inch in diameter and of the same length. There are from 1,500 to 2,000 such pieces to the pound. By scratching these alloys with hardened steel sparks are given off which will ignite tinder or a wick wet with alcohol or benzine. The sparks are caused by the fact that the metal cerium ignites at a low temperature. When such alloys are scratched small pieces of the metal are broken off and the heat of the friction raises these minute particles to the ignition temperature, when they burn, uniting with the oxygen in the air to form the oxide of cerium. Recently it has been suggested that the chemistry of the process is more complex, a layer of suboxide, itself pyrophoric, being formed on the metal. The igniting property of these sparks has been applied to pocket lighters for cigarettes, cigars, pipes, and miner's lamps and to various forms of gas lighters. Their use has also been suggested for the ignition of explosives, in military signaling, for defining the flight of shells, and as an illuminant in photography. Various combinations of the elements have been suggested for use as electrodes in arc lamps and flash-light powders. These alloys have been suggested as reducing agents, and the addition of 0.2 per cent of cerium to metallic aluminum is said to have a beneficial effect on its properties.

Ceria, the oxide of cerium, has been introduced, to the extent of about 10 per cent, into spectacle glasses, which thereby cut off most of the ultra-violet light and a good proportion of the heat rays. Cerium fluoride is incorporated into the carbons of arc-lamp electrodes, a very intense and even light being obtained. Several hundred tons of ceria was used annually before the war in the production of pyrophoric alloys, and about the same quantity of cerium fluoride for impregnating arc-light carbons.

Salts of cerium find an application as catalysts in the manufacture of aniline black and have been proposed for use as a catalyst in the contact process for the manufacture of sulphuric acid. The oxidizing powers of cerium salts have been applied to the manufacture of a number of organic substances. Cerium sulphate has been employed in photography for removing silver from overdeveloped negatives; cerium salts are used in color photography; and the oxalate finds a very slight use in medicine.

Attempts have also been made to use cerium salts for tanning and dyeing and in the manufacture of certain enamels and porcelains.

YTTRIUM.

OCCURRENCE

The chief sources of yttrium compounds are the minerals gadolinite and xenotime. The residues from the thorium extractions from monazite also contain yttrium. Other minerals containing yttrium in quantity are allanite, cappelenite, cenosite, rowlandite, thalenite, yttrialite, fergusonite, euxenite, samarskite, polycrase, rogersite, sipylite, yttrocrasite, yttrotantalite, tengerite, and yttrocerite. The elements erbium, terbium, holmium, thulium, dysprosium, ytterbium, lutecium, and europium belong in the same chemical group as yttrium.

The largest deposit of yttrium minerals known in this country is in Llano County, Tex.,[11] which has produced about a ton or more of yttrium minerals. About 1,200 pounds of gadolinite was produced[12] in Norway in 1905–6.

USES.

At present the elements of the yttrium group have very little technical importance. They were formerly used in the manufacture of filaments for Nernst lamps, but metal-filament lamps have now largely superseded them. Thulium oxide is said to emit a carmine-colored light when heated to a certain temperature. The oxide of terbium is a strong catalyzer and may be used as a contact agent in oxidation processes.

The present demand for these elements seems to be so small that no encouragement is held out for the development of deposits of yttrium minerals.

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[11] Hess, F. L., Minerals of the rare-earth metals at Baringer Hill, Llano County, Tex.: U. S. Geol. Survey Bull. 340, pp. 286–294, 1908.

[12] Brögger, W. C., Die Mineralien d. Süd-Norweg. Granit-pegmatit gänge, I, Niobate, Tantalate Titanate und Titanoniobate: Videnskabs-Selskabets Skrifter, Math.-naturv. Kl., No. 5, p. 20, 1906.

Gadolinite is reported [13] to have been gathered from the sand dunes in Mohave County, Ariz., by the thousands of pounds for use as a gem stone.

LANTHANUM.

OCCURRENCE.

Lanthanum and the two elements neodymium and praseodymium, which together are sometimes called didymium, form an essential part of the mineral monazite. As with cerium, the large quantities of oxides of the lanthanum group, obtained as a by-product in the extraction of thorium from monazite, would suffice to supply a considerable demand. Three other elements—samarium, scandium, and decipium—belong in the lanthanum group. These elements are widespread in their occurrence and, like most of the rare earths, are found in small quantities in many minerals. Browning [14] lists 200 names of minerals containing rare earths.

In addition to monazite the minerals cerite, allanite, bastnaesite, and lanthanite are sources of lanthanum; cerite, allanite, and bastnaesite of neodymium and praseodymium; samarskite, allanite, cerite, gadolinite, and keilhauite of samarium; gadolinite, yttrotitanite, euxenite, and keilhauite of scandium; and samarskite of decipium.

USES.

A solution of the nitrates of neodymium and praseodymium is used for marking the incandescent gas mantles. An organic dye, such as methylene blue, is added to make a visible impression on the mantle, as the solution of the nitrates is only faintly colored. On ignition, the organic dye is destroyed and the nitrates are converted to the oxides, which are deeply colored and permanent.

Lanthanum, like cerium, is pyrophoric and emits sparks when scratched. As stated under cerium, some of the pyrophoric iron alloys contain much lanthanum and other elements of this group.

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[13] Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 23, 1917.

[14] Browning, P. E., Introduction to the rarer elements, 2d ed., pp. 36–42, 1908.

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FUEL BRIQUETTING.[1]

By F. G. Tryon.

PRODUCTION.

For the fuel-briquetting industry, as for the mining of coal, the year 1919 was one of depression. The total production of briquets was 295,734 net tons, a decrease, compared with 1918, of 181,501 tons, or

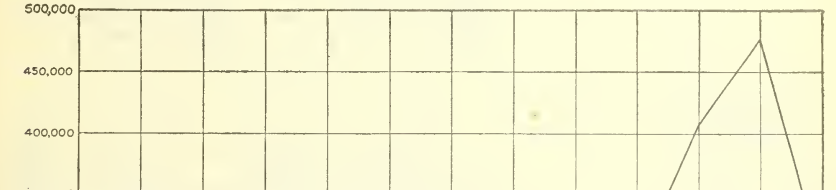

FIGURE 1.—Production of fuel briquets, 1907-1919, in the Eastern, Central, and Pacific Coast States and in the United States.

38 per cent. In fact, as shown by the accompanying diagram, the output dropped back to the position occupied in 1916.

The causes of this decline are not far to seek. During the war the scarcity of other fuels had created an active demand for briquets, a

[1] The tables in this report were prepared by Miss J. M. Corse, who has compiled the statistics of fuel briquetting since 1911.

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demand which in 1918 resulted in a production more than double that of 1915. After the armistice, however, the country was found to be stocked with coal in excess of its peace-time requirements. Not only did the closing of munition plants reduce the industrial demand for fuel, but the unusually mild weather during the winter of 1918–19 curtailed the consumption of domestic fuel as well. In consequence the production of bituminous coal fell off 21 per cent from 1918 to 1919, and that of anthracite 13 per cent. The depression in the briquet-making industry was due to essentially the same causes. As the demand for coal in general became less active, producers of briquets found increasing difficulty in meeting the competition of other forms of domestic fuel, particularly anthracite. It is significant of this competition that the production of anthracite, like that of briquets, fell back to the level of 1916.

Fuel briquets produced in the United States in 1918 and 1919.

	1918			1919		
	Number of operating plants.	Quantity (net tons).	Value.	Number of operating plants.	Quantity (net tons).	Value.
Eastern States:						
New Jersey	2			1		
Pennsylvania	3			3		
Virginia	1			1		
	6	172,266	$728,017	5	68,203	$339,051
Central States:						
Missouri	1			1		
North Dakota [a]				1		
Wisconsin	2			2		
	3	213,030	1,741,769	4	146,587	1,242,210
Pacific Coast States:						
California	1			1		
Oregon	1			1		
Washington	1			1		
	3	91,939	743,007	3	80,944	719,793
	12	477,235	3,212,793	12	295,734	2,301,054

[a] No production in 1918.

The decline in the production of briquets was most pronounced in the Eastern States, where a decrease of 60 per cent occurred in 1919, as compared with 1918. In the Central States the decrease amounted to 31 per cent, and in the Pacific Coast States, where the competition of coal is less immediate, it was only 12 per cent.

More than half the production in 1919 was reported from three States remote from coal mines—Wisconsin, California, and Oregon. The localization of so large a part of the industry in these three States is attributed in each case to the active demand for household fuel and to the presence of a local supply of materials suitable for briquetting. In Wisconsin the local material available is slack, resulting from the rehandling of coal shipped by vessel to the head of the Lakes. In California and Oregon the local material is the carbon residue from the manufacture of oil gas.

VALUE.

The value of the briquets produced in 1919 was $2,301,054, a decrease when compared with the value in 1918 of $911,739, or 28 per cent. In 1917 the value was $2,233,388, and in 1916, $1,445,662. The value per ton has increased markedly during the last four years, rising from $4.90 in 1916 to $5.49 in 1917, $6.73 in 1918, and $7.78 in 1919. Because of the increase in unit value the production of 1919, although much smaller than that of 1917, exceeded it in value.

The average value per ton was lowest in the Eastern States and highest on the Pacific coast. For the Eastern States, where the plants use anthracite or semianthracite culm, and are located at or near the mines, the average value was $4.97 a ton. In the Central States the principal materials used are anthracite, semianthracite, and bituminous slack, resulting from the degradation of coals which have been transported great distances, and both costs and selling price are correspondingly higher. In 1919 the average value per ton in the Central States was $8.47. A still higher value ($8.89 a ton) was reported from the Pacific coast.

Fuel briquets produced in the United States in 1907–1909 and 1911–1919.

Year.	Quantity (net tons).	Value.	Year.	Quantity (net tons).	Value.
1907	66,524	$258,426	1914	250,635	$1,154,678
1908	90,358	323,057	1915	221,537	1,035,716
1909	139,661	452,697	1916	295,155	1,445,662
1911	218,443	808,721	1917	406,856	2,233,888
1912	220,064	952,261	1918	477,235	3,212,793
1913	181,859	1,007,327	1919	295,734	2,301,054

RAW MATERIALS AND BINDERS.

Of the 12 plants in operation during 1919, 5 used anthracite as a raw material, 1 Arkansas semianthracite, 1 a mixture of anthracite and bituminous slack, 1 semibituminous slack, 1 a mixture of bituminous slack and subbituminous coal, 1 brown lignite, and 2 carbon residue from the manufacture of oil gas.

The total quantity of raw fuel used in 1919, shown in the following table, was 296,365 net tons, of which more than one-third was anthracite culm and fine sizes. Next in importance came semibituminous and bituminous slack, which together with semianthracite constituted 38 per cent of the total. Smaller quantities of brown lignite and of black lignite, or subbituminous coal, were also used; these have been combined with oil-gas residue in the table to avoid disclosing individual operations.

Raw fuels used in making briquets in 1917, 1918, and 1919, in net tons.

	1917	1918	1919
Anthracite culm and fine sizes	137,659	209,690	104,027
Semianthracite Semibituminous Bituminous slack	161,269	180,714	111,955
Lignite and subbituminous coal Oil-gas residue	103,408	76,602	80,383
	402,336	467,006	296,365

Three of the 12 plants which operated in 1919 used no binder, 3 used asphaltic pitch, 2 coal-tar pitch, 1 coal-tar pitch and asphaltic pitch, 1 asphaltic pitch and sulphite pitch, 1 sulphite liquor, and 1 a patent binder. Of the total quantity of briquets produced 17 per cent was manufactured without binder, and 73 per cent with a binder of either asphaltic pitch, coal-tar pitch, or a mixture of the two. The quantity produced with the use of other binders was 10 per cent of the total.

Briquets produced in 1919 by type of binder used, in net tons.

No binder	49,324
Asphaltic pitch	103,970
Asphaltic pitch and coal-tar pitch Coal-tar pitch	112,465
Asphaltic pitch and sulphite pitch Waste sulphite liquor Patent binder	29,975
	295,734

NUMBER AND LOCATION OF BRIQUETTING PLANTS IN THE UNITED STATES.

In 1919, 12 plants were in operation, the same number as in 1918. Two companies which had produced in 1918 reported no output in 1919—the Trent Brick Co., of Trenton, N. J., and the Gamble Briquette Co., of Harrisburg, Pa. The Anthracite Briquette Co. began operations at its plant at Sunbury, Pa., in December, 1919. The plant of the Johnson Fuel Co., at Scranton, N. Dak., which had been idle during 1918, operated a part of the year.

Briquetting plants operated in the United States in 1919.

Group.	Location of plant.	Date put in operation.	Raw fuel used.	Name and address of operator.
Eastern States:				
New Jersey	Trenton	1918	Anthracite	Fuel Briquet Co., 520 Brunswick Avenue, Trenton, N. J.
Pennsylvania	Sunbury	1919	do	Anthracite Briquette Co., Sunbury, Pa.
Do	Lansford	[a] 1909	do	Lehigh Coal & Navigation Co., 437 Chestnut Street, Philadelphia, Pa.
Do	Dickson City	1907	do	Scranton Anthracite Briquette Co., Dickson City, Pa.
Virginia	Parrott	1915	do	Delparen Anthracite Briquet Co., 1 Broadway, New York, N. Y.
Central States:				
Missouri	Kansas City	1909	Arkansas semianthracite.	Standard Briquet Fuel Co., 319 Fourth Street north, St. Louis, Mo.
North Dakota	Scranton	1917	Lignite.	Johnson Fuel Co., Fairfax, S. Dak.
Wisconsin	Superior	1912	Semibituminous slack.	Berwind Fuel Co., 122 Michigan Avenue south, Chicago, Ill.
Do	do	1909	Anthracite culm and bituminous slack.	Stott Briquet Co., Merchants National Bank Building, St. Paul, Minn.
Pacific Coast States:				
California	Los Angeles	1905	Carbon (petroleum residue).	Los Angeles Gas & Electric Corporation, 645 Hill Street south, Los Angeles, Calif.
Oregon	Linnton	1913	do	Portland Gas & Coke Co., 294 Yamhill Street, Portland, Oreg.
Washington	Renton	1914	Bituminous slack and subbituminous coal.	Pacific Coast Coal Co., 612 L. C. Smith Building, Seattle, Wash.

[a] Plant destroyed by fire in 1909; reconstructed in 1911.

LITHIUM MINERALS.

By Herbert Insley.

PRODUCTION.

Since the last report (1916) on lithium minerals was published by the United States Geological Survey the production has increased greatly, the output in 1919 being more than ten times that in 1916. This marked increase is no doubt due to the increased use of lithium salts in storage batteries and of lithium salts and lepidolite in the manufacture of glass.

Before 1918 South Dakota produced most of the lithium minerals in this country, but in 1918 and 1919 the value of the output in California was more than half of the value of the total output of the United States. With the exception of spasmodic production in Massachusetts and Maine in one or two years, the whole output in the United States has come from South Dakota and California.

The following table shows the production of lithium minerals in the United States from 1889 to 1919. The production for Spain is also shown, as Spain is the only other country for which figures for consecutive years are available. All of Spain's production came from one mine in the province of Cáceres.

Lithium minerals produced, 1889–1919.[a]

Year.	United States.		Spain.		Year.	United States.		Spain.	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.		Quantity (short tons).	Value.	Quantity (short tons).	Value.
1889	[b] 30	[b] $450			1909	189	$1,890		
1891	[b] 30	[b] 750			1910	238	2,380		
1898	[b] 30	[b] 750			1911	500	9,000		
1899	[b] 210	[b] 3,500			1912	360	6,800	33	[b] $175
1900	520	[b] 9,500			1913	530	14,900		
1901	1,750	43,200			1914	525	8,000	33	[b] 175
1902	1,245	25,750			1915	486	9,867	110	[b] 584
1903	1,155	23,425	19	$100	1916	619	12,035	56	(c)
1904	577	5,155	99	347	1917	2,062	42,912	11	(c)
1905	79	1,412	132	467	1918	5,894	111,600	11	(c)
1906	383	7,411	231	818	1919	6,287	115,000	(c)	(c)
1907	530	11,000							
1908	203	1,550	110	584					

[a] The statistics for the United States from 1907 to 1919 were collected and compiled by Miss A. T. Coons.
[b] Estimated.
[c] Figures not available.

PRICES AND SUPPLIES.

As a rule lithium minerals are sold by the ton, and the price depends on the mineral. Amblygonite brings by far the highest price, that paid in 1919 being from $50 to $60 a ton. Spodumene brings from $20 to $25 a ton, and lepidolite from $14 to $20. The prices of lithium minerals have not increased so rapidly in the last few years as the prices of other commodities.

Buyers often contract with the mines for a certain quantity of the mineral desired and specify that all bought must contain a certain percentage of lithium oxide. This percentage is usually high (about 8 per cent for amblygonite), as it has been found profitless to try to refine lithium minerals that contain only small quantities of lithium oxide. Large quantities of readily available lithium minerals have not been mined because their content of lithium oxide is below the standard demanded by buyers.

The known deposits of lithium minerals in the United States should be ample to supply all the demands of the manufacturers in this country for a long time to come, even if unexpected uses should be discovered.

PROPERTIES.

The element lithium was first discovered by Arfvedson in 1817. It is a silver-white, very soft metal with an atomic weight of about 7. Its density is so low (specific gravity = 0.59) that it easily floats on kerosene. It forms the oxide or some other salt on exposure to the air and decomposes water, forming the hydroxide of lithium.

SOURCES.

In nature lithium is not only found in certain minerals but also in most plants, and it has been shown that the ash of tobacco frequently carries a perceptible quantity.

The most abundant lithium minerals are lepidolite, spodumene, and amblygonite.

Lepidolite is a lithium mica and has the composition $H_2KAl_3(SiO_4)_3.R_3AlF(Si_3O_8)$. It usually occurs as a compact aggregate of very small scales forming scaly, granular masses. The color may be gray, white, yellow, pink, red, purple, or blue, although a decided pink or purple tint is characteristic. Most of the lepidolite mined in the United States comes from California.

Spodumene is a lithium-aluminum metasilicate ($LiAl(SiO_3)_2$). Much of it contains small quantities of sodium or manganese. The color may be gray, yellow, green, or purple. The crystals are elongated in habit parallel to the vertical axis. Parallel striations in the direction of elongation are very characteristic. Transparent and flawless spodumene is often cut for gem stones. Practically all the spodumene produced in the United States is mined in South Dakota. The most remarkable characteristic of spodumene crystals is their large size. Spodumene crystals from South Dakota having a length of 30 feet are not uncommon, and one 42 feet long has been reported.

Pure amblygonite has the composition $Li(AlF)PO_4$. Distinct crystals of amblygonite are rare, the mineral usually being compact and massive. In South Dakota large masses of amblygonite weighing hundreds of pounds are found. Except for a few tons all the amblygonite mined in the United States has come from South Dakota.

Other minerals which contain appreciable quantities of lithia are triphylite, a phosphate of iron and lithium; lithiophylite, a corresponding phosphate of manganese and lithium; petalite, a rare mineral with the composition $LiAl(Si_2O_5)$; and zinnwaldite, a lithium mica similar in composition to lepidolite but containing in addition about 10 per cent of iron oxide.

A more extended description of the minerals containing lithium will be found in Mineral Resources for 1916.[1]

Typical composition of lithium minerals mined as sources of lithium compounds.[a]

	Spodumene.	Lepidolite.	Amblygonite.	Triphylite.
Silica (SiO_2)	64	51		
Alumina (Al_2O_3)	27	27	34	
Lithia (Li_2O)	7	4	9	9
Potash (K_2O)		11		
Phosphoric acid (P_2O_5)			48	45
Water (H_2O), combined		2	5	
Fluorine (F)		7	5	
Iron, manganese, lime, magnesia, soda	2	1	1	46
	100	103	102	100
Less oxygen equivalent of fluorine		3	2	
	100	100	100	100

[a] Schaller, W. T., op. cit., p. 11.

OCCURRENCE AND DISTRIBUTION.

Lithium minerals in quantities sufficiently large for commercial exploitation are found only in pegmatite dikes.

In South Dakota pegmatite dikes carrying lithium minerals were one of the last products of crystallization of the igneous magma that formed the central core of the Black Hills. These pegmatites cut the sedimentary formations and schists, as well as the granites from which they are offshoots. Spodumene and amblygonite are the most common lithium minerals in South Dakota. Spodumene occurs in large "logs" and amblygonite in nodules—some of which weigh more than half a ton—in mines near Keystone, Custer, Hill City, Glendale, and Hayward. Ziegler[2] has described in some detail the occurrence of the lithium-bearing pegmatites in the Black Hills.

In the southern part of California the lithium-bearing pegmatites occur as dikes in the igneous rocks of the Peninsular Range. A large number of these dikes carrying lepidolite, amblygonite, and spodumene are found at Pala, San Diego County. Lepidolite is by far the most important lithium-bearing mineral in this locality.

A more detailed description of the South Dakota and California localities and descriptions of other localities in the United States and foreign countries may be found in Mineral Resources for 1916.[3]

[1] Schaller, W. T., Lithium minerals: U. S. Geol. Survey Mineral Resources, 1916, pt. 2, pp. 8-12, 1917.
[2] Ziegler, Victor, Lithia deposits of the Black Hills: Eng. and Min. Jour., vol. 96, pp. 1053-1056, 1913; The mineral resources of the Harney Peak pegmatites: Min. and Sci. Press, vol. 108, pp. 604-608, 654-656, 1914.
[3] Schaller, W. T., op. cit., pp. 12-17.

USES.

Lithium minerals are used as such but also as sources of the salts of lithium.

At one time the principal use of lithium salts was in medicine in the treatment of rheumatism, rheumatic tendencies, gout, and gravel, but of late years their effectiveness has been questioned and they have been superseded to a great extent by synthetic coal-tar products.

Lithium hydroxide is now used in a certain type of storage battery. A large percentage of the lithium minerals produced is undoubtedly manufactured into lithium hydroxide for this purpose.

The introduction of lithium salts and lepidolite as such into glass batches has been found to reduce the viscosity of the melted glass. On April 2, 1918, a patent was granted to Erik W. Enequist (U. S. patent No. 1261015) for the discovery of the process of adding lepidolite to glass batches. The fluorine contained in lepidolite is found to be of advantage as an opacifying agent in the manufacture of opal glasses. It is probable that lepidolite may be used to decrease the viscosity of enamels as well as of glass, but so far as is known to the Survey there has been no commercial production of enamels in which lepidolite is used.

Lithium bromide and lithium iodide have been used in photography and lithium cyanide in Roentgen-ray experiments. Lithium chloride is used to some extent in fireworks and signal lights. Lithium carbonate, mixed with carmine, is used as a staining nucleus.

Transparent spodumene is used as a gem stone, the green (hiddenite) and lilac (kunzite) varieties having considerable value.

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PEAT.

By K. W. Cottrell.

PRODUCTION.

There was a decided decrease in both the quantity and value of domestic peat marketed in 1919, notwithstanding the hopes for that year awakened by the activity of the trade during 1917 and 1918 and the increasing demand for peat as fertilizer and fuel. This decrease may doubtless be attributed to the high cost of labor and the lack of transportation facilities.

The total production of peat in the United States in 1919 was 69,197 short tons, valued at $705,532, an average price per ton of $10.20. This was a decrease of 35 per cent in quantity and of 33 per cent in value, but an increase of 44 cents in the price per ton, compared with 1918.

The accompanying table shows the output and value of peat since 1915. It includes air-dried and mechanically dried peat, in which the moisture content is low, and does not represent raw peat, which contains a large percentage of moisture.

Peat produced in the United States, 1915–1919.

Year.	Number of plants reporting.	Quantity (short tons).	Value.	Average price per ton.
1915	9	42,284	$288,537	$6.82
1916	13	52,506	369,104	7.03
1917	18	97,363	709,900	7.29
1918	25	107,261	1,047,243	9.76
1919	15	69,197	705,532	10.20

PEAT PRODUCTS.

PEAT AS FERTILIZER AND FERTILIZER FILLER.

In 1919, as in previous years, almost the entire output of peat was used as a direct fertilizer and for a nitrogenous ingredient of commercial fertilizers. The total shipment of peat for this purpose, reported from 13 plants, was 54,690 tons, valued at $557,240. This was 31 per cent less in quantity and 28 per cent less in value than that reported in 1918.

Peat used in manufacturing fertilizer in the United States, 1915–1919.

Year.	Quantity (short tons).	Value.	Average price per ton.
1915	38,304	$258,447	$6.75
1916	48,106	336,004	6.98
1917	92,263	658,500	7.14
1918	79,573	775,313	9.74
1919	54,690	557,240	10.19

PEAT AS A FUEL.

Many attempts to manufacture fuel from peat have been made in the United States, and in 1918 it seemed, in the New England States at least, that peat fuel might soon establish a place for itself in the commercial world. The shortage and high price of coal may yet render it well worth the while of some of the large manufacturing and other interests to investigate the possibilities of peat fuel. Certainly the failure of peat-fuel enterprises can not be attributed to inability to dispose of the finished product but must rather lie in the lack of proper machinery, of labor, or of sufficient capital to carry the plant over a critical period.

For years the European countries have been utilizing peat for fuel. During the recent war the scarcity of coal in the British Isles and Canada, as well as on the European Continent, due to the absence of miners, necessitated the use of a substitute for coal. The disadvantages in the use of peat for this purpose, resulting from its bulky nature and the quantity of water it contains, may be satisfactorily overcome, as has been demonstrated by the manufacture of peat briquets. Peat has long been used for direct combustion. Rough blocks of peat are cut from the bog, allowed to dry in the hot sun, and are then ready for use. This is the more economical method of drying. It is reported that a large power station in Wiesmoor, Germany, has worked successfully for many years with air-dried peat, distributing electric power within a radius of 25 miles.

In Norway the Smolen Co., which owns peat bogs on Smolen Island, off the western coast, has a modern plant with six large machines for preparing the peat for market. Consul General Marion Letcher,[1] at Christiania, does not go into the details of the preparation of the peat, but he states that the company intends to extend its business to the manufacture of peat briquets for use by steamers and factories and that a coastwise steamship company serving the local trade in that vicinity has already used peat for its steamers, thus being able to keep up its sailings to the full extent while other local lines had to reduce their sailings because of the shortage of coal.

In Esthonia[2] peat has been tried as fuel on a narrow-gage State railway. The results were reported satisfactory, the principal difficulties encountered being the large space required for storing the fuel on account of its light weight and the fact that it had to be fed by hand instead of by shovel.

Consul Frederick Simpich,[3] on duty in Berlin, states that in Germany a society has been organized among 35 towns of Thuringia for the purchase and development of peat bogs lying in the Weser Basin, south of Bremen, as a source of fuel supply for these towns.

These are only a few of the many instances in which peat is being satisfactorily used as fuel in foreign countries, and it is hoped that another year may show that the United States has taken its place among the countries successfully manufacturing from peat an acceptable substitute for coal.

Dr. C. D. Jenkins, president of the New Era Development Co., of Shirley, Mass., the only producer of peat fuel in New England who

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[1] Peat production in Norway: Commerce Repts., June 29, 1920.
[2] Peat as railway fuel in Esthonia: Commerce Repts., Dec. 29, 1919.
[3] Commerce Repts, Apr. 17, 1920.

reported sales in 1919, writes that he has "invented and patented machinery for excavating, extracting water to 30 per cent, drying or carbonizing, and briqueting" the peat, and has sent very interesting samples of the briquets as they will be made when the machinery is in place.

No production of peat fuel was reported to the United States Geological Survey for 1915; an insignificant quantity was reported for 1916, but none for 1917. The production in 1918 and 1919 is given in the table on page 45, but in order that the returns of individual operators in 1919 may not be disclosed peat fuel, which was reported from only two plants, and miscellaneous products are combined.

PEAT AS FOOD FOR STOCK.

Crude peat may not be considered a food for live stock, but properly prepared or carbonized peat has been used with good results in this country for the last 10 years and in European countries for more than 20 years as an ingredient in the preparation of commercial feeds for both live stock and poultry. Although carbonized peat is reported to contain nitrogen, phosphoric acid, and oil, all of which are important ingredients in the feed, it is not claimed to have any particular nutritive value. The effect is rather to stimulate the appetite and aid digestion, thus permitting the feeding of larger quantities of the fattening foods. The chief ingredients of the commercial feeds in which peat is used are cottonseed meal and molasses from beet or cane sugar factories. The mechanical influence of the peat in the use of molasses feeds is to prevent hardening and loss from evaporation. In addition to its value in commercial feeds, properly prepared peat or humus has proved to be a corrective and preventive in live-stock diseases.

The following extracts quoted from a letter of August 9, 1920, from Mr. John Wiedmer, president of the Wiedmer Chemical Co., which specializes in the manufacture of carbonized peat, are given as representing the arguments and conclusions of the manufacturer, himself an experienced student of peat:

My first knowledge and observation of this use for our special carbonized peat was in 1908–9. A manufacturer of sweetened stock feeds, of which black-strap molasses was the base, purchased a car of our product that we were preparing for the fertilizer trade. This looked very strange to me, and I visited him to ascertain what he was doing. He had visited Europe and knew of the uses of peat in some of the European countries, of which he told me. It was practically what Prof. Charles A. Davis of your department published in his Bulletin 16 [Bur. Mines], issued in 1911. Being personally acquainted with Prof. Davis, I talked this matter over with him, and he confirmed what this manufacturer told me. I have never positively ascertained how these European countries using peat in stock feed prepared their peat, but found that the principal object was to add the peat in order to overcome the bad effects of molasses, such as scouring, belching, and bloating. Charcoal is one of the best preventives for this trouble, so we began to carbonize our peat by subjecting it to a very high degree of heat, practically making it a charcoal. We made careful chemical analyses of our finished product, as per copy herewith, and found that the manufacturers of molasses feeds could only use about 20 per cent of black-strap molasses without the use of a corrector, but with the addition of this product of ours feeding tests developed the fact that as high as 50 per cent of black-strap molasses could be used. This, as long as molasses was cheap, was quite an item, and besides the feeders in the intense feeding district of the territories adjoining us called for a feed with our product in it.

Our contention, of course, is based on our special carbonized peat, holding in general that we have never offered our product as a food but as a corrector and digester, a practical charcoal, and we contend that our material is as good for the purpose set forth as charcoal is.

Carbonization takes peat out of its raw state and changes its nature just as much as making charcoal from wood or cooking raw products changes their natures.

I call your attention to analyses by Dr. H. E. Wiedemann; you will note he finds about 18 per cent of protein in our material. The pepsin test shows that this is about 30 per cent digestible. Some of the State chemists objected to this high protein content, holding that manufacturers of feed took advantage of this in the formula of their feed. But as the manufacturer uses less than 5 per cent of the peat in his feeds the protein thus applied would be very slight. The moisture of 10 per cent shown is not actual water, but more of a humic acid. The other analysis is of the ash content of our peat. * * * The actual sand in the material is very slight.

Analysis of peat.

Protein	17.84
Carbohydrates	35.50
Crude fiber	15.01
Fat	1.10
Moisture	10.06
Ash	20.49

Analysis of peat ash.

Silica	51.66
Iron oxide	4.27
Alumina	9.15
Calcium oxide	21.43
Magnesia	2.74
Sulphur trioxide	8.04
Phosphoric acid	1.57
Potash	.60
Soda	.51

Although there is evidence that the use of carbonized peat is desirable rather than otherwise in the manufacture of some kinds of commercial stock feeds, the objections made to its use in some of the States might well tend to discourage operators in those localities. Nevertheless the total quantity of peat used in the manufacture of stock food in 1919 was 6,402 short tons, valued at $98,940, an average price per ton of $15.45. Though this quantity was 10 per cent less than that used in 1918, it was greater than in any other previous year, according to the records of the Geological Survey. The average price per ton increased 38 cents.

Peat used in manufacturing stock food in the United States, 1915–1919.

Year.	Quantity (short tons).	Value.	Average price per ton.
1915	3,980	$30,090	$7.56
1916	4,300	32,250	7.50
1917	5,100	51,400	10.08
1918	7,096	106,935	15.07
1919	6,402	98,940	15.45

PEAT AS A SOURCE OF ALCOHOL.

Erwin W. Thompson, commercial attaché at Copenhagen, Denmark,[4] reports that successful experiments have been made in extracting alcohol from peat. The peat is boiled under pressure with sulphuric acid, and a sugar solution is obtained and some residual products. After the acid has been neutralized with lime,

[4] Commerce Repts., Jan. 8, 1919.

the sugar solution is made into alcohol, and the peat residue is collected and made into briquets for fuel.

The Swedish Government has agreed to the building of a factory on the understanding that the shareholders in the company should have the right to purchase and use the alcohol for their motor boats, trucks, and private automobiles irrespective of Government prohibitions and maximum prices.

IMPORTS AND EXPORTS.

The imports of peat during 1919 were 464 tons, valued at $16,345, and consisted of peat moss. The quantity was so small that records of the countries from which it was received were kept only at the port of entry. No exports of crude peat or peat products were reported in 1919.

Peat moss imported for consumption in the United States, 1915–1919.

Year.	Quantity (short tons).	Value.	Average price per ton.
1915	7,514	$48,142	$6.41
1916	3,042	27,859	9.16
1917	506	4,966	9.81
1918			
1919	464	16,345	35.23

SUMMARY.

Peat and peat moss used in the manufacture of peat products in the United States in 1918 and 1919.

Kind of product.	Production.		Imports.		Consumption.	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
1918.						
Fertilizer and fertilizer ingredient	79,573	$775,313			79,573	$775,313
Stock food	7,096	106,935			7,096	106,935
Fuel	20,567	164,745			20,567	164,745
Miscellaneous	25	250			25	250
	107,261	1,047,243			107,261	1,047,243
1919.						
Fertilizer and fertilizer ingredient	54,690	557,240			54,690	557,240
Stock food	6,402	98,940			6,402	98,940
Fuel and miscellaneous products	8,105	49,352			8,105	49,352
Moss			464	$16,345	464	16,345
	69,197	705,532	464	16,345	69,661	721,877

DISTRIBUTION OF PEAT PLANTS.

The 15 plants reporting production for 1919 were distributed as follows: California 2, Florida 1, Illinois 2, Indiana 1, Massachusetts 1, New Hampshire 1, New Jersey 3, New York 3, and North Carolina 1.

New Jersey, the leading State in the production of peat, reported sales of 27,743 tons, valued at $267,567, an average price per ton of $9.64.

The New York plant reporting the largest production for 1918 was idle during 1919, and the operations of the three producing plants were very small.

Word has been received that the Alphano Humus Co., one of the largest producers of peat fertilizer and fertilizer ingredients in the United States, with plants in Marion County, Fla., and Warren County, N. J., expects to enlarge its fertilizer plant in New Jersey and to build a larger plant in the near future in Florida for the production of organic ammoniate and sulphate of ammonia.

PRODUCERS OF PEAT IN THE UNITED STATES.

The following individuals and companies reported to the Geological Survey that they produced crude peat or peat products in the United States in 1919:

Alphano Humus Co., Whitehall Building, New York, N. Y.
American Peat Products Co., Morrison, Ill.
Chapman, I. S., & Co. (Inc.), 937 Third Street, San Bernardino, Calif.
Cole, Norvin G., Hopewell Junction, N. Y.
Commercial Humus Co., 903 Ordway Building, Newark, N. J.
Day, James H., 35 South Street, Milford, N. H.
Hyper-Humus Co., Newton, N. J.
McElhone, Asa, Fishkill, N. Y.
New Era Development Co., 110 State Street, Boston, Mass.
Nitro-Phospho Corporation, 519 East Franklin Street, Richmond, Va.
Riverside Orange Co. (Ltd.), Arlington Heights, Riverside, Calif.
St. Joseph Humus Co., Van Wert, Ohio.
Sims, Alfred F., Sag Harbor, N. Y.
Wiedmer Chemical Co., Pierce Building, St. Louis, Mo.

SODIUM COMPOUNDS.

By Roger C. Wells.[1]

INTRODUCTION AND SUMMARY.

Nearly all the compounds of sodium consumed in the United States except common salt are manufactured products. Even the salts that occur naturally are usually refined before they are used. As the natural salts, however, form only a small part of the annual production, this report deals almost entirely with manufactured products. The following table summarizes the production of sodium and sodium compounds reported in 1918 and 1919. On succeeding pages will be found more detailed statements concerning the separate products. The rule of the United States Geological Survey that the output of individual producers shall not be revealed unless special permission has been given requires that the returns from at least three producers be combined, and this requirement has necessitated reporting the production of several of the minor compounds in groups.

Sodium and sodium compounds produced in the United States in 1918 and 1919.

	1918		1919	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.
Sodium (metal)	264	$153,437	(a)	(a)
Sodium acetate	2,622	460,783	2,426	$311,175
Sodium benzoate	203	886,058	126	230,224
Sodium bicarbonate	118,535	3,293,153	134,962	3,486,635
Sodium bichromate	28,334	9,868,118	26,526	6,233,566
Sodium bisulphite and sodium sulphite	16,362	478,482	11,819	687,750
Sodium bromide	574	438,730	499	493,319
Sodium carbonate:				
Soda ash	1,390,628	35,635,520	981,054	29,895,343
Monohydrate and sesquicarbonate	22,678	482,958	31,278	714,930
Sal soda	82,465	2,020,271	80,090	2,229,994
Sodium chlorate and sodium perborate	2,413	1,004,250	1,210	62,980
Sodium chloride: b				
Salt in brine	2,830,600	1,245,265	2,850,639	1,423,424
Rock salt	1,683,941	5,684,661	1,642,057	6,240,450
Evaporated salt	2,724,203	20,010,435	2,390,206	19,410,820
Sodium citrate, tartrate, and bitartrate	(a)	(a)	33	58,128
Sodium cyanide, peroxide, and iodate	9,077	5,361,000	9,148	4,515,106
Sodium ferrocyanide	4,525	2,690,110	3,437	1,346,285
Sodium fluoride, acid sodium fluoride, and sodium fluosilicate (silicofluoride)	1,879	387,224	1,171	244,004
Sodium hydroxide (caustic soda)	513,363	31,854,470	355,466	22,196,898
Sodium iodide	(a)	(a)	12	86,985
Sodium nitrate (refined)			8,040	816,647
Sodium nitrite	1,701	609,779	1,182	265,121
Sodium phosphate (including all sodium phosphates)	15,620	1,427,947	14,760	1,733,996
Sodium silicate	317,161	5,870,973	300,138	5,879,628
Sodium sulphate:				
Salt cake	141,054	2,844,897	129,042	2,019,460
Glauber's salt	50,715	1,041,070	47,730	877,060
Niter cake	143,155	595,660	83,402	271,424
Sodium sulphide	43,490	2,293,304	45,448	2,645,181
Sodium tetraborate (borax)	26,673	3,909,565	28,518	4,351,891
Sodium thiosulphate (hyposulphite)	26,868	1,051,623	32,212	1,709,223
Miscellaneous sodium compounds	390	1,188,792	841	756,548
	10,199,493	142,788,535	9,213,472	121,194,195

a Included under "Miscellaneous sodium compounds."
b Insley, Herbert, Salt, bromine, and calcium chloride: U. S. Geol. Survey Mineral Resources, 1919, pt. 2, pp. 239-256.

[1] The statistics of production in this report were collected with the assistance of Mrs. B. L. Thompson, of the United States Geological Survey.

The production given in the table is practically identical with the sales for most of the salts, especially soda ash, as the soda ash used by manufacturers in making caustic soda in their own plants is not included in the table. On the other hand, the caustic soda made and consumed in their own plants by paper manufacturers and others is included, as well as small quantities of certain other salts, such as sodium acetate, sodium bichromate, sodium silicate, salt cake, and niter cake, consumed by the makers.

Sodium salts derived from natural sources in the United States in 1918 and 1919.

	1918		1919	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.
Sodium chloride:				
Salt in brine	2,830,600	$1,245,265	2,850,639	$1,423,424
Rock salt	1,683,941	5,684,661	1,642,057	6,240,450
Evaporated salt	2,724,203	20,010,435	2,390,206	19,410,820
Sodium carbonate, sodium bicarbonate, sodium sulphate, and borax	24,053	992,788	29,120	874,083
	7,262,797	27,933,149	6,912,022	27,948,777

IMPORTS.

Sodium nitrate is the principal sodium salt imported. The imports of most of the other salts are very small compared to the domestic production, according to the records of the Bureau of Foreign and Domestic Commerce, which furnishes the data on imports and exports.

Sodium salts imported into the United States for domestic consumption in 1918 and 1919.

	1918		1919	
	Quantity (pounds).	Value.	Quantity (pounds).	Value.
Sodium arsenate	35	$88		
Sodium benzoate	54,150	11,469	68,566	$14,435
Sodium bicarbonate[a]	12,383	629	17,122	3,616
Sodium carbonate:				
Soda ash	1,445	29	829,266	12,998
Monohydrate and sesquicarbonate	44,800	1,281		
Sal soda	25	2	45,060	1,182
Sodium chlorate	44,810	8,066	39,022	3,814
Sodium chloride (common salt)	80,580,700	281,468	119,028,200	242,704
Sodium chromate and sodium bichromate	5,102	1,184		
Sodium cyanide	69,279	12,615	5,174,831	305,426
Sodium ferrocyanide (yellow prussiate of sodium)	271,063	98,505	1,299,521	218,222
Sodium hydroxide or caustic soda	2,002	193	42,724	6,888
Sodium nitrate	4,138,758,400	90,216,935	912,932,160	19,558,963
Sodium nitrite	2,857,631	289,182	2,550,779	246,729
Sodium phosphate			56	22
Sodium silicate	464,461	9,902	931,086	25,421
Sodium sulphate, crude, or salt cake and niter cake	138,880	947		
Sodium sulphide	112,821	4,673	1,668,562	54,251
Sodium sulphite	30,450	1,287	58,524	2,376
Sodium tetraborate or refined borax	2	1	378	155
Sodium thiosulphate, or sodium hyposulphite	1,120	975	27,616	6,312
	4,223,449,559	90,939,431	1,044,713,473	20,703,514

[a] Or supercarbonate, or saleratus, and other salts containing 50 per cent or more of sodium bicarbonate.

EXPORTS.

Sodium compounds exported from the United States in 1919, by countries.[a]

Country.	Sodium chloride (common salt).		Soda ash.		Sal soda.		Caustic soda.		Sodium silicate.		All other.	Total value.
	Quantity (pounds).	Value.	Quantity (pounds).	Value.	Quantity (pounds).	Value.	Quantity (pounds).	Value.	Quantity (pounds).	Value.		
Europe:												
Austria-Hungary							336,000	$10,695			$751	$11,446
Azores and Madeira Islands	1,471	$25										25
Belgium							91,212	3,175			312,091	315,266
Denmark			2,419,695	$88,219			3,116,903	112,416			81,451	282,086
France							15,564	4,101			595,001	599,102
Germany	820	17									14,507	14,524
Greece			56,389	1,018	375	$7	992,758	34,461	58,700	$2,574	9,943	48,003
Iceland	12,570	439	1,200	26	72,718	1,769	9,900	223			966	3,423
Italy	2,520	48			112,000	3,000	5,043,522	351,607			49,585	404,240
Netherlands	1,000	20					25	7			250,914	250,941
Norway	7,500	222	266,175	9,558			1,512,896	102,728			17,969	130,477
Portugal							350	198			15,022	15,220
Rumania							275,520	11,076			1,594	12,670
Russia in Europe	5,308	174			36,475	548	512,050	12,082				12,804
Serbia, Montenegro, etc.	200	3					22,400	1,100			49	1,152
Spain							2,938,662	132,979	1,280	25	321,878	454,882
Sweden			3,175,174	134,658			1,287,919	52,053			108,185	294,896
Switzerland							112,073	3,949			57,106	61,055
Turkey in Europe	8,536	526	48,000	1,320			651,375	19,542			7,331	28,719
United Kingdom—												
England			42,000	842			191,834	13,027	16,006	891	792,713	807,473
Scotland											107,070	107,070
North America:												
Bermuda	34,840	622			28,341	656	594	15			989	2,282
British Honduras	320,166	3,228	225	13	20,108	535	1,745	90	60	2	311	4,179
Canada	157,596,910	654,657	58,350,583	1,276,779	8,937,764	133,569	7,072,699	279,350	20,604,420	205,700	1,073,048	3,623,103
Central American States—												
Costa Rica	649,177	6,233	28,500	940	13,243	272	166,657	7,731	1,749	50	6,160	21,386
Guatemala	132,199	1,883	4,600	205	890	27	57,391	2,952			7,174	12,241
Honduras	1,842,919	17,730	275,289	8,242	3,810	92	134,517	6,028	22,102	532	17,508	50,132
Nicaragua	700,306	8,932	34,498	1,191	2,239	62	154,020	7,005	41,919	1,132	6,213	24,535
Panama	3,945,329	37,980	45,168	1,299	276,485	6,516	233,052	13,159	162,746	4,345	5,621	68,920
Salvador	5,632	336	8,955	263	705	10	71,343	3,671	12,197	342	11,248	15,870
Mexico	7,931,184	89,534	3,096,055	86,752	133,860	2,698	10,916,733	480,301	772,939	28,229	1,336,359	2,023,873
Miquelon, Langley, etc.	1,656	63			6,250	131						194

[a] Compiled from records of the Bureau of Foreign and Domestic Commerce, Department of Commerce.

Sodium compounds exported from the United States in 1919, by countries [a]—Continued.

Country.	Sodium chloride (common salt).		Soda ash.		Sal soda.		Caustic soda.		Sodium silicate.		All other.	Total value.
	Quantity (pounds).	Value.	Quantity (pounds).	Value.	Quantity (pounds).	Value.	Quantity (pounds).	Value.	Quantity (pounds).	Value.		
North America—Continued.												
Newfoundland and Labrador	4,891,549	$31,211	73,195	$1,734	10,925	$213	25,246	$765			$894	$34,817
West Indies—												
British—												
Barbadoes	15,557	219			37,310	765	61,600	3,832			3,866	8,682
Jamaica	28,511	334	7,050	175	111,556	2,706	17,800	748			9,874	13,837
Trinidad and Tobago	4,890	66	400	16	58,091	1,125	17,400	1,021	3,200	$112	3,612	5,952
Other British	19,327	646	750	15	35,802	970	4,087	379			2,637	4,647
Cuba	47,291,884	388,956	2,896,391	48,233	809,974	13,085	5,591,323	184,729	742,405	19,586	123,691	778,280
Virgin Islands	16,714	466	10,820	374	12,699	421	4,120	302			1,117	2,680
Dutch	190	12	11,000	332	9,197	231	224	10			720	1,305
French	24,281	705			7,404	277	10,886	618	600	24	13,672	15,296
Haiti	7,530	304			2,621	98	22,415	897	2,500	69	2,687	4,055
Dominican Republic	361,246	4,630	36,551	1,381	8,186	185	350,025	13,680	43,900	1,390	5,773	27,039
South America:												
Argentina	521,600	4,110	515,865	15,564	43,280	983	10,434,091	450,305	114,599	4,594	383,742	859,298
Bolivia	1,400	8	5,300	160			170,020	8,530	800	28	5,442	14,168
Brazil	3,799	118	4,022,414	156,436	86,733	1,540	11,299,348	558,633	179,206	8,218	181,603	906,548
Chile	5,160	132	222,981	7,319	29,050	494	1,356,929	58,442	106,764	4,525	101,114	172,026
Colombia	445,096	4,283	401,379	16,472	9,421	190	1,221,116	62,025	178,993	7,121	43,910	134,001
Ecuador	244	12	9,132	330	480	12	41,560	1,373	17,100	916	7,055	9,698
Guiana—												
British	710	19	310	12	25,120	675	1,000	60			1,845	2,611
Dutch	21,910	370			5,300	148	7,600	380	19,500	585	78	1,561
French	5,000	75									165	240
Paraguay			64,812	1,202			56,025	1,597			4,475	7,274
Peru	148	4	368,440	13,563	20,347	451	1,374,673	62,498	19,744	447	44,412	121,375
Uruguay			153,903	3,187			1,529,131	69,775	204	7	37,196	110,165
Venezuela	1,320	40	75,827	2,038	21,445	753	679,077	31,035	230,810	8,393	27,989	70,248
Asia:												
China	36,651	1,882	1,477,619	60,136	9,658	258	9,566,700	420,538	361,793	15,435	40,167	538,416
Japanese China	36	3					403,635	17,563			260	17,826
Chosen	11,297	386					120,780	4,713			723	5,822
East Indies—												
British—												
India	18,619	1,201	5,600	135	8,400	149	1,946,044	71,805	450	20	17,385	90,695
Straits Settlements	18,728	742	19,120	797			108,200	4,981			1,518	8,038

Other British	5,506	299	300	15			22,400	731	50,000	1,873	190	3,108
Dutch	95,222	3,626	623,205	25,532	32,225	470	3,065,269	146,927	8,240	258	17,023	193,836
French	4,192	230					45	5			200	435
Hongkong	29,360	2,257	41,395	1,807	1,600	22	1,531,691	72,874	124,212	6,313	7,740	91,013
Japan	7,138,600	38,974	18,941,838	537,411	1,380	20	70,812,545	2,499,000	64,356	1,662	478,732	3 555,799
Persia											348	348
Russia in Asia	249,600	2,287					215,340	12,573	75	2	2,004	16,866
Siam	595	57					42,550	2,595	13,340	534	112	3.298
Turkey in Asia	12	1					37,950	1,068			85	1,154
Oceania—												
British—												
Australia	2,209,634	44,457	2,901,274	141,601			2,035,696	132,461	255,518	10,170	295,035	623,724
New Zealand	1,553,914	26,484	35,560	1,153	22,400	540	703,957	45,438	7,012	592	53,372	127,579
Other British	21,069	552			257	17	3,650	310			885	1,764
French	174,384	2,865	610	18	300	15	9,014	403	23,656	718	4,691	8,710
German	44,836	866			378	5					17	888
Philippine Islands	192,976	7,760	155,080	8,100	53,577	1,395	2,890,299	119,200	35,232	1,326	56,979	194,760
Africa:												
Belgian Kongo	6,605	343			490	17					40	400
British Africa—												
West	61,110	1,034	1,300	35	2,876	97	27,261	750			7,812	9,728
South					2,550	61	278,356	10,632	2,240	78	23,094	33,865
East	595	19					22,400	685				704
Canary Islands											238	238
French Africa	89,648	901										901
German Africa	74	3									2	5
Liberia	56	1									12	13
Morocco											806	806
Portuguese Africa	78	3					228	30			17	50
Egypt					75	5	196,000	6,125			509	6,639
	238,831,706	1,396,625	100,961,927	2,656,608	11,126,370	178,285	164,235,420	6,748,762	24,300,567	338,818	7,226,322	18,545,420

[a] Compiled from records of the Bureau of Foreign and Domestic Commerce, Department of Commerce.

Domestic sodium salts exported from the United States in 1918 and 1919, by classes.

	1918		1919	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.
Sodium carbonate:				
Soda ash	119,217	$7,805,550	50,481	$2,656,608
Sal soda	6,358	213,865	5,563	178,285
Sodium chloride (common salt)	136,783	1,677,577	119,416	1,396,625
Sodium hydroxide (caustic soda)	48,689	5,602,813	82,118	6,748,762
Sodium silicate	14,125	404,796	12,150	338,818
All other salts of sodium	....	6,587,134	....	7,226,322
	....	22,291,735	....	18,545,420

Foreign sodium salts reexported from the United States, 1915–1919.

Year.	Sodium chloride (common salt).		Sodium cyanide.		Sodium nitrate.		All other sodium salts.
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Value.
1915	52	$31,841	949	$347,079	25,472	$1,123,761	$40,358
1916	7,448	61,525	111	58,265	60,079	3,432,273	193,086
1917	1,900	21,830	138	115,067	78,152	5,367,281	25,632
1918	723	13,903	(a)	145	61,271	5,204,413	73,402
1919	457	7,992	....	....	15,314	1,299,563	387,090

a 125 pounds.

EFFECT OF THE WAR ON SODIUM COMPOUNDS.

Much of the effect of the war on chemical industry, and on sodium compounds particularly, noted in the chapter for 1918 continued in 1919. Although imports of sodium nitrate were greatly curtailed, imports of all other sodium compounds increased from 42,346 short tons, valued at $722,496, in 1918 to 65,891 tons, valued at $1,144,551, in 1919. Imports of sodium cyanide, sodium ferrocyanide, and sodium sulphide were notably greater in 1919 than in 1918. Exports of soda ash decreased greatly in 1919, but exports of caustic soda and miscellaneous sodium compounds increased, indicating that foreign business was being held in certain lines and even increased in others.

The use of sodium compounds instead of potassium compounds, initiated by war conditions, was for the most part continued in 1919.

The war greatly augmented the capacity of the domestic chemical industries, especially those dealing with explosives and dyestuffs—industries that consume a large quantity of Chile saltpeter, or sodium nitrate. The problem of developing an independent nitrogen industry is therefore a prominent one in the United States. Much of this nitrate goes into the manufacture of such explosives as dynamite and blasting powder used in mining, quarrying, and building roads; some goes into the production of nitrocellulose products, including the artificial leather now so widely used in automobile upholstery, photographic films, and all forms of celluloid.

The large Government plants developed during the war were intended to produce fixed nitrogen compounds in the form of lime nitrogen, ammonia, and ammonium nitrate. Sodium nitrate has not yet appeared as a product of nitrogen fixation in the United States. Ammonia, however, is a necessary factor in the Solvay process of making soda and is also used in making sodium cyanide, so that any developments in the ammonia industry must eventually be reflected to some extent in the soda industry.

According to the Journal of Industrial and Engineering Chemistry for February, 1920, the General Chemical Co. has joined forces with the Solvay Process Co. in the matter of nitrogen fixation. It appears that the cheapest known process for making hydrogen, needed in making synthetic ammonia, is the water-gas process. This process as generally worked produces a gas containing a large proportion of carbon monoxide; it appears that the monoxide is to be converted into carbon dioxide, which is essential in making soda, as is also a certain quantity of ammonia, which would be produced from the hydrogen. Accordingly, a synthetic ammonia plant and a Solvay soda plant appear to supplement each other, the principal products being the sodas described on succeeding pages and ammonium chloride, which is essential in the fertilizer and chemical industries.

VALUE AND USES OF SODIUM COMPOUNDS.

The commercial value of sodium compounds is generally estimated from one of two different points of view—they may be valued for the basic part (Na_2O or Na) or for the acid part (nitrate, sulphide, chromate, borate). In the first case the value per ton is very low, as the sodium is useful only as a carrier, so to speak, of other elements; in the second case the value per ton may be extremely high according to the value of the acidic part of the compound. The fact that the cheaper compounds are used chiefly for their content of base or basic oxide is indicated by the common use of the term soda for so many of them. Although soda ash is a low-priced chemical, the value of the total annual production runs well into the millions, exceeding that of common salt and potash, and about equaling that of lime, which is the next cheapest alkaline substance. This indicates that soda ash has many and varied uses. It finds application in making glass, soap, paper, chemicals, drugs, paints, leather, enamel ware, and cleansing agents, in refining oils, and in metallurgic operations. In most of these operations the soda is used merely as a carrier of another element or as an alkali to neutralize acids. On the other hand, the different compounds of sodium have various uses according to the elements of which they are composed. These are discussed more fully under the individual compounds.

As a basic oxide soda is cheaper than potash, but slight differences in properties give some potassium compounds a superiority over the corresponding sodium compounds. For instance, potassium chlorate crystallizes well and is more easily obtained in a pure state than sodium chlorate. Soda has no specific use such as that of potash as a fertilizer, from which it follows that the inherent value of most sodium compounds depends on the acidic portion.

DISTRIBUTION OF SODIUM IN NATURE.

The element sodium is very widely distributed in nature. It forms about 2.36 per cent of known terrestrial matter and is the most abundant of the alkali metals. Sodium appears to occur in nature only in combination with other elements, if its alleged occurrence as the free element in blue rock salt is neglected.

Sodium is an important constituent of the feldspars and several other insoluble minerals from which sodium salts are not extracted commercially but which are nevertheless regarded as the ultimate source of the salts that are soluble in water.

Sodium chloride is obtained by simple evaporation from sea water, the water of the Great Salt Lake, and many natural brines. Sodium carbonate in the form of trona is thus obtained from the water of Owens Lake. The brine of Searles Lake yields sodium chloride, sodium sulphate, sodium carbonate, and sodium borate, but these salts can be separated only by elaborate treatment.

The soluble salts above mentioned, as well as sodium nitrate, are found at or near the surface in dry desert regions, but elsewhere they are carried in solution to the sea. The deposits of sodium nitrate in northern Chile and the deposit of sodium carbonate at Magadi, British East Africa, are conspicuous examples of accumulation due to favorable geologic and climatic conditions. Many beds of rock salt in various regions have probably originated similarly and have been preserved from solution by impervious covers. Large deposits of salt have been found at considerable depths in Michigan, Kansas, Louisiana, Texas, and New York, in the Stassfurt region in Germany, at Salzburg in Austria, in the Province of Orenberg in southeastern Russia, at Northwich in Cheshire, England, in Alsace and Lorraine, and in many other regions. From the soluble natural or crude salts are derived all the refined salts described in the following pages.

TRADE NAMES FOR VARIOUS SODIUM COMPOUNDS.

The name soda was originally used to mean sodium oxide, Na_2O, the name being analogous to those of other basic oxides. However, it has long been used in trade for the carbonate and in household economy for the bicarbonate and the hydrated carbonate, known as sal soda, and is frequently applied indiscriminately to all compounds of sodium, as "nitrate of soda." The better usage is to call such substances "sodium" compounds—for instance, "sodium nitrate"—to prevent ambiguity.

The following table gives the various trade names, the chemical formula of the important constituent, the usual percentage of the compound designated in the marketed product, and the ordinary chemical name:

Trade names and formulas of sodium compounds.

Trade name.	Formula.	Percentage.	Chemical name.
Soda ash	Na_2CO_3	98–100Na_2CO_3	Sodium carbonate.
Sodium sesquicarbonate, trona.	$Na_2CO_3.NaHCO_3.2H_2O$	47Na_2CO_3,37$NaHCO_3$	Hydrated sodium carbonate-sodium bicarbonate.
Sal soda, washing soda, crystal carbonate.	$Na_2CO_3.10H_2O$	37.1Na_2CO_3	Hydrated sodium carbonate.
Bicarbonate of soda, baking soda, saleratus.	$NaHCO_3$	99.5–99.7$NaHCO_3$	Sodium bicarbonate or acid sodium carbonate.
Caustic soda	$NaOH$	75–99 $NaOH$	Sodium hydroxide.
Soda lime	$NaOH+CaO$		Sodium hydroxide and calcium oxide.
Borax Tincal	$Na_2B_4O_7.10H_2O$	52.7$Na_2B_4O_7$	Sodium tetraborate.
Sodium hyposulphite "Hypo."	$Na_2S_2O_3.5H_2O$	64$Na_2S_2O_3$	Sodium thiosulphate.
Yellow prussiate of soda	$Na_4Fe(CN)_6.10H_2O$	62.7$Na_4Fe(CN)_6$	Sodium ferrocyanide.
Red prussiate of soda	$Na_3Fe(CN)_6.H_2O$	94$Na_3Fe(CN)_6$	Sodium ferricyanide.
Sodium nitroprusside	$Na_2Fe(CN)_5NO.2H_2O$	88$Na_2Fe(CN)_5NO$	Sodium nitroprusside.
Salt cake	Na_2SO_4	98–100Na_2SO_4	Sodium sulphate.
Niter cake	$NaHSO_4$	61–86$NaHSO_4$	Sodium bisulphate or sodium acid sulphate.
Glauber's salt	$Na_2SO_4.10H_2O$	44.1Na_2SO_4	Hydrated sodium sulphate.
Chile saltpeter Soda niter	$NaNO_3$	95–96$NaNO_3$	Sodium nitrate.
Water glass	$Na_2O.4SiO_2$(approx.)		Sodium silicate.
Sodium carbonate monohydrate.	$Na_2CO_3.H_2O$	85–86Na_2CO_3	Sodium carbonate monohydrate.

SODIUM (METAL).

As only two firms reported the production of metallic sodium in 1919, the figures have been added to those for miscellaneous compounds in order not to reveal individual production.

Metallic sodium is used in the manufacture of sodium cyanide, sodamide, sodium peroxide, and indigo, as well as in the laboratory. It has been proposed for use in desulphurizing petroleum, and some was formerly used in reducing such metals as magnesium and titanium from their chlorides. Sodium has also been proposed as a substitute for copper as an electrical conductor—its conductivity being three times that of copper per unit weight—but it can be used only in metallic containers, on account of the action of air on it and its low melting point.

Sodium is made commercially by electrolyzing fused sodium hydroxide at about 330° C. It may also be made by heating sodium carbonate or other sodium salts with charcoal, and when so made it is separated from the reaction mixture by distillation. Patents have been granted for producing metallic alloys by electrolysis, the alloys being run off and the sodium distilled. United States patent 1319148, issued October 21, 1919, to H. Freeman, describes a method of making metallic sodium from common salt and calcium carbide. Sodium vapor is recovered in a suitable condenser.

A considerable quantity of metallic sodium is made in Norway, where water power is abundant, more than 600 tons having been exported from that country in 1916.

Metallic sodium was produced in 1919 by the Niagara Electro Chemical Co., 709–717 Sixth Avenue, New York, N. Y., and the Semet-Solvay Co., Syracuse, N. Y.

SODIUM ACETATE.

Sodium acetate, crystals of which have the formula $NaC_2H_3O_2.3H_2O$, is manufactured in the process of purifying acetic acid obtained in the distillation of wood. United States patent 1298481 was issued March 2, 1919, to V. Drewsen for a process for recovering sodium acetate from waste soda-pulp liquor. This salt is used in making acetic acid and dry colors, in dyeing, in photography, in purifying glucose, and in medicine. Production of this material in the United States in 1919 amounted to 2,426 short tons, valued at $311,175 compared with 2,622 short tons, valued at $460,783, in 1918.

Sodium acetate was manufactured in 1919 by the following producers:

Albany Chemical Co., 2-24 Broadway, Albany, N. Y.
Anderson Chemical Co., Box 135, Passaic, N. J.
Dow Chemical Co., Midland, Mich.
Heyden Chemical Works, 135 William Street, New York, N. Y.
Maas & Waldstein Co., 92 William Street, New York, N. Y.
McKesson & Robbins (Inc.), 91 Fulton Street, New York, N. Y.
Mallinckrodt Chemical Works, St. Louis, Mo.
Powers-Weightman-Rosengarten Co., Philadelphia, Pa.
E. R. Squibb & Sons, 78 Beekman Street, New York, N. Y.

SODIUM BENZOATE.

Sodium benzoate ($NaC_7H_5O_2$) is manufactured from benzoic acid, which is obtained from light tar oils by several processes or from gum benzoin or is made synthetically. It is used principally as a preservative. A small quantity is also used in medicine, in making certain aniline blues, and in printing textiles.

The production reported to the United States Geological Survey for 1919 amounted to 126 short tons, valued at $230,224.

Sodium benzoate was manufactured in 1919 by the following firms:

Hord Color Products Co., 1636 Columbus Avenue, Sandusky, Ohio.
Mallinckrodt Chemical Works, St. Louis, Mo.
Seydel Manufacturing Co., 86 Forrest Street, Jersey City, N. J.

SODIUM BICARBONATE.

Sodium bicarbonate, or monosodium carbonate, familiarly known as baking soda ($NaHCO_3$), is used principally in baking. Sales of the salt in 1919 amounted to 134,962 tons, valued at $3,486,635.

In the following table the production of sodium bicarbonate for the years 1899, 1904, 1909, and 1914 is taken from the report of the Bureau of the Census,[2] and the figures for the other years are supplied by the Geological Survey.

Sodium bicarbonate produced in the United States in certain years.

	Quantity (short tons).	Value.		Quantity (short tons).	Value.
1899	68,856	$1,332,765	1916	115,117	$2,303,540
1904	68,869	1,135,610	1917	119,177	4,029,499
1909	82,800	1,515,045	1918	118,535	3,293,153
1914	90,169	1,439,014	1919	134,962	3,486,635

[2] Chemicals and allied industries: Census of manufactures, p. 18, U. S. Dept. Commerce Bur. Census, 1918.

Sodium bicarbonate is the first product obtained in the manufacture of sodium carbonate by the ammonia process. The bicarbonate made in this way, however, contains a small quantity of ammonia, which renders it unfit for most purposes for which sodium bicarbonate is used, and it must be treated further to obtain a pure salt—for example, it may be either partly calcined and recarbonated or entirely reprecipitated under suitable conditions.[3]

The following firms manufactured sodium bicarbonate in 1919:

Diamond Alkali Co., Pittsburgh, Pa.
Mathieson Alkali Works (Inc.), 25 West Forty-third Street, New York, N. Y.
Michigan Alkali Co., Wyandotte, Mich.
Natural Soda Products Co., Keeler, Calif.
Solvay Process Co., Syracuse, N. Y.

SODIUM BICHROMATE.

Sodium bichromate ($Na_2Cr_2O_7 . 2H_2O$) is used extensively in tanning leather, in making paints, in refining the precious metals obtained from the cyanide solution by means of zinc, as a mordant (principally in wool dyeing), as an oxidizing agent in dyeing, and as a laboratory reagent.

In making sodium bichromate sodium chromate is first made by heating the mineral chromite with soda ash and lime. The object of the lime is to prevent fusion and keep the mass porous to facilitate oxidation. The roasted mass is extracted with water containing some sodium carbonate to convert any calcium chromate into sodium chromate, and after separation of the solids the solution is treated with sulphuric acid to form sodium bichromate, which is freed from the sodium sulphate by evaporation and crystallization.

The production of sodium bichromate in the United States in 1919 amounted to 26,526 short tons, valued at $6,233,566, compared with 28,334 short tons, valued at $9,868,118 in 1918.

Sodium bichromate is manufactured by the following firms:

Martin Dennis Co., Newark, N. J.
E. I. du Pont de Nemours & Co., Wilmington, Del.
Grasselli Chemical Co., Cleveland, Ohio.
Mutual Chemical Co. of America, 55 John Street, New York, N. Y.
National Electrolytic Co., Niagara Falls, N. Y.
Natural Products Refining Co., Jersey City, N. J.
Sherwin-Williams Co., Cleveland, Ohio.

SODIUM BISULPHITE AND SODIUM SULPHITE.

Sodium sulphite (Na_2SO_3) and sodium bisulphite ($NaHSO_3$) are made from sodium carbonate and sulphur dioxide and are used as a source of sulphur dioxide in making wood pulp, in sterilizing brewer's casks, as reducing agents in photography, dyeing, and bleaching, as a depilatory in cleaning hides, and for removing traces of chlorine where a chlorine bleach has been used. Sodium sulphite may also be made by heating a mixture of sodium sulphate and iron in an atmosphere of sulphur dioxide.

The total production of these salts in the United States in 1919 amounted to 11,819 short tons, valued at $687,750, compared with 16,362 short tons, valued at $478,482, in 1918.

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[3] Martin, Geoffrey, The salt and alkali industry, p. 79, London, 1916.

The following list gives the domestic manufacturers of sodium sulphite and sodium bisulphite in 1919:

Sodium sulphite:
- Charles Cooper & Co. (Inc.), Van Buren and Clifford streets, Newark, N. J.
- A. R. Maas Chemical Co., Los Angeles, Calif.

Sodium bisulphite:
- Atlantic Carbonic Co., 268 Third Street, Chelsea, Mass.
- Avery Chemical Co., 88 Broad Street, Boston, Mass.
- Butterworth-Judson Corp., 61 Broadway, New York, N. Y.
- Grasselli Chemical Co., Cleveland, Ohio.
- A. Lee Co., Lawrence, Mass.
- Charles Lennig & Co., 112 South Front Street, Philadelphia, Pa.
- Mallinckrodt Chemical Works, St. Louis, Mo.
- Mechling Bros. Manufacturing Co., Camden, N. J.
- Merrimac Chemical Co., 148 State Street, Boston, Mass.
- D. D. Williamson & Co., 86 Fulton Street, New York, N. Y.

Sodium hydrosulphite ($Na_2S_2O_4$) has recently appeared on the market as a material used in dyeing with indigo to keep the dye in solution in the reduced condition before exposure of the fabric to air, where the dye is oxidized. It is made from sodium bisulphite by the action of zinc.

SODIUM BROMIDE.

The sodium bromide produced and sold in the United States in 1919 amounted to 499 short tons, valued at $493,319. Most of this material is produced from natural brines found at Midland, Mich.; the remainder, principally refined material of high purity, is recovered in the manufacture of other chemical products. Inasmuch as this salt is not recovered from the brines directly, it can not properly be included in the list of natural salts produced in the United States. The bromides are first decomposed into free bromine and this is then reconverted into sodium bromide by the use of sodium carbonate. Sodium bromide is used chiefly in the photographic industry, and to a slight extent in medicine.

The following is a list of the producers of sodium bromide in 1919:

- American Bromine Co., Maywood, N. J.
- Dow Chemical Co., Midland, Mich.
- Mallinckrodt Chemical Works, St. Louis, Mo.

SODIUM CARBONATE.

SODA ASH.

PRODUCTION.

Soda ash is the commercial term used for normal sodium carbonate without water of crystallization (Na_2CO_3; theoretically Na_2O, 58.49 per cent, CO_2, 41.51 per cent). It is supplied commercially in various grades, such as 58 and 48 per cent, ordinary, or dense. The percentages refer to content of soda (Na_2O). The 58 per cent ash is the highest grade and contains about 99 per cent of Na_2CO_3. The distinction between the ordinary and the dense grades is merely one of density; the dense variety is preferred by glassmakers.

The soda ash produced and marketed as such in the United States in the calendar year 1919 amounted to 981,054 short tons, valued at $29,895,343, as compared with 1,390,628 short tons, valued at $35,635,520, in 1918. These figures do not include sodium carbonate reported in the form of monohydrate and sesquicarbonate nor the soda ash consumed where it was made in the manufacture of caustic soda and other sodium compounds. The quantity of soda ash so consumed in 1918 was about 664,000 short tons; corresponding figures were not collected in 1919. The following table gives such figures as are available for the annual production of soda ash:

Soda ash produced in the United States in certain years.[a]

	Quantity (short tons).	Value.		Quantity (short tons).	Value.
1899	390,653	$4,859,656	1916	1,194,183	$16,464,774
1904	518,954	8,204,545	1917	1,390,625	38,028,000
1909	646,057	10,362,656	1918	1,390,628	35,635,520
1914	935,305	10,937,945	1919	981,054	29,895,343

[a] The figures for 1899, 1904, 1909, and 1914 are from Chemicals and allied industries: Census of manufactures, p. 18, U. S. Dept. Commerce Bur. Census, 1918.

The manufacture of soda ash for sale in the United States is confined almost entirely to New York, Ohio, Virginia, Michigan, California, and Kansas.

The following is a list of the producers of soda ash in 1919:

Columbia Chemical Co., Pittsburgh, Pa.
Diamond Alkali Co., Pittsburgh, Pa.
Mathieson Alkali Works (Inc.), 25 West Forty-third Street, New York, N. Y.
Michigan Alkali Co., Wyandotte, Mich.
Solvay Process Co., Syracuse, N. Y.
California Alkali Co., Hellman Building, Los Angeles, Calif.
Natural Soda Products Co., Keeler, Calif.

Of these seven companies the first five manufacture their material from salt brine; the last two have deposits of the natural salt.

IMPORTS AND EXPORTS.

The imports of soda ash for consumption in the United States in 1919 amounted to 415 tons, valued at $12,998, according to the records of the Bureau of Foreign and Domestic Commerce, Department of Commerce. In 1918 they were negligible.

The exports in 1919 amounted to 50,481 short tons, valued at $2,656,608, a decline of 58 per cent in quantity and 66 per cent in value, as compared with 1918. The principal countries receiving this material in 1919, named in decreasing order of quantity exported, were Canada, Japan, Brazil, Sweden, Mexico, and Australia. Canada received 29,175 short tons, valued at $1,276,779.

PRICES.

The price of light soda ash in bags for car lots, quoted in the New York market at the beginning of the year 1919, was the lowest known in several years—about $1.40 per hundred pounds. A slow advance then began which continued irregularly until at the end of the year it had reached about $2. The average price in 1919 was therefore considerably lower than that in 1918. It should be remembered that spot quotations usually fluctuate more widely than prices made on long-term contracts by large manufacturers, and also that prices regularly quoted in the New York market are much higher than those representing the value of the marketed product in large lots f. o. b. at point of shipment.

USES.

Sodium carbonate in the form of soda ash is the foundation of the alkali industry, for it is used in the manufacture of glass, soap, and dyes, as well as of caustic soda and most other sodium compounds. It is second only to lime and limestone in cheapness and general applicability as a base. It is used directly in making glass and after conversion into sodium hydroxide or other sodium compounds it is used in nearly all the chemical industries, especially in making soap, wood pulp, paper, dyes, explosives, bleach liquor, and cleansing preparations and in tanning.

MANUFACTURE.

Methods of making soda ash were summarized in some detail in the report for 1918 and need not be again set forth here. The only changes that have come to the attention of the writer are the suggestions noted on page 53.

MONOHYDRATE AND SESQUICARBONATE.

When a solution of sodium carbonate evaporates above 35.1° C. the resulting crystals have the formula $Na_2CO_3.H_2O$. This salt is termed monohydrate or crystal sodium carbonate. It dissolves in water with the evolution of heat.

The sesquicarbonate ($Na_2CO_3.NaHCO_3.2H_2O$), which when found in nature is known as trona, is prepared by allowing a solution containing proper proportions of sodium carbonate and sodium bicarbonate to crystallize at a temperature above 35° C. It is said to possess the advantage of being neither efflorescent nor deliquescent.

The production of these two salts, reported to the United States Geological Survey in 1919, was 31,278 short tons, valued at $714,930, compared with 22,678 short tons, valued at $482,958, in 1918.

The producers in 1919 were as follows:

Church & Dwight Co., 27 Cedar Street, New York, N. Y.
Los Angeles Soap Co., 633 East First Street, Los Angeles, Calif.
Mallinckrodt Chemical Works, St. Louis, Mo.
Solvay Process Co., Syracuse, N. Y.
West Viiginia Pulp & Paper Co., 200 Fifth Avenue, New York, N. Y.

SAL SODA.

Sal soda, hydrated sodium carbonate, washing soda, or crystal carbonate, having the chemical formula $Na_2CO_3.10H_2O$, is made from soda ash by dissolving it in water and allowing the solution to crystallize below 32° C.

The production of sal soda in the United States in 1919 was 80,090 short tons, valued at $2,229,994. The output for the years for which figures are available is shown in the following table:

Sal soda produced in the United States in certain years.[a]

	Quantity (short tons).	Value.		Quantity (short tons).	Value.
1899	63,249	$875,243	1917	77,939	$1,698,520
1904	59,548	831,869	1918	82,465	2,020,271
1909	86,644	1,156,882	1919	80,090	2,229,994
1914	106,591	1,510,449			

[a] The figures for 1899, 1904, 1909, and 1914 are taken from Chemicals and allied industries: Census of manufactures, p. 18, U. S. Dept. Commerce Bur. Census, 1918.

Sal soda is used in softening water and for many other purposes for which soda ash is used where purity is an essential requirement. It is also used in cleansing compounds or alone as washing soda.

The imports of sal soda into the United States for consumption, according to the records of the Department of Commerce, are practically negligible. The exports in 1919 amounted to 5,563 short tons, valued at $178,285, a very slight decrease from 1918.

The following firms reported the production of sal soda in 1919:

California Soap Co., 2437 East Ninth Street, Los Angeles, Calif.
Central Chemical Co., foot of Chapel Street, Newark, N. J.
Church & Dwight Co., 27 Cedar Street, New York, N. Y.
Columbia Chemical Co., Pittsburgh, Pa.
Columbus Crystal Co., Doremus Avenue, Newark, N. J.
Charles Cooper & Co. (Inc.), Van Buren and Clifford streets, Newark, N. J.
Detroit Soda Products Co., 2595 Jefferson Street west, Detroit, Mich.
Fresno Soap Co., Fresno, Calif.
E. Griswold & Co., Sixth and Parker streets, West Berkeley, Calif.
Iowa Soda Products Co., Council Bluffs, Iowa.
Los Angeles Soap Co., 633 East First Street, Los Angeles, Calif.
Mechling Bros. Manufacturing Co., Camden, N. J.
Morton Salt Co., 80 Jackson Boulevard east, Chicago, Ill.
Mount Hood Soap Co., 270 Glisan Street, Portland, Oreg.
Newell & Bro., 1462 San Bruno Avenue, San Francisco, Calif.
Pennsylvania Salt Manufacturing Co., Philadelphia, Pa.
C. T. Perry & Co., Helena, Mont.
John Reardon & Sons Co., Waverly and Allston Streets, Cambridge, Mass.
Soda Refining Co., 60 California Street, San Francisco, Calif.
Stauffer Chemical Co., 624 California Street, San Francisco, Calif.
Valley Chemical Manufacturing Co., 111 North Market Street, Chicago, Ill.
Vera Chemical Co., Hopkins and Villard avenues, North Milwaukee, Wis.

NATURAL SODA.

The United States Geological Survey long ago called attention to the value of the natural soda in the Western States.[4] The deposits have been worked commercially in a number of places, at first for local consumption and later for wider use as transportation facilities became available. Natural soda has been suggested as cheap and effective in all processes where purity is not a prime requisite, as in treating ores by flotation. Moreover, the extraction of potassium salts, principally potassium chloride and potassium sulphate, from natural brines and lake waters, has recently been carried out conjointly with the production of sodium salts, especially sodium chloride, sodium bicarbonate, and borax, and the methods of separating these various salts are being studied and improved constantly.

[4] Chatard, T. M., Natural soda—its occurrence and utilization: U. S. Geol. Survey Bull. 60, pp. 27-101, 1890.

Natural soda has been produced commercially at the following places:

Soda lakes, Ragtown, Nev.
Long Valley, southeast of Mono Lake, Calif.
Owens Lake, Inyo County, Calif.
Grant County, Wash.
Green River, Wyo.
Vernon, Calif.
Dorris, Calif.
Antioch, Nebr.
North of Clinton, British Columbia.[5]

Owens Lake, Calif., is the principal source of natural soda in the United States. The Inyo Development Co., which was the original operator at Owens Lake, has been combined with the California Alkali Co. Their plants are located at Cartago and Keeler, on Owens Lake, and their office has been moved from San Francisco to Los Angeles. The California Alkali Co., of Los Angeles, and the Natural Soda Products Co., of Keeler, Calif., were the only companies reporting the production of natural soda in 1919. The latter company produced both bicarbonate and soda ash. The plant of the Soda Products Corporation of California has not been begun, according to the latest reports.

No soda was reported to have been produced from Searles Lake in 1919.

The Western Alkali Refining Co., of Omaha, Nebr., which produced some sodium carbonate in the form of sal soda in 1918 as a by-product of the potash industry of Nebraska, sold its equipment in 1919 to the Potash Reduction Co., of Hoffland, Nebr. According to reports, it was intended to remove this equipment to Hoffland.

No information further than that contained in the reports for 1918 has appeared concerning the large deposit of natural soda at Lake Magadi in British East Africa. A deposit of trona has been found near Fezzan, Province of Tripoli, however, and a preliminary consignment was sent to Tripoli from the interior.

A "soda" mine was reported in 1919 to be located at Lagunillas, about 20 miles from Merida, western Venezuela, but no details were given concerning the purity of the material or the extent of the deposit. Soda has also been observed in the arid plateau regions of Chile.

SODIUM CHLORATE.

Sodium chlorate ($NaClO_3$) is prepared from sodium carbonate and chlorine or from sodium hydroxide and chlorine or by the electrolysis of hot sodium chloride brine. This salt has recently supplanted potassium chlorate to a considerable extent in medicine. It is also used in making dyes, matches, and high explosives, and in setting free bromine from natural brines.

The small production of sodium chlorate reported in the United States in 1919 has been combined with that of sodium perborate. One of the producers did not desire to submit figures.

Imports in 1919 were 20 short tons, a slight decrease from 1918.

SODIUM CHLORIDE (COMMON SALT).

The production and utilization of sodium chloride (NaCl) are set forth in full in the chapter on salt in Mineral Resources by Herbert Insley,[7] of the United States Geological Survey, whose final figures for the production in 1919 are 2,850,639 short tons in brine,

[5] Canadian Chem. Jour. vol. 3, p. 182, 1919.
[7] Salt, bromine, and calcium chloride: U. S. Geol. Survey Mineral Resources, 1919, pt. 2, pp. 239–256.

1,642,057 short tons of rock salt, and 2,390,206 short tons of evaporated salt, with a total value of $27,074,694. The corresponding figures for 1918 are shown in the table on page 47.

SODIUM CITRATE.

Sodium citrate ($Na_3C_6H_5O_7.2H_2O$) is a white salt which effloresces slowly when exposed to dry air. Its solution is very slightly alkaline. It is used in medicine.

The production of this salt in 1919 has been combined with that of sodium tartrate and sodium bitartrate, the total being 33 tons, valued at $58,128. It was produced by the Albany Chemical Co., 2–24 Broadway, Albany, N. Y.; the Mallinckrodt Chemical Works, St. Louis, Mo.; and E. R. Squibb & Sons, New York City.

SODIUM CYANIDE.

Since the war sodium cyanide has been largely substituted for potassium cyanide in the cyanide process of recovering gold and silver from their ores. Sodium cyanide is manufactured by the Niagara Electro Chemical Co., Niagara Falls, N. Y.

In order not to reveal the production of individual firms, the figures for the production of sodium cyanide have been combined with those for sodium peroxide and sodium iodate. The combined production of these salts in 1919 was 9,148 short tons, valued at $4,515,106.

Sodium cyanide is widely used as a solvent of the precious metals in metallurgy and in electroplating, and also as a source of hydrocyanic acid for fumigation in orchards where gaseous hydrocyanic acid is applied as an insecticide to individual trees, which are covered with tents during the process. The great production of gold from low-grade properties in the last two decades, beginning in the Transvaal and extending all over the world, is largely due to the "cyanide process." The effective solution in the cyanide process contains usually only about 0.20 per cent of sodium cyanide. Sodium cyanide is also used in case hardening and in synthesizing organic acids.

Sodium cyanide may be made from ferrocyanide or sulphocyanide obtained from gas works, coke works, or beet-sugar waste. It results, for example, from heating sodium ferrocyanide with sodium according to the reaction $Na_4Fe(CN)_6 + 2Na = 6NaCN + Fe$. The process is carried out in iron crucibles, the melted cyanide being filtered through spongy iron by means of compressed air. When made in this way the only impurities are small quantities of sodium cyanate, sodium carbonate, and sodium hydroxide.[8]

The Castner process of making sodium cyanide consists in heating together at the proper temperature sodium and ammonia, and finally also charcoal in furnaces especially designed for that purpose. The intermediate products are sodamide ($NaNH_2$) and sodium cyanamide (Na_2CN_2). The final result is summarized by the equation $2NH_3 + 2Na + 2C = 2NaCN + 3H_2$.

Sodium cyanide is at present being supplanted by a product made from calcium cyanamide. This material appears to be calcium cyanide, but is for most purposes practically equivalent to sodium

[8] Martin, Geoffrey, and Barbour, William, Industrial nitrogen compounds and explosives, p. 72, New York, 1917.

cyanide. It is made by heating commercial calcium cyanamide ($CaCN_2+C$) with salt to a high temperature for a few minutes and quickly cooling the melt. The reaction is carried out continuously in electric furnaces with conducting hearth and a single suspended electrode. The product made by the American Cyanamide Co. is known as Aëro brand cyanide. "Grade X" is equivalent to 37 per cent of sodium cyanide. It can be used directly in the extraction of gold and silver, but not in the case-hardening industry. From it are also manufactured sodium ferrocyanide and prussic acid. Its manufacture and uses have been described by W. S. Landis.[9]

The manufacture of cyanides directly from atmospheric nitrogen has been the subject of much study and now offers promise of commercial development. The Bucher process consists in heating soda ash and powdered coke with iron ore in a furnace through which air is passed.

SODIUM FERROCYANIDE.

Sodium ferrocyanide, yellow prussiate of sodium ($Na_4Fe(CN)_6.10H_2O$), is used in making certain blue colors, such as Prussian blue, Chinese blue, and Paris blue, which are employed extensively in dyeing textiles and in making paint and printing ink. It is made from material obtained in purifying coal gas. Such material is mixed with lime, and the soluble calcium ferrocyanide is leached out and subsequently converted into sodium ferrocyanide by treatment with sodium carbonate. Sodium ferrocyanide may also be made from calcium cyanamide cyanide, as mentioned above, by combining it with ferrous sulphate, filtering, concentrating, crystallizing, and, for the highest purity, recrystallizing.

Still another method of making sodium ferrocyanide is to use a mixture of one part of coke and four parts of barium carbonate. When this mixture is heated for about six hours with nitrogen in a suitable retort a mixture of cyanide and cyanamide is obtained that may be converted into sodium salts with soda ash and into ferrocyanide by heating with finely divided iron. The products are separated by crystallization and sodium carbonate and barium carbonate used over again. (United States patent No. 1318258.)

Before the war a considerable quantity of this salt was imported from England and Germany, but the war caused a greatly increased domestic production, owing to the decreased importation as well as to the supplanting of potassium ferrocyanide by sodium ferrocyanide on account of the scarcity of potash.

The quantity of sodium ferrocyanide marketed in the United States in 1919 was 3,437 short tons, valued at $1,346,285. This was a decrease from the corresponding figures for 1918, which were 4,525 short tons, valued at $2,690,110. The domestic production in both 1917 and 1918 was much larger than in any previous year. Imports of sodium ferrocyanide increased in 1919, amounting to 650 short tons, valued at $218,222.

Prices obtained for sodium ferrocyanide in 1919 were notably lower than the average of 1918, but they have since risen to somewhere near the average of 1918.

[9] Chem. and Met. Eng., vol. 22, p. 265, 1920.

Sodium ferrocyanide was manufactured in 1919 by the following firms:

- Citizens Gas Co., Indianapolis, Ind.
- Henry Bower Chemical Manufacturing Co., Grays Ferry Road and Twenty-ninth Street, Philadelphia, Pa.
- Penman-Littlehales Co., Syracuse, N. Y.
- Semet-Solvay Co., Syracuse, N. Y.
- Worcester Gas Light Co., Worcester, Mass.

SODIUM FLUORIDE.

Sodium fluoride (NaF) is made by treating cryolite with NaOH, the NaF being sparingly soluble. It may also be made from hydrofluoric acid and soda ash. This salt is used in making enamels and also as a flux and insecticide. Sodium fluosilicate or silicofluoride is also used in making enamels.

The reported production of sodium fluoride, acid sodium fluoride, and sodium fluosilicate in the United States in 1919 amounted to 1,171 short tons, valued at $244,004, compared with 1,879 short tons, valued at $387,224, in 1918.

Sodium fluoride is produced by the General Chemical Co., New York, N. Y., the Harshaw, Fuller & Goodwin Co., 720 Electric Building, Cleveland, Ohio, and Wiarda & Co., Brooklyn, N. Y. The production of sodium fluosilicate in 1919 was reported by the Baugh Chemical Co., 25 South Calvert Street, Baltimore, Md., and the Armour Fertilizer Works, Chicago, Ill.

SODIUM HYDROXIDE (CAUSTIC SODA).

Sodium hydroxide, or caustic soda (NaOH; theoretically Na_2O 77.48 per cent, H_2O 22.52 per cent) is a base and not a salt of sodium.

Production.—The total production of caustic soda in the United States in 1919, as reported by the producers and not including that made in soap works, amounted to 355,466 short tons, valued at $22,196,898, as compared with 513,363 short tons, valued at $31,854,470, in 1918. Of this quantity about 85 per cent is estimated to represent sales; the remainder was consumed by the producers in their own plants.

The production of caustic soda may be further classified according to the method of manufacture. Exact figures for 1919 are not available; in 1918 about 72 per cent of the product was made from sodium carbonate and lime, and 28 per cent was made by the electrolysis of sodium chloride. The average price of that made in the first way was $59 a ton, as reported by the producers, and of that made by electrolysis $64 a ton. Electrolytic caustic, however, varies widely in value according to its purity, the method of preparation, and the purpose for which it is made.

Imports and exports.—The imports of caustic soda for consumption in the United States increased from 2,002 pounds, valued at $193 in 1918, to 42,724 pounds, valued at $6,888 in 1919, according to the Department of Commerce. The exports in 1919 were 82,118 short tons, valued at $6,748,762, a decided increase over 1918.

Manufacture.—Sodium hydroxide is made by causticizing soda-ash liquors with lime or by electrolyzing common salt brine. The details of the methods and descriptions of several of the cells commonly employed were given in the report for 1918.

Many pulp and paper mills make caustic soda for their own use, using both processes. When the electrolytic process is employed, the chlorine produced at the anode is generally converted into bleaching powder or solution. The following list gives the pulp and paper mills producing their own bleach and the type of cell used, according to the latest available information:

	Type of cell used.
D. M. Bare Paper Co., Roaring Springs, Pa.	MacDonald.
Brown & Co., Berlin, N. H.	Allen-Moore and Burgess.
Champion Fiber Co., Canton, N. C.	Wheeler.
Dill & Collins Co., Philadelphia, Pa.	Allen-Moore.
Eastern Manufacturing Co., South Brewer, Me.	Allen-Moore.
Hammersley Manufacturing Co., Garfield, N. J.	Nelson.
Jessup & Moore Paper Co., Wilmington, Del.	Allen-Moore.
Jessup & Moore Paper Co., Elkton, Md.	Allen-Moore.
Kimberly-Clark, Neenah, Wis.	Wheeler.
Miami Paper Co., West Carrollton, Ohio.	Allen-Moore.
New York & Pennsylvania Co., Johnsonburg, Pa.	Hargreave-Bird.
Oxford Paper Co., Rumford, Me.	Whiting (mercury).
Penobscot Chemical Fibre Co., Great Works, Me.	Larchar.
Riordan Pulp & Paper Co. (Ltd.), Merritton, Ontario	Allen-Moore.
S. D. Warren Co., Cumberland Mills, Me.	Allen-Moore.
West Virginia Pulp & Paper Co., Covington, Va.	Hargreave-Bird.

Uses.—Sodium hydroxide is used in large quantities in making soap, lye, and pulp or fiber for making paper. It is also used in mercerizing cotton, in purifying oils and fats, in refining petroleum, in reclaiming rubber, in making dyes and phenol (which is used in the manufacture of the picrates for explosives), in making pigments, in cleaning metals for electroplating, and in the chemical trade.

Producers.—The following list gives the producers of caustic soda in 1919, exclusive of soap makers:

Brown & Co., 404 Commercial Street, Portland, Maine.
Champion Fibre Co., Canton, N. C.
Columbia Chemical Co., Pittsburgh, Pa.
Diamond Alkali Co., Pittsburgh, Pa.
Dill & Collins Co., Sixth and Cherry Streets, Philadelphia, Pa.
Dow Chemical Co., Midland, Mich.
Eastern Manufacturing Co., South Brewer, Maine.
Fields Point Manufacturing Co., Municipal Wharf, Providence, R. I.
Great Western Electro-Chemical Co., 9 Main Street, San Francisco, Calif.
Gulf Refining Co., Frick Building Annex, Pittsburgh, Pa.
Hooker Electro-Chemical Co., Niagara Falls, N. Y.
Isco Chemical Co., Niagara Falls, N. Y.
Kimberly-Clark Co., Neenah, Wis.
Los Angeles Soap Co., 633 East First Street, Los Angeles, Calif.
Mathieson Alkali Works, 25 West Forty-third Street, New York, N. Y.
Mead Pulp & Paper Co., Chillicothe, Ohio.
Merrimac Chemical Co. (Inc.), 148 State Street, Boston, Mass.
Miami Paper Co., West Carrollton, Ohio.
Michigan Alkali Co., Wyandotte, Mich.
Michigan Electro-Chemical Co., Menominee, Mich.
Niagara Alkali Co., Niagara Falls, N. Y.
Niagara Smelting Corporation, Niagara Falls, N. Y.
Oxford Paper Co., 200 Fifth Street, New York, N. Y.
Pennsylvania Salt Manufacturing Co., Philadelphia, Pa.
Penobscot Chemical Fibre Co., 49 Federal Street, Boston, Mass.
Republic Chemical Co., Pittsburgh, Pa.
Solvay Process Co., Syracuse, N. Y.
Warner-Klipstein Chemical Co., 52 Vanderbilt Avenue, New York, N. Y.
S. D. Warren Co., Boston, Mass.
West Virginia Pulp & Paper Co., 200 Fifth Avenue, New York, N. Y.

SODIUM HYPOCHLORITE.

Sodium hypochlorite (NaOCl) is largely used in solution (Dakin solution) as an antiseptic surgical wash. As generally prepared this solution may also contain sodium chloride or sea salt. It is formed by the action of chlorine on caustic soda, usually during electrolysis.

In United States patent No. 1292241, granted January 21, 1919, to Niswonger & McDorman, a small cell formed of hard rubber with electrodes of graphite is described which is adapted for using currents of about 25 amperes or less to produce small quantities of sodium hypochlorite.

Solutions of sodium hypochlorite used in medicine require a carefully adjusted alkalinity. They are frequently stabilized by borax to maintain the exact alkalinity that is essential for the germicidal efficiency of the solution.

SODIUM IODIDE.

Sodium iodide (NaI) may be prepared in several ways, as, for example, from caustic soda and iodine. It is used in photography, in analytical chemistry, and in medicine, especially for making solutions of iodine. It is said that this salt may be employed in medicine with fully as favorable results as are obtained from potassium iodide.

The production of sodium iodide in the United States in 1919 amounted to 12 tons, valued at $86,985. It was manufactured by the Albany Chemical Co., 2–24 Broadway, Albany, N. Y.; McKesson & Robbins (Inc.), 91 Fulton Street, New York, N. Y.; the Mallinckrodt Chemical Works, St. Louis, Mo.; and the Powers-Weightman-Rosengarten Co., Philadelphia, Pa.

SODIUM NITRATE.

Data on the occurrence and production of sodium nitrate ($NaNO_3$) are given in a previous volume of Mineral Resources.[10] As is well known, most of the sodium nitrate used in the United States is imported from South America, principally from Chile. The imports for consumption in 1916 were 1,275,962 short tons, valued at $38,131,364; in 1917, 1,728,390 short tons, valued at $60,727,100; in 1918, 2,069,379 short tons, valued at $90,216,935; and in 1919, 456,466 short tons, valued at $19,558,963, according to the records of the Department of Commerce.

In 1919 8,040 short tons of refined sodium nitrate, valued at $816,647, was produced by E. R. Squibb & Sons, New York, N. Y.; the Mallinckrodt Chemical Works, St. Louis, Mo.; the San Francisco Salt Refining Co., 624 California Street, San Francisco, Calif.; and the Stauffer Chemical Co., 624 California Street, San Francisco, Calif.

Many samples of nitrate-bearing material have been examined by the United States Geological Survey from time to time, but although the percentages of nitrate in some of them have been very promising, the material has so far either not been found in quantity in any given locality or it has been found to be so widely disseminated in lavas or tuffs as to make its successful commercial treatment doubtful.

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[10] Phalen, W. C., Potash salts: U. S. Geol. Survey Mineral Resources, 1914, pt. 2, p. 18, 1916.

SODIUM NITRITE.

Sodium nitrite ($NaNO_2$) is made by heating sodium nitrate with lead. The product is extracted with water and the solution is allowed to crystallize, when anhydrous sodium nitrite separates. It is used in making coal-tar dyes and as a chemical reagent. The production reported for 1919 was 1,182 short tons, valued at $265,121, compared with 1,701 short tons, valued at $609,779, in 1918.

The imports for consumption in 1919 were 1,275 short tons, valued at $246,729, compared with 1,429 short tons, valued at $289,182, in 1918.

Sodium nitrite was manufactured in 1919 by the following firms:

American Nitrogen Products Co., Seattle, Wash.
Atlas Powder Co., 140 North Broad Street, Philadelphia, Pa.
E. I. du Pont de Nemours & Co., Wilmington, Del.
Harshaw, Fuller & Goodwin Co., 720 Electric Building, Cleveland, Ohio.
Mallinckrodt Chemical Works, St. Louis, Mo.
Semet-Solvay Co., Syracuse, N. Y.

The American Nitrogen Products Co., Seattle, Wash., did not report any sodium nitrite in 1919.

SODIUM PERBORATE.

Sodium perborate, which is made by suspending borax in a solution of sodium carbonate that is being electrolyzed, is used in laundry work, in bleaching cotton and linen, and for hygienic purposes. It is an oxidizing agent. According to the mode of preparation, sodium perborate has the formula $Na_2B_4O_8.10H_2O$ or $NaBO_3.4H_2O$. The addition of sulphuric acid to a solution of sodium perborate sets free hydrogen peroxide, or the same result can be obtained by merely heating the solution; in fact, in bleaching, sodium phosphate is often used with sodium perborate to maintain an alkaline solution.

Figures for the production of this salt have been combined with those for the production of sodium chlorate, the total for 1919 being 1,210 short tons, valued at $62,980, compared with 2,413 tons, valued at $1,004,250, in 1918.

Sodium perborate was manufactured in 1919 by the Roessler & Hasslacher Chemical Co., 709–717 Sixth Avenue, New York, N. Y.

SODIUM PERMANGANATE.

Sodium permanganate ($NaMnO_4$) is made by the electrolytic oxidation of sodium manganate or ferromanganese. Also, United States patent No. 1318432, issued October 14, 1919, to J. R. MacMillan, describes a method of making permanganate by merely heating manganiferous ore with about its own weight of caustic soda or potash to 600°–800° C. while treating the mixture with a current of air. Some sodium permanganate is made as an intermediate product in the process of manufacturing potassium permanganate, but no production of sodium permanganate was reported in 1919.

SODIUM PEROXIDE.

Sodium peroxide is manufactured by the Niagara Electro Chemical Co., 709–717 Sixth Avenue, N. Y. It is made by burning metallic sodium in an excess of air or oxygen. It is used in chemical analysis and in bleaching, also for generating oxygen in hospitals, submarines, and mine-rescue apparatus and in making hydrogen peroxide. In the commercial product known as "oxone" sodium peroxide is used to generate oxygen merely through the action of water.

In order not to reveal the output of single producers the production of sodium peroxide in 1919 has been added to that of sodium cyanide and sodium iodate, the combined figures being 9,148 short tons, valued at $4,515,106, compared with 9,077 short tons, valued at $5,361,000, in 1918.

SODIUM PHOSPHATE.

Sodium phosphate ($Na_2HPO_4.12H_2O$) is one of several different phosphates, all of which are derived originally from phosphate rock. The rock is first treated with sulphuric acid, the solution of phosphoric acid thus obtained is separated from the insoluble calcium sulphate and neutralized with soda ash, and this solution is allowed to crystallize.

Sodium phosphate is used in the textile industry, as a water softener, in making baking powder, and in the pharmaceutical trade.

Sodium phosphate was manufactured in 1919 by the following firms:

Bowker Chemical Co., 60 Trinity Place, New York, N. Y.
Grasselli Chemical Co., Cleveland, Ohio.
Charles Cooper & Co., Newark, N. J.
Mallinckrodt Chemical Works, St. Louis, Mo.
E. R. Squibb & Sons, 78 Beekman Street, New York, N. Y.
Stauffer Chemical Co., 624 California Street, San Francisco, Calif.
Victor Chemical Works, Fisher Building, Chicago, Ill.
Warner Chemical Co., 52 Vanderbilt Avenue, New York, N. Y.

Trisodium phosphate was manufactured by the Bowker Chemical Co., Grasselli Chemical Co., and Warner Chemical Co.

The total production of all varieties of sodium phosphate, including monosodium phosphate, disodium phosphate, and trisodium phosphate, in the United States in 1919 amounted to 14,760 short tons, valued at $1,733,996. The following table contains such figures as are available for the annual production of sodium phosphate to date:

Sodium phosphate produced in the United States, 1899–1919.[a]

	Quantity. (short tons).	Value.		Quantity. (short tons).	Value.
1899	2,340	$155,989	1917	13,305	$711,283
1904	4,830	244,373	1918	15,620	1,427,947
1909	12,290	540,282	1919	14,760	1,733,996
1914	15,397	853,528			

[a] The figures for the years 1899, 1904, 1909, and 1914 are from Chemicals and allied industries: Census of Manufactures, p. 18, U. S. Dept. Commerce Bur. Census, 1918.

SODIUM SILICATE.

Sodium silicate or water glass, as manufactured commercially, is not a definite chemical compound. The bulk of the commercial product is of 1.38 specific gravity, but it ranges from 1.34 to 1.91. The molecular ratio of SiO_2 to Na_2O in these different grades varies from about 1 to 4, being lowest in the most concentrated solutions.[11]

[11] Vail, J. G., Some properties of commercial silicate of soda: Jour. Ind. Eng. Chemistry, vol. 11, pp. 1029, 1919.

The production of sodium silicate for the calendar year 1919 amounted to 300,138 short tons, valued at $5,879,628, compared with 317,161 short tons, valued at $5,870,973, in 1918. The last production reported before 1917 was that given by the Bureau of the Census for 1914, which amounted to 169,049 short tons, valued at $1,648,854, a great advance over all preceding years. Prices for the 60° B. strength averaged about 4 cents a pound during 1919.

Exports fell off and imports of sodium silicate doubled in 1919, as compared with 1918.

The original use of sodium silicate in this country and the use still requiring the largest quantity is as an ingredient of household and laundry soap. Other important uses are as an adhesive in the manufacture of corrugated and combined fiber shipping cases, wall board, veneer panels, asbestos products, and in sealing shipping cases; as a binder in abrasive wheels, arc light electrodes, and acid-proof and heat-resisting cements; in sizing barrels, grease-proofing paper board, paper sizing, egg preserving, silk weighting, and as a boiler compound.

Sodium silicate was manufactured by the following firms in 1919:

Frohman Chemical Co., Sandusky, Ohio.
General Chemical Co., New York, N. Y.
Grasselli Chemical Co., Cleveland, Ohio.
Mechling Bros. Manufacturing Co., Camden, N. J.
Philadelphia Quartz Co., 121 South Third Street, Philadelphia, Pa.
Philadelphia Quartz Co. of California, Berkeley, Calif.
Valley Chemical & Manufacturing Co., 111 North Market Street, Chicago, Ill.

SODIUM SULPHATE.

SALT CAKE.

Sodium sulphate (Na_2SO_4) is obtained in large quantities in the manufacture of hydrochloric acid from sodium chloride, either with the aid of niter cake, of sulphuric acid, or by Hargreave's process from sulphur dioxide, air, and steam. The product is generally termed "salt cake."

The salt cake marketed in the United States in 1919 amounted to 129,042 short tons, valued at $2,019,460, a slight decrease in quantity and value from the output for 1918. The Bureau of the Census reported an output of 90,442 tons of salt cake, valued at $841,887, for the year 1914.

Sodium sulphate as salt cake is used in making plate glass, window glass, and bottles, in making paper pulp by the sulphate process, and in making water glass.

It is claimed that sodium sulphate can be used instead of sodium carbonate in the soda wood pulp industry. In this process of making pulp the waste liquors containing sodium carbonate and carbonaceous matter are evaporated, and the residue is finally calcined to recover sodium carbonate. If sodium sulphate is added to the waste liquors it is converted by calcination into sodium sulphide, which is said to have the same action on pulp as caustic soda. But if the proper quantity of limestone is added before calcining it appears that sodium carbonate and sodium hydroxide would be the principal products obtained by extraction.

Crude sodium sulphate is used in precipitating barium from certain Ohio salt brines and in the Miles process for treating sewage.

Manufacturers.—The following firms produced sodium sulphate as salt cake in 1919:

Ault & Wiborg Co., Cincinnati, Ohio.
Chicago Copper & Chemical Co., Chicago, Ill.
Consolidated Chemical Co., McKittrick, Calif.
Contact Process Co., P. O. Drawer 98, Buffalo, N. Y.
E. I. du Pont de Nemours & Co., Wilmington, Del.
General Chemical Co., New York, N. Y.
Grasselli Chemical Co., Cleveland, Ohio.
Kalbfleisch Corporation, 31 Union Square west, New York, N. Y.
Charles Lennig & Co., Philadelphia, Pa.
Merrimac Chemical Co., 148 State Street, Boston, Mass.
Monsanto Chemical Works, St. Louis, Mo.
Naugatuck Chemical Co., Elm Street, Naugatuck, Conn.
New Jersey Zinc Co., 160 Front Street, New York, N. Y.
Pennsylvania Salt Manufacturing Co., Philadelphia, Pa.
Powers-Weightman-Rosengarten Co., Philadelphia, Pa.
Rollin Chemical Corp., Equitable Building, New York, N. Y.
Stauffer Chemical Co., 624 California Street, San Francisco, Calif.

GLAUBER'S SALT.

The hydrated salt obtained by recrystallization below 32.4° C. ($Na_2SO_410H_2O$), Glauber's salt, is in demand where purity is an essential. It is used in dyeing, in tanning, in the textile industry as a mordant assistant, and in medicine. It is, however, an expensive form in which to transport sodium sulphate. Much Glauber's salt is made from impure salt cake and, after heating to remove the excess water, is sold as "glassmaker's salt cake."

The Glauber's salt marketed in 1919 amounted to 47,730 short tons, valued at $877,060.

The following list gives the manufacturers of Glauber's salt in 1919:

Atlantic Carbonic Co., 268 Third Street, Chelsea, Mass.
Central Chemical Co., foot of Chapel Street, Newark, N. J.
Chicago Copper & Chemical Co., 111 West Jackson Boulevard, Chicago, Ill.
Columbus Crystal Co., 15 Arch Street, Newark, N. J.
E. I. du Pont de Nemours & Co., Wilmington, Del.
General Chemical Co., New York, N. Y.
John D. Gill & Co., Cheyenne, Wyo.
Grasselli Chemical Co., Cleveland, Ohio.
Iowa Soda Products Co., Council Bluffs, Iowa.
Kalbfleisch Corporation, 31 Union Square west, New York, N. Y.
Charles Lennig & Co. (Inc.), Philadelphia, Pa.
Merrimac Chemical Co., 148 State Street, Boston, Mass.
Powers-Weightman-Rosengarten Co., Philadelphia, Pa.
The Roessler & Hasslacher Chemical Co., 709–717 Sixth Avenue, New York, N.Y.

NITER CAKE.

Niter cake, the residual product in the manufacture of nitric acid from sodium nitrate and sulphuric acid, differs from salt cake in containing acid sodium sulphate ($NaHSO_4$) in varying quantity. Manufacturers report either the percentage of bisulphate or the percentage of sulphuric acid in the product. Pure sodium bisulphate carries 40.8 per cent of sulphuric acid and commercial grades carry from 25 to 35 per cent of sulphuric acid, which corresponds to 61 to 86 per cent of sodium bisulphate.

The reported sales of niter cake for 1919 amounted to 83,402 short tons, valued at $271,424. Very few manufacturers of fertilizers making sulphuric acid have reported the production of niter cake, which, if made, is doubtless consumed in their own works.

Niter cake is used as a substitute for sulphuric acid for many purposes, as in metal pickling, in absorbing ammonia, in making paper, sodium sulphate, and fertilizers. Experiments have shown that superphosphates containing 15 per cent of available P_2O_5 can be readily produced from Florida pebble phosphate by mixing the finely ground material with niter cake, the reaction taking place without the application of heat.

The following firms manufactured niter cake in 1919:

- Aetna Explosives Co., New York, N. Y.
- American Steel & Wire Co. of New Jersey, 503 Western Reserve Building, Cleveland, Ohio.
- American Zinc & Chemical Co., Oliver Building, Pittsburgh, Pa.
- Atlas Powder Co., 140 North Broad Street, Philadelphia, Pa.
- Ault & Wiborg Co., Cincinnati, Ohio.
- Contact Process Co., P. O. Drawer 98, Buffalo, N. Y.
- Davison Chemical Co., Baltimore, Md.
- General Chemical Co., New York, N. Y.
- Grasselli Chemical Co., Cleveland, Ohio.
- Kalbfleisch Corporation, 31 Union Square west, New York, N. Y.
- Merrimac Chemical Co., 148 State Street, Boston, Mass.
- Monsanto Chemical Works, St. Louis, Mo.
- Naugatuck Chemical Co., Naugatuck, Conn.
- Powers-Weightman-Rosengarten Co., Philadelphia, Pa.
- Tennessee Copper Co., 61 Broadway, New York, N. Y.
- Victor Chemical Works, Fisher Building, Chicago, Ill.

NATURAL SODIUM SULPHATE.

Sodium sulphate is an abundant constituent of surface salts in several localities in the Western States, especially in Wyoming, Utah, and Nevada; in fact, it is found in many soils in regions of deficient rainfall. It is known as white alkali, in contrast to sodium carbonate, which is known as black alkali on account of its corrosive action on vegetation. The exact proportion of white alkali that may exist in a soil without being positively deleterious is a matter of disagreement among soil experts, but it is generally considered less deleterious than the other sodium salts. Its presence in fertilizers, at least as a double ammonium salt, is even considered advantageous.

Glauber's salt decreases markedly in solubility with falling temperature, so that it deposits from many lakes containing strong brine in cold weather. Some "lakes" in western Saskatchewan, Canada, are reported to contain very large quantities of nearly pure Glauber's salt, and this salt, which is known mineralogically as mirabilite, as well as the anhydrous salt, thenardite, has been reported in considerable abundance at several localities in the Western States.

Large deposits of bloedite have been reported in Muskiki Lake near Maskakee Springs, Saskatchewan, Canada. It is estimated that there are 9,000,000 tons in these deposits. Some of this material has been shipped to Ontario to be refined into Glauber's salt, Epsom salts, and other compounds. Similar salts, as well as glaserite, have been noted in some of the arid regions of Asia.

Natural sodium sulphate has been utilized at various times in small quantity. It seems as if greater use could be made of it. When it occurs mixed with sodium carbonate the mixture may be regarded as having been carried nearly through the Leblanc process, so that instead of attempting to separate the two salts it might be possible to transform the sulphate into carbonate by calcination with limestone and coal producing soda ash, a large proportion of soda ash being already present in the natural salts. Moreover, the natural mixture might be used directly in making glass.

In 1885 some of the crude sodium sulphate from the Union Pacific Lakes, 13 miles southwest of Laramie, Wyo., was converted into salt cake, soda ash, and caustic soda at the Laramie Chemical Works, and two years later glassmaking was carried on for a time. Since 1892, however, the deposits have not been worked, as the elimination of the water of the Glauber's salt has apparently proved too expensive.

The Southern Chemical Co., 925 Mills Building, El Paso, Tex., with works 25 miles west of Valmont station, N. Mex., was expecting to begin the extraction of sodium sulphate in 1919, but has not produced any according to the latest reports.

A recent report states that another company, the Western Chemicals Co., of Silver Peak, Nev., has been incorporated to work similar deposits in that locality.

From time to time the Geological Survey has inquiries from buyers concerning new sources of natural salts and is glad to be informed of discoveries or possibilities of that kind. So far as known, J. D. Gill and associates, Cheyenne, Wyo., and the Consolidated Chemical Co., McKittrick, Calif., were the only producers of the natural salt in 1919.

SODIUM SULPHIDE.

Sodium sulphide (Na_2S) is made by heating salt cake with coal, or from niter cake, sodium chloride, and coal, with the incidental production of hydrochloric acid. After lixiviation the product is obtained as crystals ($Na_2S.9H_2O$) carrying about 32 per cent of sodium sulphide. A more concentrated salt may be prepared by evaporating until the temperature reaches about 160° C. and then allowing the liquor to cool. The product thus obtained carries about 62 per cent of sodium sulphide.

Sodium sulphide is used in dyeing, in cleaning fabrics, in making the sulphur dyes and other dyes, in tanning, for removing hair from skins, in sulphidizing oxidized lead and copper ores preparatory to flotation, and in precipitating silver from cyanide solutions. A dilute solution of it has also been used as a solvent for gold in the hydrometallurgy of gold ores, the gold being later precipitated by copper or an aluminum-zinc alloy.

Sodium sulphide can be employed in making wood pulp. The losses in the process are compensated by adding salt cake to the black ash before calcination. According to United States patent No. 1322043, issued to Ellis Olsson, November 18, 1919, niter cake may be used instead of salt cake, thereby dispensing with subsequent causticizing of the carbonate, as sulphide is formed instead of carbonate.

The production of soduim sulphide in the United States in 1919 amounted to 45,448 short tons, valued at $2,645,181. This material includes both the 32 and the 62 per cent grades, the larger part, however, being the 62 per cent grade. The quantity is greater than that reported in 1918, 43,490 short tons, which included more of the 32 per cent grade. The value is greater than that in any previous year for which figures are available.

The production of sodium sulphide given by the Bureau of the Census for 1914 was 20,263 tons, valued at $516,644, and 7,673 tons, valued at $206,450, for 1909.

In 1919 there was imported for consumption 834 tons of sodium sulphide, valued at $54,251, according to the figures of the Department of Commerce, whereas the imports in 1918 were 56 tons, valued at $4,673.

The following list gives the manufacturers of sodium sulphide in 1919:

Ault & Wiborg Co., Cincinnati, Ohio.
Chicago Copper & Chemical Co., Chicago, Ill.
Charles Cooper & Co. (Inc.), Van Buren and Clifford streets, Newark, N. J.
Durex Chemical Corporation, Sweetwater, Tenn.
General Chemical Co., New York, N. Y.
Grasselli Chemical Co., Cleveland, Ohio.
Charles Lennig & Co. (Inc.), Philadelphia, Pa.
Merrimac Chemical Co., 148 State Street, Boston, Mass.
Rollin Chemical Corp., Equitable Building, New York, N. Y.

SODIUM TARTRATE.

Sodium tartrate ($Na_2C_4H_4O_6.2H_2O$) and sodium bitartrate are used in medicine. Their production has been combined with that of sodium citrate, given on p. 63. These salts were produced in 1919 by the Mallinckrodt Chemical Works, St. Louis, Mo., and E. R. Squibb & Sons, New York, N. Y.

SODIUM TETRABORATE (BORAX).

DESCRIPTION AND USES.

The most important derivatives of the chemical element boron are boric acid and borax. Boric acid occurs in the water of certain hot volcanic springs in Italy and has been extracted on a commercial scale there for more than a century. The principal sodium salt of boric acid is sodium tetraborate, or common borax ($Na_2B_4O_7.10H_2O$). Borax may be made from boric acid and soda, but in the United States only borates are available as raw materials, so that boric acid is made from them. Natural crystals of borax were first noted at Tuscan Springs, Tehama County, Calif., by J. A. Veatch, in 1856. They have since been found in several counties in California, and borates have been detected in the waters of numerous saline lakes and playas in Nevada, California, and Oregon, and in the hot springs of the Yellowstone National Park. In the early days refined borax was made by simply recrystallizing the natural salt. Since then the industry has utilized almost entirely only colemanite, a calcium borate which is converted into borax by treatment with sodium carbonate. In 1919, however, the recovery of borax from the water of Searles Lake was taken up in connection with the extraction of potash, and production from this source is being continued. A number of patents have been granted for methods of separating borax and potassium chloride, which is one of the problems at Searles Lake. Some of these patents depend on the usual methods of fractional precipitation and others on the formation of sodium metaborate, which is more soluble than borax.

Borax is largely used in making the enamel coating for iron and steel ware used in plumbing fixtures, equipment for chemical factories, and kitchen utensils, also in making borosilicate glasses, such as are used in making lamp chimneys, baking dishes, and laboratory glassware. Considerable borax is also used in the laundry and kitchen, in making soap and starch, in sizing paper, and in tanning and welding.

Several uses have been proposed for metallic boron and boron alloys, but so far as known these proposals have not yet passed into the stage of commercial development.

Boric acid, on the other hand, is recognized as an antiseptic and is also used in cosmetics. It is sometimes used in preserving meat where its use is not forbidden by the food and drugs act. The production of boric acid in the United States is estimated at 5,000 to 6,000 tons a year. From 100 to 200 tons of boric acid is annually imported into the United States, principally from Italy. Patents have been granted for extracting boric acid from saline mixtures as the volatile methyl borate, the methyl alcohol being recovered and used over again.

PRODUCTION AND PRICES.

The quantity of borax produced and sold in the United States in 1919 was 28,518 short tons, valued at $4,351,891. This salt was made by the American Trona Corporation, 233 Broadway, New York, N. Y.; the Pacific Coast Borax Co., 100 William Street, New York, N. Y.; Charles Pfizer & Co., 81 Maiden Lane, New York, N. Y.; the Stauffer Chemical Co., 624 California Street, San Francisco, Calif.; and the Thorkildsen-Mather Co., 111 West Monroe Street, Chicago, Ill.

According to quotations in the trade journals, the price of borax in 1919, in the New York market, for crystals in bags, in car lots, averaged about $8\frac{3}{4}$ cents a pound, compared with about $8\frac{1}{4}$ cents a pound in 1918.

SOURCES OF DOMESTIC BORAX.

Colemanite, a borate of calcium, is the chief source of domestic borax. This is produced from mines at Lang, Ryan, and Death Valley, Calif. Most of the colemanite is concentrated before shipment. The crude ore is first calcined and the colemanite then separated from the other minerals by mechanical means The colemanite is converted into borax by boiling it with a solution of soda, thus forming insoluble calcium carbonate and a solution of borax. The latter is filtered and, on cooling, the borax crystallizes out. The other source of borax is the water of Searles Lake.

The primary borate ore produced in the United States in 1919, including the naturally occurring borax, is estimated to have been 66,146 tons, valued at $1,380,000. This is a decrease both in quantity and value from the 88,794 tons reported in 1918, but part of this difference is due to the inclusion of more concentrated ores. As exact figures for the grade of the ores are not available, the quantities offer a very poor basis for comparison.

Below is given a statement of the production of crude borates and of refined borax for the last six years:

Crude borates and refined borax produced in the United States, 1914–1919.

Year.	Crude borates.		Refined borax.	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.
1914	62,400	$1,464,400	26,501	$2,071,774
1915	67,003	1,677,099	26,794	2,293,631
1916	103,525	2,409,459	27,969	3,353,432
1917	108,875	3,609,632	28,309	3,805,711
1918	88,794	2,263,230	26,673	3,909,565
1919	66,146	1,380,000	28,518	4,351,891

IMPORTS AND EXPORTS.

Imports of borax and crude borates into the United States in 1919 were practically negligible, but 276,795 pounds of boric acid, valued at $20,716, was imported.

No statistics on exports are available. During the war a substantial export business in borax was developed, but it is not known whether this is being maintained.

SODIUM THIOSULPHATE.

Sodium thiosulphate, which is very generally known in the trade as sodium hyposulphite or "hypo," is made by treating sodium sulphite with sulphur, or from milk of lime, sulphur, and soda ash, or from waste materials containing sulphur, such as Leblanc tank waste.

The principal use of this salt is in the leather trade. It is also used in the textile industry for removing the last traces of chlorine from bleached fabrics, and in bleaching wool, straw, oils, ivory, and bones (as a source of sulphur dioxide), and in dyeing, in analytical chemistry, and in the manufacture of dyes, paper, and mordants. Its use in photography as a fixing agent depends on its solvent action on silver salts which have not been affected by light.

The production of this salt in the United States in 1919 was 32,212 short tons, valued at $1,709,223.

Sodium thiosulphate was manufactured in 1919 by

General Chemical Co., New York, N. Y.
Grasselli Chemical Co., Cleveland, Ohio.
Charles Lennig & Co. (Inc.), Philadelphia, Pa.
A. R. Maas Chemical Co., Los Angeles, Calif.
Mechling Bros. Manufacturing Co., Camden, N. J.

MISCELLANEOUS SODIUM COMPOUNDS.

A scattered production of various sodium salts, chiefly organic chemicals used in analytical chemistry, photography, and medicine, was reported in 1919, which can not be given in detail without revealing figures of individual producers. The list includes sodium phenolsulphonate, sodium salicylate, sodium oxalate, sodium arsenate, sodium arsenite, sodium hypochlorite or chlorinated soda solution, sodium formate, sodium succinate, sodium hydrosulphite, and sodium sulphocarbolate.

The total production of these salts reported in 1919, including metallic sodium, amounted to 841 short tons, valued at $756,548.

The producers reporting include

Dow Chemical Co., Midland, Mich.
Eastman Kodak Co., Rochester, N. Y.
Hayden Chemical Works, New York, N. Y.
Mallinckrodt Chemical Works, St. Louis, Mo.
Monsanto Chemical Works, St. Louis, Mo.
E. R. Squibb & Sons, 78 Beekman Street, New York, N. Y.
Jacques Wolf & Co., Passaic, N. J.

POTASH.

By W. B. Hicks and M. R. Nourse.[1]

INTRODUCTION.

The potash industry of the United States was at a critical period of its history at the beginning of 1919. Developments had progressed under the high war prices of \$4 to \$5 a unit of potash (20 pounds of K_2O) until the annual productive capacity of the plants in operation or about ready to operate was estimated at 100,000 short tons of potash (K_2O) and the capital invested in these plants was reported to be about \$25,000,000. Comparatively few of the larger plants had been fully paid for, and many were still under construction or had been operated only a short time. The total production in 1918 had been 54, 803 short tons of potash(K_2O), but nearly one-third of it was still in the hands of the producers. Money had been advanced on these stocks; prices had dropped from about \$5 a unit of potash (K_2O) in November, 1918, to about \$2.50 a unit, and the market for domestic potash was dull even at that price, because lower-priced potash was expected from Alsace and Germany. Owing to these conditions most of the producers closed their plants, at least temporarily, early in 1919, and some of them went out of business. Efforts were made by the producers and their organizations to induce Congress to pass protective legislation for the domestic potash industry, and public hearings [2] on a bill designed for this purpose were held but thus far no such legislation has been enacted. Gradually, the belief became prevalent that imports of potash in 1919 would be small. This belief was supported by the reports of H. S. Gale and other Government officials, who visited the Alsatian mines in the early part of the year and stated that the mines were in a poor state of repair, that stocks were low, that production in the immediate future would be small, and that home consumption would absorb a large part of the output. Even the action of the War Trade Board in July in removing all restrictions on the importation of potash, including that from Germany, did not cause any large influx of the material. Consequently, prices were maintained at \$2 to \$2.75 a unit, and ready markets were found for the domestic output.

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[1] The assistance of Mrs. B. L. Thompson in the statistical work is gratefully acknowledged.

[2] Domestic potash production: Hearings before Committee on Mines and Mining, 65th Cong., 3d sess., on S. 5557, February, 1919; Potassium salts: Hearings before Committee on Ways and Means, on H. R. 4870, July, 1919.

DOMESTIC PRODUCTION.[2a]

The quantity of potash produced in 1919 fell far short of the production in 1918 and about equaled that of 1917, as is shown by the following table:

Domestic potash produced and sold in the United States in 1915–1919.

Year.	Number of plants.	Production.		Sales.		
		Crude potash (short tons).	Available content of potash (K_2O) (short tons).	Crude potash (short tons).	Available content of potash (K_2O) (short tons).	Value.
1915	5	4,374	1,090	4,374	1,090	$342,000
1916	70	35,739	9,720	35,739	9,720	4,242,730
1917	95	126,961	32,573	126,961	32,573	13,980,577
1918	128	207,686	54,803	140,343	38,580	15,839,618
1919 [a]	102	116,634	32,474	166,063	45,728	11,271,269

[a] Production for 1919 includes a quantity of material either utilized by producer or reported as not marketed; sales for 1919 include material produced in 1918 but sold in 1919.

The potash-bearing materials reported to the United States Geological Survey as produced in the United States in 1919 amounted to 116,634 short tons, having an approximate average content of potash (K_2O) of nearly 28 per cent. This was equivalent to a total content of 32,474 short tons of potash (K_2O). The sales in 1919 amounted to 45,728 short tons of potash (K_2O), including 16,223 short tons of potash (K_2O) produced in 1918 but held in storage, as noted on page 77 and as shown in the following table:

Potash held by producers in the United States at the end of 1918.

Source.	Stocks.	
	Crude potash (short tons).	Available content of potash (K_2O) (short tons).
Salines:		
Nebraska lakes	59,140	14,843
Other sources	1,541	543
Cement dust	1,480	183
Steffens waste water	5,145	632
Wood ashes	37	22
	67,343	16,223

The production of crude material from the alkali lakes of western Nebraska continued to exceed that from any other region or source, but more actual potash was produced from Searles Lake. At the beginning of 1919 about 20 plants in Nebraska were ready to operate, but only 10 of these reported production for the year.

At Searles Lake, Calif., the plants of the American Trona Corporation and the Solvay Process Co. were in operation practically the entire year. There were no other producers in this field, though the

[2a] The figures on domestic production and sales given here differ somewhat from those published in the advance chapter because additional data were received through the Bureau of the Census early in 1921, after the chapter had been published.

West End Consolidated Mining Co. was developing its process and plant.

The Utah-Salduro Co., at Salduro, Tooele County, Utah, utilizing the brines of the Salduro Marsh, successfully operated its plant and increased its former production several fold. The Bonneville Co. was reported to be erecting a plant at Wendover, near the Utah-Nevada line, for the utilization of brines from land adjoining that of the Utah-Salduro Co. The Diamond Potash Co., at Arinosa, east of Salduro, was also planning production from this region.

The Salt Lake Chemical Co., with factory at Burmester, continued production from the brines of Great Salt Lake, and the Salt Lake Potash Co., with factory at Kosmo, began production from the same source.

In the Marysvale region, Utah, the Mineral Products Corporation, one of the pioneer potash companies of the country, continued production from alunite in 1919, though the plant was in operation only part of the year. Some potash alum was produced by one company from alunite, and several companies are known to have shipped raw and calcined alunite either for experiments or for incorporation in fertilizers. The mill of the Florence Mining & Milling Co. was used by several companies for experimental purposes.

Silicate rocks as a possible source of potash continued to receive attention. The plant of the Liberty Potash Co., at Green River, Wyo., which utilized the potash-bearing rocks of the Leucite Hills, was completed during the year and operated for a short time in November and December but was closed on account of technical difficulties. A plant for the extraction of potash from greensand was constructed by the Eastern Potash Corporation on Raritan River near New Brunswick, N. J., but no production was reported. It was stated that experimental work on the extraction of potash from Georgia slates was successfully conducted, but that the unstable condition of the potash market prevented the commercial development of this project.

In the early part of 1919 eighteen cement mills had potash-recovery plants installed or under construction. Of this number 14 were in operation, several for only a part of the year. Several discontinued the production of potash at the end of the year.

A very small quantity of potash was produced from blast-furnace dusts.

Only two kelp plants other than the experimental plant of the Bureau of Soils, United States Department of Agriculture, at Summerland, Calif., reported production of potash in 1919. The Government plant, under the direction of J. W. Turrentine, has continued in operation and has extended its experiments to develop more efficient processes for the recovery of potash and of useful by-products such as active charcoal and iodine. The Bureau of Soils also made a survey of the occurrence of borax in potash materials. Its investigation of the quantity of potash that may be recoverable in the blast-furnace industry of the country was continued during part of the year but has not been completed.

Few developments have been recorded in connection with the production of potash from molasses-distillery waste, beet-sugar refineries, or wood ashes. No production from wool washings was reported for the year.

Of the total production of potash (K_2O) in 1919, natural brines from localities other than western Nebraska yielded 38.6 per cent; Nebraska brines, 27.9 per cent; Steffens waste water from sugar refineries, 11.1 per cent; molasses distillery waste, 8.9 per cent; alunite, 7.1 per cent; dust from cement mills, 3.8 per cent; wood ashes, 1.5 per cent; silicate rocks and dust from blast furnaces, 0.7 per cent; and kelp and miscellaneous industrial waste, 0.4 per cent.

Potash produced and sold[a] in the United States in 1919, classified according to sources.

Source.	Production.				Sales.[a]		
	Number of plants.	Crude potash (short tons).	Available content of potash (K_2O). Quantity (short tons).	Available content of potash (K_2O). Percentage of total.	Crude potash (short tons).	Available content of potash (K_2O) (short tons).	Value f. o. b. plant.
Mineral:							
Natural brines—							
Nebraska lakes	10	36,176	9,072	27.9	95,276	23,908	$5,240,352
Other brines	7	37,395	[b] 12,518	38.6	25,677	10,584	2,744,963
	17	73,571	21,590	66.5	120,953	34,492	7,985,315
Alunite	7	6,599	2,294	7.1	6,599	2,294	718,506
Dust from cement mills	14	11,665	1,258	3.8	13,115	1,439	311,365
Dust from blast furnaces and silicate rocks	8	2,408	221	.7	2,328	214	48,021
Organic:							
Kelp and miscellaneous industrial waste	4	370	134	.4	370	134	37,274
Molasses distillery waste	6	8,791	2,892	8.9	8,541	2,802	801,533
Steffens water from beet-sugar refineries	11	[c] 12,423	3,601	11.1	13,313	3,847	1,081,053
Wood ashes	35	807	484	1.5	844	506	288,202
	102	116,634	32,474	100.0	166,063	45,728	11,271,269

[a] Inclusive of material sold in 1919 but produced in 1918.
[b] Considerable material lost through accident to plant.
[c] A large part of this material is used privately.

Crude mixed salts made up 52.4 per cent of the potash (K_2O) which was produced in 1919 and sold; muriate, 34.1 per cent; sulphate, 8.0 per cent; dust from cement mills and blast furnaces, 2.3 per cent; and other materials, 3.2 per cent. The potash material produced in 1919 and marketed is classified in the following table according to the nature of the product:

Domestic potash produced and sold[a] in the United States in 1919, classified according to material marketed.

Material marketed.	Crude potash (short tons).	Available content of potash (K_2O). Percentage.	Available content of potash (K_2O). Quantity (short tons).	Available content of potash (K_2O). Percentage of total.
Crude mixed salts	55,821	8–44	15,470	52.4
Chloride (muriate)	22,750	35–60	10,056	34.1
Sulphate	4,883	37.5–52	2,375	8.0
Low-grade chloride	3,383	3–33	435	1.5
Dust from cement mills and blast furnaces	11,074	2.5–12.8	683	2.3
Caustic	319	70–80	252	.9
Crude carbonate	490	40–70	234	.8
	98,720	....	29,505	100.0

[a] Exclusive of material produced in 1918 but not sold until 1919.

California produced 42.4 per cent of the output in 1919; Nebraska, 29.9 per cent; Utah, 16.7 per cent; and other States, 11 per cent, as shown in the following table:

Potash produced in the United States in 1919, classified according to States.

State.	Number of plants.	Crude potash (short tons).	Available content of potash (K_2O). Quantity (short tons).	Percentage of total.
California	15	39,673	13,756	42.4
Nebraska	11	37,637	9,721	29.9
Utah	13	22,426	5,411	16.7
Colorado	3	3,777	1,678	5.2
Wisconsin	18	616	370	1.1
Pennsylvania	10	3,080	310	1.0
Michigan	18	666	166	.5
Other States [a]	14	8,759	1,062	3.2
	102	116,634	32,474	100.0

[a] Includes two plants in Maryland, and one each in Georgia, Illinois, Indiana, Iowa, Massachusetts, Missouri, New York, Ohio, Porto Rico, Tennessee, Washington, and Wyoming.

Refined potassium salts were manufactured in the United States by a number of firms, but the details of that manufacture are not contained in this report.

EXPORTS.

A comparatively small quantity of potash materials, including refined potassium salts, is exported from the United States, and data concerning these exports are meager. The available data on exports for 1919 are shown in the following table:

Potassium salts exported from the United States in 1918 and 1919.

Salt.	1918 Quantity (short tons).	1918 Value.	1919 Quantity (short tons).	1919 Value.
Chlorate	696	$534,491	991	$524,193
All other	....	837,679	....	2,231,351
	....	1,372,170	....	2,755,544

IMPORTS.

Prior to 1913 the United States imported annually more than 250,000 tons of potash (K_2O) from Germany. This source of supply was cut off entirely during the recent war, and imports declined to less than 8,000 tons annually. France gained control of the Alsatian potash mines and shipped some potash to the United States in 1919, but not nearly as much as had been anticipated, because of the condition of the mines and of difficulties in transportation and labor. In July the War Trade Board removed restrictions on the importation of German potash, and in September it began to come into this country. But the imports from Germany were small, as stocks were low, especially of muriate, transportation facilities were inadequate, labor was unreliable, and the coal situation was unfavorable. The potash imported and entered for consumption in the United States from 1913—the last normal year prior to the war—to 1919 is shown in the following table:

Potash materials imported and entered for consumption in the United States, 1913–1919.[a]

Material.	Approximate potash (K_2O) content (per cent).	1913				1914				1915			
		Quantity (short tons).	Available content of potash (K_2O).		Value.	Quantity (short tons).	Available content of potash (K_2O).		Value.	Quantity (short tons).	Available content of potash (K_2O).		Value.
			Quantity (short tons).	Percentage of total.			Quantity (short tons).	Percentage of total.			Quantity (short tons).	Percentage of total.	
Kainite	12.4	521,176	64,626	23.9	$2,201,730	351,566	43,594	21.0	$1,551,115	7,475	927	1.9	$95,440
Manure salts	20.0	250,529	50,106	18.5	2,245,509	189,245	37,849	18.3	1,846,475	15,403	3,081	6.3	200,584
Muriate	50.0	237,630	118,815	43.8	7,075,745	185,761	92,881	44.9	5,745,385	64,670	32,335	66.2	2,296,606
Sulphate	48.6	44,349	21,554	8	1,677,429	40,224	19,554	9.4	1,557,224	12,708	6,176	12.6	664,484
Total[b]		1,053,684	255,101	94.2	13,200,413	766,796	193,878	93.6	10,700,199	100,256	42,519	87.0	3,257,114
Bicarbonate	46.0	223	103		20,968	169	78		16,030	132	61	.1	14,456
Bitartrate (argol)	20.0	14,499	2,900	1.1	2,779,180	13,664	2,733	1.4	3,016,073	8,339	1,668	3.4	2,132,276
Bitartrate (cream of tartar)	25.0	75	19		28,314	590	148	.1	234,657	123	31	.1	60,869
Carbonate, crude	61.0	4,858	2,963	1.1	272,973	4,663	2,844	1.4	265,158	2,693	1,643	3.4	191,621
Carbonate, crude black salts	50.0	344	172	.1	17,852	1,284	642	.3	44,086	2,074	1,037	2.1	98,409
Carbonate, refined	67.0	6,145	4,117	1.5	393,284	3,371	2,259	1.1	224,384	622	417	.9	60,491
Caustic	80.0	4,324	3,459	1.3	342,056	3,642	2,914	1.4	285,739	1,016	813	1.7	100,035
Chlorate	38.0	596	226	.1	64,468	13	5		2,235	8	3		3,666
Chromate and bichromate	40.0	9	4		1,819	15	6		2,375	16	6		2,902
Cyanide	70.0	735	514	.2	216,844	209	146	.1	59,278	436	305	.6	134,123
Ferricyanide (red prussiate)	42.0	34	14		12,035	40	17		14,446	26	11		9,044
Ferrocyanide (yellow prussiate)	44.0	1,706	751	.3	388,379	1,522	670	.3	334,592	558	246	.5	124,382
Iodide	28.0					c 270	c 76		491	c 4	c 1		13
Nitrate (saltpeter), crude	40.0	4,826	193	.1	261,078	1,115	446	.2	74,869	3	1		400
Nitrate (saltpeter), refined	46.0	203	93		22,602	135	62		15,062				
Permanganate	29.0	273	79		38,188	746	216	.1	102,619	315	91	.2	64,592
Rochelle salt	22.0	54	12		13,412	113	25		29,318	69	15		3,955
Total[d]		38,904	15,619	5.8	4,873,452	31,291	13,211	6.4	4,721,412	16,430	6,348	13.0	3,001,234
Grand total		1,092,588	270,720	100.0	18,073,865	798,087	207,089	100.0	15,421,611	116,686	48,867	100.0	6,258,348

a The figures in this table were compiled from the records of the Bureau of Foreign and Domestic Commerce, United States Department of Commerce, by recalculation to short tons and to actual potash (K_2O) and by giving the totals for calendar years instead of fiscal years. The tons are calculated to the nearest even unit and the values are those given in the original records, so that the value given for a high-priced commodity received in small quantity may not be strictly applicable to the quantity given. For instance, 2,705 pounds of cyanide received in 1916 is reported as 1 ton, but the value given is that of the actual quantity received. Furthermore the values are those placed on the commodities by the shippers, and represent the values at point of shipment and do not agree with market quotations in this country.

b Used principally in fertilizers. c Pounds. d Used principally in chemical industries.

Material.	Approximate potash (K_2O) content (per cent).	1916				1917			
		Quantity (short tons).	Available content of potash (K_2O).		Value.	Quantity (short tons).	Available content of potash (K_2O).		Value.
			Quantity (short tons).	Percentage of total.			Quantity (short tons).	Percentage of total.	
Kainite	12.4	40	5	0.1	$1,173	....	....	....	....
Manure salts	20.0	1,241	248	3.1	21,273	252	50	0.6	$9,047
Muriate	50.0	1,299	650	8.3	348,961	683	342	4.2	158,410
Sulphate	48.6	1,693	823	10.4	81,684	230	112	1.4	21,702
Total [a]	....	4,273	1,726	21.9	453,091	1,165	504	6.2	189,159
Bicarbonate	46.0	2	1	....	1,133	76	35	.4	71,975
Bitartrate (argol)	20.0	14,943	2,989	37.9	5,021,291	14,277	2,855	35.2	4,740,912
Bitartrate (cream of tartar)	25.0	48	12	.2	29,213	48	12	.2	25,434
Carbonate, crude	61.0	341	208	2.6	113,413	2,967	1,810	22.4	1,042,639
Carbonate, crude black salts	50.0	1,081	541	6.9	109,121	903	452	5.6	220,403
Carbonate, refined	67.0	76	51	.7	40,496	222	149	1.9	121,111
Caustic	80.0	24	19	.2	16,694	35	28	.4	29,308
Chlorate	38.0	5	2	....	7,167	503	191	2.4	404,783
Chromate and bichromate	40.0	[b] 459	[b] 184	....	75	1	[b] 800	....	962
Cyanide	70.0	1	1	....	803	35	25	.3	49,608
Ferricyanide (red prussiate)	42.0	2	1	....	6,952	5	2	....	18,262
Ferrocyanide (yellow prussiate)	44.0	25	11	.1	45,497	39	17	.2	57,897
Iodide	28.0	5	1	....	26,578	15	4	....	66,823
Nitrate (saltpeter), crude	40.0	5,769	2,308	29.3	1,519,375	4,606	1,842	22.7	669,044
Nitrate (saltpeter), refined	46.0	2	1	....	771	368	169	2.1	50,606
Permanganate	29.0	45	13	.2	33,728	5	1	....	21,462
Rochelle salt	22.0	....	....	....	....	17	4	....	8,018
Total [c]	....	22,369	6,159	78.1	6,972,307	24,122	7,596	93.8	7,599,247
Grand total	....	26,642	7,885	100.0	7,425,398	25,287	8,100	100.0	7,788,406

[a] Used principally in fertilizer. [b] Pounds. [c] Used principally in chemical industries.

Potash materials imported and entered for consumption in the United States, 1913–1919—Continued.

Material	Approximate potash (K_2O) content (per cent).	1918				1919			
		Quantity (short tons).	Available content of potash (K_2O).		Value.	Quantity (short tons).	Available content of potash (K_2O).		Value.
			Quantity (short tons).	Percentage of total.			Quantity (short tons).	Percentage of total.	
Kainite	12.4					57,427	7,121	18	$921,481
Manure salts	20.0					45,372	9,074	22.9	1,269,750
Muriate	50.0	424	212	2.7	$102,109	23,202	11,601	29.2	1,783,916
Sulphate	48.6	101	49	.6	15,329	1,415	688	1.8	188,592
Total *a*		525	261	3.3	117,438	127,416	28,484	71.9	4,163,739
Bicarbonate	46.0	36	17	.2	34,279	24	11		8,921
Bitartrate (argol)	20.0	14,041	2,808	35.3	4,782,267	12,904	2,581	6.5	4,311,610
Bitartrate (cream of tartar)	25.0	7	2		3,355	12	3		10,879
Carbonate, crude	61.0	4,297	2,621	32.9	2,273,202	258	157	.4	104,744
Carbonate, crude black salts	50.0	228	114	1.5	47,956	102	51	.2	10,075
Carbonate, refined	67.0	104	70	.9	65,974	23	15		9,665
Caustic	80.0					242	194	.5	134,166
Chlorate	38.0	355	135	1.7	248,160	100	38	.1	34,996
Chromate and bichromate	40.0	*b* 20	*b* 8		8	8	3		4,271
Cyanide	70.0	12	8	.1	10,278	588	412	1.1	68,848
Ferricyanide (red prussiate)	42.0	8	3		29,201	17	7		18,096
Ferrocyanide (yellow prussiate)	44.0	65	29	.4	112,729	258	108	.3	122,372
Iodide	28.0	32	9	.1	142,324	9	3		54,250
Nitrate (saltpeter), crude	40.0	4,672	1,869	23.5	906,549	18,826	7,530	19.0	1,107,313
Nitrate (saltpeter), refined	46.0	2	1		730	37	17		8,171
Permanganate	29.0	27	8	.1	128,438	2	1		10,163
Rochelle salt	22.0	8	2		4,948	20	4		9,537
Total *c*		23,894	7,696	96.7	8,790,398	33,430	11,135	28.1	6,028,077
Grand total		24,419	7,957	100.0	8,907,836	160,846	39,619	100.0	10,191,816

a Used principally in fertilizers. *b* Pounds. *c* Used principally in chemical industries.

The following tables represent in terms of K_2O approximately the total imports of potash for consumption in the United States during recent years. For the years 1905 to 1912, inclusive, they have been compiled from a report on the fertilizer industry prepared by the Federal Trade Commission,[3] recalculated from metric to short tons, and for the years 1913 to 1919 they have been calculated from the preceding table of imports compiled from the records of the Bureau of Foreign and Domestic Commerce, United States Department of Commerce.

Potash (K_2O) imported for consumption in the United States, 1905–1919.

	Short tons.		Short tons.		Short tons.
1905	129,084	1910	279,780	1915	48,867
1906	155,974	1911	274,446	1916	7,885
1907	144,351	1912	253,678	1917	8,100
1908	136,057	1913	270,720	1918	7,957
1909	173,220	1914	207,089	1919	39,619

Until 1915 practically all the potash brought into this country came from Germany; from 1916 to 1919 it came from many different countries, during 1919 principally from Germany, France, Chile, Holland, and Belgium, though that from Holland and Belgium doubtless originated in Germany and France. Unfortunately there is no authentic information at hand concerning the original source of the shipments. The potash imported by the United States in 1919 from various countries is shown in the following table:

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[3] Report on the fertilizer industry, 1916, p. 115

Potash materials imported into the United States in 1919, in short tons.[a]

Country.	Manure salts.		Kainite.		Muriate.		Sulphate.		Bitartrate (argol).		Carbonate.		Cyanide.		Nitrate.		Hydrate.		All others.		Total quantity.		Percentage of total.
	Quantity.	Content of potash (K_2O) (20 per cent).	Quantity.	Content of potash (K_2O) (12.4 per cent).	Quantity.	Content of potash (K_2O) (50 per cent).	Quantity.	Content of potash (K_2O) (48.6 per cent).	Quantity.	Content of potash (K_2O) (20 per cent).	Quantity.	Content of potash (K_2O) (61 per cent).	Quantity.	Content of potash (K_2O) (70 per cent).	Quantity.	Content of potash (K_2O) (40 per cent).	Quantity.	Content of potash (K_2O) (80 per cent).	Quantity.	Content of potash (K_2O) (50 per cent).	Quantity.	Content of potash (K_2O).	
Belgium	14,102	2,820	11,038	1,369	1,384	692	32	16											11	5	26,567	4,902	12.4
France	12,242	2,448	9,759	1,210	5,022	2,511			3,922	785									27	14	30,972	6,968	17.6
Germany	13,039	2,608	17,737	2,199	14,237	7,119													23	11	45,036	11,937	30.1
Greece									162	32											162	32	
Italy									1,422	285							221	177			1,643	462	1.2
Netherlands	5,846	1,169	18,893	2,343	1,726	863	1,232	599			22	13	1	1					137	69	27,857	5,057	12.8
Norway															lbs. 220				13	6	13	6	
Portugal									1,834	367											1,834	367	1.0
Spain									3,357	671											3,357	671	1.7
Sweden																	20	16	89	45	109	61	0.2
Turkey in Europe											36	22							11	5	47	27	
England	112	22			1				16	3			3	2	586	234			42	21	760	282	0.7
Scotland	2	1							11	2											13	3	
Canada	29	6					2	1	10	2	lbs796		584	409	lbs. 336				2	1	627	419	1.0
Panama									3	½											3	½	
Mexico															34	14					34	14	
Cuba															8	3					8	3	
Argentina									823	165											823	165	0.4
Chile									181	36					14,824	5,930					15,005	5,966	15.0
Colombia											1	1									1	1	
Peru									5	1											5	1	
China							27	13			23	14									50	27	
British India											112	68			3,038	1,215			23	12	3,173	1,295	3.3
Dutch East Indies											102	62									102	62	0.2
Hongkong											4	2									4	2	
Japan					280	140	122	59			45	28					1	1	79	40	527	268	0.7
Philippine Islands											37	23									37	23	
British South Africa									2	½											2	½	
French Africa									1,120	224											1,120	224	0.6
Italian Africa					552	276															552	276	0.7
Portuguese Africa															336	134					336	134	0.4
	45,372	9,074	57,427	7,121	23,202	11,601	1,415	688	12,868	2,574	382	233	588	412	18,826	7,530	242	194	457	229	160,779	39,656	100

a The figures in this table were compiled from the records of the Bureau of Foreign and Domestic Commerce, United States Department of Commerce, by recalculation to short tons and to actual potash (K_2O) and by giving the totals by the calendar year instead of the fiscal year. The tons are calculated to the nearest even unit. The data present general imports and include imports both for immediate consumption and those going to warehouses, which may or may not be entered for consumption during the year. They differ slightly from the figures in the preceding table of imports, which represents imports for consumption.

FOREIGN PRODUCTION.

Formerly Germany produced almost the entire world's supply of potash, about 95 per cent of the output coming from the mines at Stassfurt and about 5 per cent from the mines in Alsace. Practically normal production (about 1,000,000 metric tons of K_2O) was maintained by Germany throughout the war, and, according to figures by Edwards,[4] the total production of actual potash in 1919 from the mines at Stassfurt was 946,000 short tons, or 858,439 metric tons (K_2O). The output from the Alsatian mines in 1919 was 96,546 tons (probably metric).[5] The combined output from Germany and France was therefore 954,985 metric tons. The combined output from the German and Alsatian mines during recent years is shown in the following table:

Potash (K_2O) produced by the German and Alsatian mines, 1880–1919.[6]

	Metric tons.		Metric tons.		Metric tons.
1880	68,550	1911	939,927	1916	883,976
1890	122,302	1913	1,110,369	1917	1,004,281
1900	303,610	1914	903,988	1918	[7] 1,003,000
1910	857,883	1915	679,776	1919	[8] 954,985

The separation of Alsace from Germany broke the monopoly in the potash industry which Germany had theretofore held, and in this connection the shipments of potash salts from Africa and Chile (see table, p. 86) are of interest.

PATENTS FOR PROCESSES OF EXTRACTING POTASH FROM SILICATE ROCKS.

The processes of extracting potash from silicate rocks are best represented by patents that have been granted. Actual tests of a few of the proposed processes have been made, and the results have been discussed in the technical journals. Any one of these processes that may be put into actual use will doubtless be modified through the experience gained in its practical operation. The patents listed below are arranged in numerical order. Printed copies of these patents may be obtained from the United States Patent Office for 5 cents each. (See also the chapter on potash in Mineral Resources, 1918.)

United States patents issued in 1918 and 1919 for processes of extracting potash from silicate rocks.

1283951, Nov. 5, 1918, Stover, J. H. Feldspar or similar potash-bearing mineral is finely ground, mixed with an alkali, carbonate, hydroxide, or oxide, and fused at a red heat, and the soluble potash is leached out with water. The residue is then treated with acid to dissolve the remaining potash.

1286513, Dec. 3, 1918, Blumenberg, H., jr. Feldspar is mixed with powdered limestone and with acid sludge from petroleum refining, and the mixture is heated to 700°–1,000° C. to produce K_2SO_4.

1286718, Dec. 3, 1918, Morse, H. N. Feldspar or other potash-bearing silicate which has previously been treated with caustic alkali is heated to 250° C. in a current of SO_2 gas to produce K_2SO_3, which is then oxidized by the air to K_2SO_4.

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[4] Edwards, P. V., Commerce Repts., Feb. 11, 1920, p. 835. The New York representative of the German Kali Works in a letter gives the German production in 1919 as 895,078 short tons of K_2O.

[5] Prosser, W. L., Commerce Repts., July 16, 1920, p. 308.

[6] Figures, except for 1918 and 1919, taken from U. S. Geol. Survey Mineral Resources, 1918, pt. 2, p. 417, 1920.

[7] Standard Daily Trade Service, Mar. 15, 1920; Board of Trade Jour., Mar. 18, 1920, p. 406.

[8] Commerce Repts., Feb. 11, 1920, p. 835; July 16, 1920, p. 308.

1289736, Dec. 31, 1918, Grauel, A. Feldspar or similar potash-bearing silicate is heated with $CaCl_2$ or $CaSO_4$, and the fumes are absorbed in a preheated solution maintained under pressure.

1289789, Dec. 31, 1918, Jackson, L. L. Feldspar is digested with milk of lime for 10 hours at 95°, and the solution is heated with CO_2 and evaporated to dryness.

1292929, Jan. 28, 1919, Tschirner, F. Glauconite is mixed with "lime sand" and NaCl, and the mixture is finely ground and heated to 800° C. in a rotary kiln. The mixture is further heated in a muffle and dropped into a "soaking pit," where it is allowed to remain to permit the completion of reactions. The product is then leached with water and KCl is obtained by crystallization.

1295601, Feb. 25, 1919, Richardson, W. D. Feldspar, mica, leucite, or similar materials are mixed with CaF_2 or other fluoride and H_2SO_4; the mixture is allowed to react and is finally dried to form a suitable ingredient for fertilizers.

1296035, Mar. 4, 1919, Andrews, A. B. Feldspar and caustic lime are introduced into a digester at one end of a series and treated with liquor from a preceding digester, a counter-current principle being used in the operation.

1296141, Mar. 4, 1919, Von Kolnitz, G. F. Potash-bearing material, such as glauconite, is heated to about 350° C. and then subjected to the action of HCl gas to produce KCl, which is recovered by leaching.

1296457, Mar. 4, 1919, Blumenberg, H., jr. Finely ground feldspar, gypsum, and acid sludge from petroleum refining are mixed and heated for several hours to 700°–800° C. to form potash alum and aluminum sulphate. The temperature is then raised to 800°–1,000° C. to produce K_2SO_4, which is recovered by leaching.

1296458, Mar. 4, 1919, Blumenberg, H., jr. Finely ground feldspar is mixed with lead nitrate and fused, producing a complex lead-potassium-aluminum silicate. The product is treated with HNO_3 and dehydrated, and potassium nitrate is leached out with water and separated by crystallization.

1296459, Mar. 4, 1919, Blumenberg, H., jr. Finely ground feldspar is fused in a closed retort, and the melt is pulverized, mixed with water, and treated with SO_2 gas to form sodium and potassium sulphites, which are recovered by leaching.

1297078, Mar. 11, 1919, Brookby, H. E. Potash-bearing clay, shale, slate, or other hydrous silicates are mixed with NaCl and limestone, and the mixture is heated to 800°–1,000° C. for one hour, the sinter leached, and the potash obtained by evaporation and crystallization.

1297640, Mar. 18, 1919, Blumenberg, H., jr. Feldspar, cement dust, phonolite, lepidolite, or similar materials are calcined at about 815° C., dropped into water, ground to 100–200 mesh, and then heated to about 535° C. with $NaNO_3$. KNO_3 is extracted from the product by boiling with water under a pressure of four or five atmospheres.

1309744, July 15, 1919, Peacock, B. A. Greensand is heated with KOH or K_2CO_3 to produce potassium zeolites, which are then treated with $Ca(OH)_2$ and water and boiled, the potassium being thus converted to KOH.

1310413, July 22, 1919, Eberhardt, L. A. Sericite, feldspar, or other potash-bearing silicate is ground to about 100 mesh and mixed with CaF_2 and $CaSO_4$, and the mixture is calcined at a red heat in a rotary kiln. The calcined product is digested with H_2SO_4 at a temperature of 150°–300° C., and potash alum and aluminum sulphate are obtained from the residue by leaching, evaporation, and fractional crystallization. Silicofluorides are obtained as by-products.

1310770, July 22, 1919, Peacock, B. A. Potash-bearing silicates, such as feldspar, leucite, or glauconite, are mixed with serpentine rock or other magnesium silicate and H_2SO_4 and the temperature is raised to 200° C. After standing from 24 to 48 hours the mass is digested with water, and a double sulphate of potassium and magnesium is obtained by crystallization.

1312053, Aug. 5, 1919, Scholes, S. R. Ground feldspar and Na_2CO_3 or K_2CO_3 are fused, and the melt is poured into water, pulverized, and heated with water under pressure to about 160° C., the alkali being thus rendered soluble. The solution obtained is a water glass, which may be converted to carbonate by treatment with CO_2.

1312592, Aug. 12, 1919, Spencer, A. C. Feldspar, nephelite or syenite, and limestone or similar mixtures are heated under conditions to produce a potash-bearing fume and clinker nodules. The clinker is then disintegrated and further heated to fume off additional potash compounds, which are recovered.

1317524, Sept. 30, 1919, Robertson, F. D. S. Ground feldspar, mica, leucite, etc., are heated with a solution of H_3PO_4, and the soluble constituents are extracted and recovered as sulphate or other salt, the phosphoric acid also being recovered.

1320193, Oct. 28, 1919, Ashcroft, E. A. Feldspar or similar potash-bearing material is treated with chlorin gas in the presence of a catalyzer while suspended in a fused medium and is then lixiviated with water to recover the potassium salt.

1320211, Oct. 28, 1919, Edwards, R. S. Finely crushed feldspar or similar material is mixed with at least 60 per cent of sodium chloride. Hydrated lime or hydromagnesite is added and the mixture fused. Steam is formed and dissociated, and the hydrogen thus produced combines with the chlorin of the salt to produce HCl and potassium chloride.

1320212, Oct. 28, 1919, Edwards, R. S (an improvement on 1320211). The kiln product discharges into water, which is thus kept at boiling temperature.

1322900, Nov. 25, 1919, Hart, E. Greensand is cleaned and powdered, then mixed with sulphuric acid and allowed to stand several hours, after which it is heated to about 600°. The heated material is quenched with water and kept damp for several weeks. The mass is then lixiviated with boiling water, which dissolves out the soluble salts of aluminum and potash and any magnesium sulphate present.

1323228, Nov. 25, 1919, Hart, E. The metal compounds of greensand, marl, or glauconite are so treated as to produce an iron-free solution of chlorides, the calcium and aluminum being precipitated and removed separately and the remaining solution containing potassium compounds being concentrated.

1323464, Dec. 2, 1919, Glaeser, W. Potassium-bearing silicates are heated to redness, suddenly cooled, powdered, mixed with powdered pyrites, and then burned in the presence of air and steam at a temperature above 900° to produce potassium sulphate.

1323764, Dec. 2, 1919, Hauber, M., jr. Greensand is intimately mixed with about 30 per cent of its own weight of $FeSO_4$ in solution, and the mixture is heated to a temperature sufficient to decompose the $FeSO_4$ and convert a large portion of the potassium and aluminum in the greensand into sulphates.

1325713, Dec. 23, 1919, Chaplin, E. D. The mica from which K is to be removed is fused with KOH in excess of the amount of K in the mica. The melt is cooled and treated with water, and the resulting solution is subjected to the action of CO_2 to produce K_2CO_3.

1325881, Dec. 23, 1919, Rody, F. A. Leucite is first fused, then the K content of the material is replaced by Na by digesting the fused product under pressure with a solution of sodium salts.

1325882, Dec. 23, 1919, Rody, F. A. Leucite or similar material is fused and the fused product digested in a solution containing sodium or potassium salts to effect replacement of potassium by sodium in the fused leucite and a corresponding enrichment of the solution in potassium.

1326412, Dec. 130, 919, Meadows, T. C., and Sample, F. L. In the digestion of lime, water, and feldspar or similar potassiferous material under pressure with lime and water the mixtures are continuously forced through a pipe coil in which the appropriate temperature and pressure are maintained.

14773, Dec. 23, 1919, Ellis C. Reissue. Cement and potassium compounds from feldspar and lime. (See original patent 1186522.)

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STRONTIUM.

By George W. Stose.

GENERAL CONDITIONS.

No domestic strontium ore was mined or sold in the United States in 1919, so far as the records of the United States Geological Survey show. Crude ore was imported from England by manufacturers of strontium salts, and some manufactured salts were also imported. Strontium nitrate and strontium carbonate were the chief chemicals made.

PRODUCTION OF CRUDE ORE.

Strontium ore was first mined in quantity in the United States in 1916, when, under the stimulus of high prices and war needs, 250 short tons of ore was produced and marketed. In 1917 a total of 4,035 tons of domestic ore was marketed, but in 1918 the quantity marketed declined to 400 tons, and in 1919 there was no production. Ore produced in 1916 and 1917, which was chiefly celestite (strontium sulphate), came from California, Arizona, Texas, and Washington, and at this time three factories began to make strontium salts in the far West to replace the chemicals formerly made in the eastern States from foreign ore, which was not obtainable during the war. Some western ore was sent to eastern factories also during this period. After the war ended English celestite was again freely imported, and the eastern factories, having the advantages of cheap sea transportation for raw materials and of nearness to market for manufactured products, immediately absorbed all the trade, and the western factories went out of business. The mining of domestic ore, the workable deposits of which are all in the far Western States, also ceased, and will probably not be revived unless the refining of sugar by the strontium process is adopted in the beet-sugar industry of the West.

Crude domestic strontium ores produced and marketed in the United States, 1916–1919.

Mineral.	1916		1917		1918		1919	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
Celestite	240	(a)	3,630	$72,285	0	0	0	0
Strontianite	10	(a)	405	15,415	400	$20,000	0	0
	250	$3,650	4,035	87,700	400	20,000	0	0

a Figures not available.

PRODUCTION OF STRONTIUM SALTS.

Strontium salts were made in the United States in 1919 from imported crude ore in four plants in four States—New Jersey, Pennsylvania, New York, and Missouri. Some strontium salts were also made in other factories, but as these compounds were manufactured from strontium salts bought in open market, and not from crude ore, they are not included in these statistics. The industry centered chiefly around the ports of Philadelphia and New York, where foreign ore can be had cheaply.

In 1919 four factories used 1,393 short tons of English celestite, imported at an average price of $22.75 a ton, in the manufacture of 1,607,430 pounds of strontium salts. Strontium nitrate, most of which was used in pyrotechnics and signal lights, was the chief product, but some chemically pure nitrate was made for pharmaceutical purposes. Strontium carbonate was also made in quantity; most of it was used in the same factory in making other salts, but some was sold for experimental use in refining sugar by a process extensively used in Europe. Bromide, chloride, hydroxide, sulphate, iodide, and salicylate were also reported made from strontium carbonate obtained from celestite in the same factory.

The strontium salts made from crude ore and marketed in 1919 amounted to much less than was manufactured and marketed in 1918, the last year of the war, but about the same as was marketed in 1916, earlier in the war.

Strontium salts manufactured from domestic and imported crude ore in the United States and marketed in 1916–1919, in pounds.

1916	2,006,000	1918	4,927,000
1917	2,499,676	1919	2,191,409

IMPORTS.

The 1,393 short tons of crude celestite imported from England in 1919 was about half as much as was imported in 1918 and less than was imported in several preceding years. The average price paid was $22.75 a ton. The details of importation can not be given without divulging confidential information.

As a record of the importation of only those strontium salts that are duty free (carbonate and oxide) is kept at the ports of entry, the salts that are dutiable, such as strontium nitrate, are not included in the following table. The strontium salts reported to have been imported in 1919 were valued at more than the imports in 1918 but much less than the imports during the earlier years of the war.

Value of strontium carbonate and strontium oxide[1] imported for consumption in the United States, 1895–1919.

1895–1913 (average)	$447	1917	$23,216
1914	1,016	1918	2,459
1915	6,411	1919	3,380
1916	11,049		

[1] Value of "oxide of strontium, protoxide of strontium, and strontianite or mineral carbonate of strontium" imported for consumption in the United States, compiled from the records of the Bureau of Foreign and Domestic Commerce.

PRICES.

The following table gives the prices of strontium salts commonly made from celestite:

Prices of strontium nitrate and strontium carbonate in New York, 1914–1919, in cents per pound.[a]

Salt.	1914	1915	1916	1917	1918	1919
Strontium nitrate	7¼–8	15–17	22–23	40–45	25–30	25–30
Strontium carbonate:						
Technical	(b)	(b)	(b)	(b)	40–45	40–45
Chemically pure	(b)	(b)	(b)	(b)	55–60	55–60

a Oil, Paint, and Drug Reporter Yearbook, 1919. b Not quoted prior to 1918.

The high price of strontium nitrate in 1917 was due to the greatly increased use of this chemical in making signal lights and shells for war purposes and red flares and signal lights employed in the transportation of war materials.

The following price list of strontium compounds, quoted for the reader's convenience, includes many salts not made directly from crude ore or its immediate derivatives in the same factory, and therefore not directly concerned with the subject of this chapter. Many of these salts are used largely for pharmaceutical purposes.

Price per pound of strontium salts.[2]

Acetate, granular	$1.20
Arsenite, powder	2.75
Bromide, crystalline, and granular	.86
Bromide, dried, powder	1.50
Carbonate, precipitate, pure powder	.65
Chloride, granular	.45
Chloride, dried, powder	.75
Chloride, crystalline, chemically pure	.87
Iodide, fused	$4.75
Lactate, powder	2.65
Nitrate, granular	.60
Oxalate, powder	1.70
Peroxide (dioxide), powder	3.07
Phosphate, powder	1.25
Salicylate, powder	.90
Sulphate, powder	.96

USES AND MARKET.

Strontium salts are used chiefly in the manufacture of fireworks, signal lights, and medicines. Strontium nitrate and some strontium carbonate are used in the production of red fire or light in pyrotechnics, flares, fusees, signal shells, and signal lights. Bromide, nitrate, carbonate, chloride, hydroxide, sulphate, iodide, salicylate, and other salts of strontium were manufactured in 1919 from crude ore, or from simple salts derived therefrom, for use in drugs, chemicals, and medicines. A little strontium is alloyed with copper in making castings to harden it and to free it from blowholes caused by included gases. The alloy is obtained either by adding to the melt a small amount of metallic strontium or by the electrolysis of fused strontium chloride or other strontium salt, using a molten copper cathode. The small per cent of strontium required does not materially change the electric conductivity of the copper. In Europe large quantities of oxide and hydroxide of strontium are used in re-

[2] Powers, Weightman & Rosengarten Co., Philadelphia, price list, Sept. 1, 1920.

fining beet sugar, but the process is not at present employed commercially in the United States, although some domestic strontium salts were recently used experimentally in Canada in refining sugar. Should these experiments lead to the general adoption of strontium salts in the refining of beet sugar in the United States and Canada, not only will the manufacture of strontium chemicals be stimulated but the mining of strontium ore will be revived on a much larger scale than previously.

Fireworks and signal lights are manufactured in the United States almost exclusively near the Atlantic seaboard, and the demand for crude ore is therefore at present in the Eastern States. It has consequently been difficult to find a market for the strontium ore mined in the far West, which, because of high freight charges, can not in normal times compete in price in the eastern markets with the celestite obtained from England.

DEPOSITS OF STRONTIUM ORE IN THE UNITED STATES.

The known workable deposits of strontium ore in this country are in Arizona, California, Texas, Utah, and Washington. Other deposits of doubtful value occur in several other of the Western States and in a few States east of Mississippi River. Most of these have been described in some detail by James M. Hill in Mineral Resources of the United States, 1916, Part II, to which the reader is referred. Newly discovered deposits were described in Mineral Resources for 1918, Part II. Another deposit in Washington, recently reported by H. B. Brown, of Edmunds, in Whatcom County, just above the gorge of Skagit River near the mouth of Ruby Creek, and is reported to be extensive and of good grade.

GYPSUM.

By R. W. Stone.[1]

PRODUCTION.

Gypsum was mined in the United States in almost continuously increasing quantity for many years up to 1917, when there began a decrease in production that amounted to three-fourths of a million tons in two years, the production in 1918 being the lowest recorded since 1908. In 1919, however, the quantity mined was 2,420,163 short tons, an increase of 18 per cent over the output in 1918. A similar increase in 1920 would make the production of crude material greater than in any preceding year.

Crude gypsum mined in the United States, 1908–1919, in short tons.

1908	1, 721, 829	1912	2, 500, 757	1916	2, 757, 730
1909	2, 252, 785	1913	2, 599, 508	1917	2, 696, 226
1910	2, 379, 057	1914	2, 476, 465	1918	2, 057, 015
1911	2, 323, 970	1915	2, 447, 611	1919	2, 420, 163

The total value of the crude and calcined domestic gypsum sold in the last 12 years has increased greatly and in each of the last 4 years has been successively greater than ever before; in 1919 it was $15,727,907, an increase of more than $4,000,000, or 37 per cent over the total value in 1918.

Value of crude and calcined gypsum produced in the United States, 1908–1919.

1908	$4, 075, 824	1912	$6, 563, 968	1916	$7, 959, 032
1909	5, 906, 738	1913	6, 774, 822	1917	11, 116, 452
1910	6, 523, 029	1914	6, 895, 989	1918	11, 470, 854
1911	6, 462, 035	1915	6, 596, 893	1919	15, 727, 907

This considerable increase in total value is accounted for by the increase in quantity of material produced and also by the higher prices resulting from increased cost of production, including higher wages and higher cost of all supplies.

In comparison with 1918 the gypsum industry was in a particularly healthy condition. In 1918 in the principal producing States there was a decrease in quantity mined ranging from 12 to 39 per cent, and in five out of eight States there was a decrease in value. In 1919, however, in each of the nine principal producing States there was an increase in value and in all but one an increase in quantity.

[1] The statistical tables in this report were prepared by Miss K. W. Cottrell, of the United States Geological Survey, who succeeds Miss L. M. Jones, previously in charge of the work. The tables relating to imports and exports were compiled by J. A. Dorsey from records of the Bureau of Foreign and Domestic Commerce.

Increase or decrease in gypsum mined in the principal States in 1919, in per cent.

State.	Increase or decrease in quantity mined.	Increase in value.	State.	Increase or decrease in quantity mined.	Increase in value.
Iowa	+28	35	Ohio	+26	65
Kansas	+43	51	Oklahoma	− 9	11
Michigan	+18	36	Texas	+12	29
Nevada	+22	60	Wyoming	+22	45
New York	+11	32			

This table shows that the rising tide of both production and prices was strong and, with a continuation of the same or better conditions in 1920, indicates increase in the popularity of gypsum products and an early return to much better business conditions than those that have been experienced in recent years. In the following table the production in 1918 and 1919 is compared. The production of several States, in each of which there are less than three producers, is grouped to avoid revealing confidential information. In only one State (Virginia) among the States whose returns in 1919 are not shown separately was the production greater than 32,000 tons of crude rock mined, and in only two States was the production less than 10,000 tons.

Gypsum produced and sold in the United States, 1918 and 1919, by States.

State.	Number of plants reporting.	Total quantity mined (short tons).	Sold without calcining.				Sold as calcined plaster.		Total value.
			Agricultural gypsum.		For Portland cement, paint, and other purposes.				
			Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	
1918.									
Arizona, California, Colorado, Montana, Nevada, New Mexico, Oregon, South Dakota, Utah, Virginia [a]	18	331,395	40,428	$159,215	71,596	$168,082	208,763	$1,515,150	$1,842,447
Iowa	5	327,927	10,546	37,823	47,173	122,325	218,178	1,786,266	1,946,414
Kansas	3	54,958	(b)	(b)	(b)	(b)	[b] 46,710	[b] 343,749	343,749
Michigan	8	286,768	5,892	23,876	40,716	107,562	207,059	1,629,711	1,761,149
New York	6	531,038	3,139	14,552	179,968	442,087	275,333	2,213,460	2,670,099
Ohio	4	199,456	4,391	19,277	9,614	29,295	162,626	1,191,077	1,239,649
Oklahoma	4	126,208	....	....	35,211	70,437	72,271	567,207	637,644
Texas	5	157,388	(b)	(b)	(b)	(b)	[b] 129,034	[b] 834,560	834,560
Wyoming	4	41,877	(b)	(b)	(b)	(b)	[b] 29,813	[b] 195,143	195,143
	57	2,057,015	64,571	255,716	405,621	980,836	1,328,269	10,234,302	11,470,854
1919.									
Alaska, Arizona, California, Colorado, Montana, New Mexico, Oregon, South Dakota, Utah, Virginia [a]	15	305,113	24,902	128,840	69,662	193,794	187,101	1,709,761	2,032,395
Iowa	6	421,279	2,405	8,760	66,619	222,672	264,656	2,403,012	2,634,444
Kansas	3	78,479	(b)	(b)	(b)	(b)	[b] 66,008	[b] 520,673	520,673
Michigan	6	339,125	1,597	10,422	57,157	163,688	250,687	2,216,257	2,390,367
Nevada	3	91,756	(b)	(b)	(b)	(b)	[b] 79,181	[b] 497,561	497,561
New York	8	591,153	5,458	23,984	210,959	596,355	316,767	2,910,404	3,530,743
Ohio	3	251,259	1,435	6,363	6,390	20,373	219,900	2,022,987	2,049,723
Oklahoma	5	114,313	(b)	(b)	24,761	63,920	[b] 72,013	[b] 644,740	708,660
Texas	5	176,607	(b)	(b)	10,637	16,442	[b] 130,656	[b] 1,064,312	1,080,754
Wyoming	3	51,079	....	....	....	....	37,314	282,587	282,587
	57	2,420,163	39,978	185,566	470,267	1,332,637	1,596,020	14,209,704	15,727,907

[a] Includes also a small quantity sold by warehouses and not elsewhere accounted for.

[b] Crude gypsum is included with calcined plaster.

Gypsum produced and sold in the United States, 1915–1919, by uses.

Year.	Sold without calcining.											
	For Portland cement.			As agricultural gypsum.			For other purposes.			Total.		
	Quantity (short tons).	Value.	Average price per ton.	Quantity (short tons).	Value.	Average price per ton.	Quantity (short tons).	Value.	Average price per ton.	Quantity (short tons).	Value.	Average price per ton.
1915	a 406,393	a $528,161	$1.30	69,256	$122,714	$1.77	(a)	(a)	....	475,649	$650,875	$1.37
1916	a 454,112	a 607,995	1.34	81,879	167,136	2.04	a 11,128	a $15,299	$1.37	547,119	790,430	1.44
1917	a 526,881	a 867,123	1.65	84,366	230,808	2.74	a 12,748	a 26,439	2.07	623,995	1,121,370	1.80
1918	a 403,635	a 974,283	2.41	64,571	255,716	3.96	a 1,986	a 6,553	3.30	470,192	1,236,552	2.63
1919	a 470,267	a 1,332,637	2.83	39,978	185,566	4.64	(a)	(a)	....	510,245	1,518,203	2.98

Year.	Sold calcined.														
	As plaster of Paris, wall plaster, Keenes cement, etc.			For dental plaster.			To glass factories.			As boards, tile, and blocks, and for other purposes.			Total.		
	Quantity (short tons).	Value.	Average price per ton.	Quantity (short tons).	Value.	Average price per ton.	Quantity (short tons).	Value.	Average price per ton.	Quantity (short tons).	Value.	Average price per ton.	Quantity (short tons).	Value.	Average price per ton.
1915	1,520,308	$5,776,826	$3.80	534	$2,376	$4.45	11,861	$26,620	$2.25	81,017	$140,196	$1.73	1,613,720	$5,946,018	$3.68
1916	1,677,081	6,884,960	4.11	661	8,766	13.26	11,537	28,839	2.50	116,535	246,037	2.11	1,805,814	7,168,602	3.97
1917	1,531,535	8,873,176	5.79	991	7,672	7.74	13,808	72,558	5.25	131,056	1,038,676	7.93	1,677,390	9,992,082	5.96
1918	1,174,359	8,483,633	7.22	(b)	(b)	....	13,567	84,928	6.26	b 140,343	b 1,665,741	11.88	1,328,269	10,234,302	7.70
1919	1,393,141	11,809,624	8.48	(b)	(b)	....	14,677	96,561	6.58	b 188,202	b 2,303,519	12.24	1,596,020	14,209,704	8.90

a A small quantity of paint material and of gypsum sold for other purposes included with gypsum sold for Portland cement.
b Some dental plaster included with boards, tile, etc.

The average price per ton of crude gypsum sold for use as retarder in Portland cement increased from $2.41 in 1918 to $2.83 in 1919. New York produced nearly 45 per cent of the gypsum sold for this purpose, as it is the nearest source of supply to the great cement industries in eastern Pennsylvania.

Practically 50 per cent of the gypsum sold as agricultural gypsum or land plaster was produced in Virginia. New York ranked second and Iowa third in sales of gypsum for this purpose. The output of agricultural gypsum in Virginia can not be shown without revealing confidential information, because there were only two producers. The average price per ton of all agricultural gypsum sold in the United States increased from $3.96 in 1918 to $4.64 in 1919. There was a very marked decrease in quantity used, however, the output in 1919 being only 39,978 tons as compared with 64,571 tons in 1918.

Gypsum wall plaster, plaster of Paris, and Keenes cement increased 200,000 tons in quantity produced, $3,000,000 in value, and the average price rose from $7.22 a ton in 1918 to $8.48 in 1919. This average price is determined by dividing the sum received by the quantity sold and is useful only for comparison with other average prices; it includes both high and low cost plasters and is for the entire country. Keenes cement was formerly made only in two or three States, but in 1919 it was reported in 13 States by six companies. As one company objects to the publication of the figures separately, they are included with those for wall plaster. As the quantity of Keenes cement produced annually is less than 20,000 tons and the total value of this product is only about $200,000, the inclusion of this higher-priced material with wall plaster and plaster of Paris does not change the average price per ton of these common plasters more than 1 or 2 cents.

In 1916 and 1917 dental plaster was reported as produced in six States, but in 1918 it was reported by only one producer and in 1919 by two producers. To avoid revealing confidential information the quantity and value in 1918 and 1919 have been added in with those of other material. The total quantity of dental plaster reported as produced in 1919 was less than 100 tons.

The quantity and value of calcined plaster sold to glass factories was greater than ever before, but the average price per ton increased only 32 cents as compared with an increase of $1.01 in 1918. The quantity sold to glass factories was 14,677 tons, valued at $96,561, or $6.58 a ton.

Plaster board, tile, and blocks were reported from 15 States at 24 plants operated by the original producers of the gypsum used in their manufacture. Plants of firms that do not mine gypsum are not included here, because the gypsum they use is already accounted for in these tables as plaster sold by original manufacturers. Of the 185,955 tons of gypsum plaster made into gypsum boards, block, and tile, New York produced 57,000 tons, Michigan, 46,000 tons, Iowa 44,000 tons, and Ohio 21,000 tons. The total quantity of gypsum plaster used for this purpose was an increase of 34 per cent over that of 1918 and indicates the growing demand for structural material of this class. The average price per ton of gypsum plaster entering into these materials increased from $11.88 in 1918 to $12.24

in 1919. This is the valuation placed on the principal constituent of these products and does not indicate by any means the selling price of the boards and blocks. The cost of the paper or felt used in the construction of gypsum boards adds very materially to the selling price of the finished product.

BUSINESS NOTES.

The Pacific Coast Gypsum Co., whose mine at Chichagof Island, southeastern Alaska, was idle after the mine building burned in March, 1918, produced a small quantity of gypsum in 1919, which was shipped to the company's plant at Tacoma, Wash., for calcining.

The Douglas Gypsum Block & Plaster Co., which began operations at Douglas, Ariz., in August, 1918, was short lived, and made no production in 1919. The property was leased May 26, 1920, by G. O. Bohannon, of Douglas, who began production on a small scale. The Arizona Gypsum Plaster Co., at Douglas, S. G. Dowell, superintendent, continues to supply gypsum blocks to the local builders, and to ship gypsum plaster to Portland cement mills, and to copper smelters.

The United States Gypsum Co. bought out the plant of the Consolidated Pacific Cement Plaster Co. at Amboy, Calif., September 1, 1919, and continued its operation.

The Centerville Gypsum Co., Centerville, Iowa, which did not operate in 1918 because its mine was flooded, was operating from May 23 to November 11, 1919, when the work was suspended by a labor strike. The Wasem Plaster Co., Fort Dodge, Iowa, whose plant was burned in May, 1918, rebuilt it in a substantial manner, putting up a concrete mill, and made a small output in 1919, which was sold in crude form.

The Three Forks Portland Cement Co. continued to operate its plant at Hanover, Mont., but the quarry at Cavern Spur, Gallatin County, was abandoned.

The United States Gypsum Co. bought the property of the Arden Plaster Co., at Arden, Nev., June 1, 1919, and continued its operation.

The White Star Plaster Co., whose property at Moapa, Nev., was in liquidation in 1918, began production September 1, 1919, calcining gypsite in two 10-foot kettles fired with fuel oil.

The Ebsary Gypsum Co. (Inc.), Rochester, N. Y., bought the property of the Consolidated Wheatland Plaster Co., at Wheatland, and utilized two 8-foot kettles in the production of stucco and wall plaster.

The Kelly Plaster Co., Castalia, Ohio, whose plant was closed in January, 1918, because of inability to obtain service from the railway, continued idle through 1919 for the same reason.

The Gypsum Industries Association, representing 85 per cent of the gypsum industry in the United States, maintained an office at 101 West Monroe Street, Chicago, Ill. The officers directly connected with the office are H. H. Macdonald, secretary; V. G. Marani, chief engineer; William Crocker, agronomist. These officers prepared in 1919 considerable literature on different phases of the industry, which was mimeographed and distributed to the members of the association.

MINE AND MILL DATA.

There were 56 active mines, quarries, and pits in the United States and Alaska, which supplied 54 domestic calcining plants in 1919. Rock gypsum was mined at 41 localities, gypsite at 14, and selenite crystals at 1. Practically all the mills are equipped with kettles, but the number of rotary kilns is increasing, there being eight in use in 1919. These were owned and located as follows:

United States Gypsum Co., one at Fort Dodge, Iowa, and two at Oakfield, N. Y.
Niagara Gypsum Co., two at Oakfield, N. Y.
Lycoming Calcining Co., one at Garbutt, N. Y.
American Gypsum Co., two at Port Clinton, Ohio.

Sixteen mills reported the manufacture of Keenes cement, and 22 mills made gypsum boards or blocks. Domestic gypsum was calcined by the producers in 1919 at plants in the following places:

Arizona: Douglas.
California: Amboy.
Colorado: Loveland, Portland.
Iowa: Centerville, Fort Dodge.
Kansas: Blue Rapids, Medicine Lodge.
Michigan: Alabaster, Grand Rapids, Grandville.
Montana: Hanover.
Nevada: Arden, Arrowhead, Moundhouse.
New Mexico: Acme, Globe.
New York: Akron, Garbutt, Oakfield, Wheatland.
Ohio: Gypsum, Port Clinton.
Oklahoma: Acme, Cement, Eldorado, Homestead, Southard.
Oregon: Gypsum.
South Dakota: Black Hawk, Piedmont.
Texas: Acme, Plastico.
Utah: Nephi, Sigurd.
Virginia: North Holston, Plasterco.
Washington: Tacoma (using Alaska gypsum).
Wyoming: Laramie, Red Buttes.

IMPORTS.

The gypsum imported into the United States is very largely in the crude lump or unground form. As shown by the following table, the imports in 1919 included about 172,000 tons of crude gypsum and 10,000 tons of ground or calcined gypsum. This indicates a marked recovery from the importation of 50,000 tons of unground gypsum in 1918, the smallest quantity imported in many years—a result of the diversion of the vessels ordinarily used in the transportation of gypsum to the coastwise movement of coal. The crude gypsum imported into the United States comes almost exclusively from Nova Scotia and New Brunswick, and in 1919 it was calcined at New Haven, Conn., and New Brighton and New York City, N. Y. As the quarries commonly supplying these plants are on the Bay of Fundy, the rock is shipped by boat. The closing of the bay by ice throughout the winter requires that shipments be made during the open season and that stock be accumulated at the plants for use during the winter.

Gypsum imported and entered for consumption in the United States, 1913–1919.[a]

Year.	Unground.		Ground or calcined.		Value of manufactured plaster of Paris.	Keenes cement.		Total value.
	Quantity (short tons).	Value.	Quantity (short tons).	Value.		Quantity (short tons).	Value.	
1913	447,383	$473,594	4,542	$31,277	$52,051	1,851	$26,185	$583,107
1914	369,214	392,118	3,559	27,931	24,792	1,007	17,511	462,352
1915	336,856	356,791	5,749	22,873	10,095	427	6,656	396,415
1916	254,131	275,043	11,706	72,345	9,085	600	9,890	366,363
1917	240,269	265,504	16,533	109,732	6,016	484	8,003	389,255
1918	50,653	55,004	6,117	70,028	1,765	111	2,259	129,056
1919	171,733	211,946	10,415	126,405	7,719	187	5,984	352,054

[a] Figures compiled from records of the Bureau of Foreign and Domestic Commerce, Department of Commerce.

Only three companies reported to the Geological Survey that they imported gypsum in 1919. These were J. B. King & Co. and the Rock Plaster Manufacturing Co., New York City, N. Y., and the Connecticut Adamant Plaster Co., New Haven, Conn. The plant of the Keystone Plaster Co., Chester, Pa., was idle and for sale, and no report was received from the other one of the five firms that usually import gypsum for calcining.

The quantity of crude gypsum reported by the three companies as imported by them was practically the same as that reported by the Bureau of Foreign and Domestic Commerce. These companies sold only about 8,000 tons of gypsum in the crude or uncalcined form. One-half of this was sold for agricultural plaster, one-quarter was sold to other plaster mills, and the remainder to paint mills and as terra alba. About 130,000 tons was sold calcined. More than 113,000 tons was sold as wall plaster, plaster of Paris, molding and finishing plaster, and the remainder was used in the manufacture of gypsum plaster board, tile, and blocks, and for dental plaster and other purposes.

Values for the imported gypsum manufactured and sold by these companies can not be given, because two of the companies did not report them in detail, it being found impracticable to arrive at correct figures. It is estimated, however, that the total value of sales of gypsum and gypsum products by these three firms in 1919 was more than $2,000,000, in comparison with a business of more than $15,000,000 done by the entire domestic industry.

EXPORTS.

The data in the following tables were obtained from the Bureau of Foreign and Domestic Commerce, Department of Commerce. Exports of plaster of Paris were separately reported in 1916 and the first half of 1917, but since July, 1917, they have been included under "All other articles." Figures for plaster or wall board are given below:

Destination and value of gypsum plaster or wall board exported from the United States, 1916–1919.

Country.	1916	1917[a]	1918	1919
North America:				
Bermuda	$125		$21	
British Honduras		$41	61	$4
Canada	5,485	28,316	39,785	107,462
Central America:				
Costa Rica	15			18
Guatemala		9	4,067	8,288
Honduras		4		1,856
Nicaragua				
Panama	9	26	53	7,290
Salvador	82		1,181	495
Mexico	328	487	3,518	14,663
Newfoundland		471	51	2,789
British West Indies:				
Barbados				28
Jamaica	38		47	90
Trinidad and Tobago		66		175
Other British	103		52	1,131
Cuba	13,782	2,424	81,910	8,455
Dominican Republic	20		1,808	398
Dutch West Indies				57
Haiti	144	163	308	
Virgin Islands	500		225	182
South America:				
Argentina	2,622	12,813	12,031	62,715
Bolivia				116
Brazil	50	864	4,907	19,419
Chile	10,617	6,386	3,156	15,546
Colombia	141			1,320
Ecuador	32			
Guiana:				
British			80	
Dutch				
Peru			4,574	663
Uruguay		1,046		5,171
Venezuela	46		6	330
Europe:				
Belgium				4,398
Denmark				3,516
Greece				2,177
France		68		
Iceland and Faroe Islands			1,975	
Italy		5	454	
Netherlands				18,573
Norway		550		4,456
Russia				27
Spain	63	632		487
Sweden				5,553
United Kingdom:				
England	30,094	7,765	15,394	303,573
Scotland				12,564
Ireland				9,058
Asia:				
China		257	407	22,623
British East Indies:				
India		5,282	4,585	8,293
Straits Settlements				38
Other British	92	145	24	
Dutch East Indies			5,440	5,535
Hongkong			170	4,723
Japan	1,294		113,931	229,010
Russia in Asia				78
Turkey in Asia				8,886
Australia	26,249	36,696	70,796	90,091
New Zealand	6,996	88	20,285	53,054
French Oceania			65	3
German Oceania				142
Philippine Islands			10,608	5,608
Africa:				
British Africa:				
South	6,447	1,419	13,786	79,556
West	133	95	3,838	7,099
East			2,386	8
Egypt	2,998			808
Portuguese Africa				3,187
	108,505	106,118	421,985	1,141,815

[a] Figures for first half of year only.

Value of gypsum plaster or wall board exported from the United States in 1919, by districts.

Maine and New Hampshire	$213	San Francisco	$95,174
Massachusetts	55,313	Oregon	440
New York	477,075	Washington	188,831
Philadelphia	150,098	Montana and Idaho	4
Maryland	1,920	Dakota	12,653
Florida	6,577	Duluth and Superior	12,531
Mobile	4	Michigan	11,617
New Orleans	6,435	Buffalo	97,448
Sabine	7,396	St. Lawrence	11,839
San Antonio	199	Vermont	3,741
El Paso	104		
Arizona	1,887		1,141,815
Southern California	316		

Exports of plaster or wall board in 1919 were valued at $1,141,815, an increase of nearly 171 per cent over the exports of 1918. England took material valued at $303,573, or 27 per cent of the total. Japan more than doubled her purchases, increasing them from $113,931 in 1918 to $229,010 in 1919. Canada was third in rank, with purchases of gypsum board valued at $107,462. Australia has been a heavy buyer for several years, but her increase, from $70,000 to $90,000, was not nearly so large a percentage as that of many other countries. The value of exports to New Zealand more than doubled, increasing from $20,000 to $53,000, and those to British South Africa grew from about $14,000 to $79,000.

Exports of plaster board to South America have been larger each succeeding year. Argentina took material valued at $62,715, or more than all the other South American countries combined. It is noticeable that the demand comes alike from tropical countries and cold countries, including Newfoundland, Iceland, and Sweden, from our neighbors in Central America and West Indies, and from Asia and the Philippines, on the opposite side of the world.

More than 40 per cent of the gypsum plaster board exported was shipped from the New York customs district. The second largest exporting district was Puget Sound, Wash., with shipments valued at $188,831; Philadelphia was third, with $150,098.

The very notable increase in exports to England and the decrease in those to Cuba may possibly be explained by offerings of cargo space, which resulted in material going to Cuba from England rather than direct from this country.

PRODUCTION OF GYPSUM IN CANADA.[2]

The total quantity of gypsum rock quarried in Canada in 1919 was 304,532 tons, of which 121,499 tons was calcined. The shipments of all grades amounted to 306,947 tons, valued at $1,217,345, and included lump gypsum, 180,553 tons, valued at $208,916; crushed, 27,939 tons, valued at $68,002; fine ground, 3,955 tons, valued at $18,901; and calcined, 94,501 tons, valued at $921,526. By provinces the shipments were: Nova Scotia, 171,623 tons, valued at $252,232; New Brunswick, 42,522 tons, valued at $315,656; Ontario, 59,899 tons, valued at $278,120; Manitoba, 32,903 tons, valued at $371,337.

[2] Preliminary report on the mineral production of Canada during the calendar year 1919, Canada Dept. Mines, Mines Branch, Feb. 28, 1920.

Gypsum produced and marketed in Canada, 1917—1919.

Year.	Quantity (short tons).	Value.
1917	336,332	$881,984
1918	152,287	823,006
1919	306,947	1,217,345

AGRICULTURAL GYPSUM AND ITS USES.[3]

By WILLIAM CROCKER.[4]

Land plaster, or agricultural gypsum, is a ground natural rock fertilizer, consisting mainly of hydrated calcium sulphate. It therefore bears two essential plant foods, calcium and sulphur.

Eighty years ago land plaster was one of the most used of fertilizers, and there are indications that it will again come into general use.

There are four main uses of this substance in agriculture: As a source of sulphur for alfalfa, red clover, or other crops of high sulphur requirement, and for combination with ground-rock phosphate as a substitute for acid phosphate; as a preserver of manure; as a soil stimulant; and as an amendment for black alkali.

AS A SOURCE OF SULPHUR.

The value of ground gypsum as a fertilizer was discovered separately in Germany and France somewhat after 1760.

From these two centers the use of this fertilizer spread over Germany and France and later to America, and finally from here to England. Benjamin Franklin was one of the first to introduce it into America. He had a field of red clover that sloped down to one of the main roads out of Philadelphia. On this he sowed ground gypsum in the form of the following words:

LAND PLASTER USED HERE, BEN FRANKLIN.

The words soon became conspicuous to passers-by, due to the luxuriant growth of clover where the plaster was sown.

The use of land plaster soon became general in the United States and England, and it proved strikingly effective on clover, alfalfa, and other crops of the legume or pea family, on turnips, cabbage, and other crops of the mustard family, as well as on some other crops. Most of these crops, we now know, use much sulphur, and the sulphur supplied by the plaster was no doubt the main source of its effectiveness.

Now let us shift our sketch over a century of time and to a distant geographic region—Washington and Oregon to-day. Here they are getting increased tonnage yields of legume crops (clover, alfalfa, and vetch) amounting to 25 to 1,000 per cent, and they get these increases not only with gypsum but with raw sulphur or any other sulphur fertilizer; but they do not get any increases with phosphates or any fertilizer not carrying sulphur. This confirms the claim of some of the investigators of a century ago that sulphur was the effective agent.

Any fertilizer that increases the growth of these nitrogen-fixing crops, including, besides those mentioned above, the peanut, beans, peas, and others, whether it be lime, gypsum, or phosphate, strikes the matter of building up and maintaining soil fertility at a very critical point, for nitrogen is the most expensive of plant foods, and is commonly deficient.

Why did the use of gypsum as a fertilizer decline? This is not unique for gypsum, for the same happened with lime. In the old days marling was very common. This excellent practice largely disappeared, but to-day it is returning with a rush in the commendable practice of applying agricultural lime. The introduction and advertising of soluble complete commercial fertilizers, beginning with Lawes's invention of acid phosphate in 1842, gradually dis-

[3] Manufacturers' Record, Nov. 27, 1919, pp. 110–111.
[4] Professor of plant physiology, University of Chicago.

placed the old practice of using natural ground-rock fertilizers, gypsum as well as marls.

The main factor in delaying a clear explanation of the fertilizer value of gypsum and in giving general credence to the idea that it acted merely as a soil stimulant was a long-standing misconception of the importance of sulphur in crop growth. This misconception grew out of Wolff's long-used and erroneous method of determining the sulphur content of crops. He ashed the crop and determined the amount of sulphur in the ash. In ashing, all but an insignificant portion of the sulphur was lost. According to Wolff's method, 100 bushels of corn sold from a farm remove 0.2 of a pound of sulphur, while new accurate methods of analysis show that this amount of corn removes 8.5 pounds of sulphur, or more than forty times as much as was estimated on the old basis. A similar relation holds for other crops. The new accurate methods of analysis are rapidly shifting the question of sulphur fertilizers from one not supposed to deserve special attention to one of the most serious of our fertilizer problems.

The statements and figures that follow show the low supply of sulphur in soils, the very considerable consumption of sulphur by crops, and the much greater loss of it from the soil by leaching.

The average earth's crust contains about 0.11 per cent each of sulphur and phosphorus, and the average virgin soils bear about equal amounts of these two elements, but considerably less than the average earth's crust. After soils are put under cultivation, their sulphur content falls much faster than their phosphorus content. The drop in phosphorus can be accounted for almost entirely by the amount removed by the crop, while three to six times as much sulphur is leached out of the soil as is withdrawn by the crop, and in addition, crops remove nearly as much sulphur as phosphorus.

The phosphorus and sulphur removed from the soil by crops may be roughly estimated as follows, considering only the portion of the crop commonly removed from the land in grain farming and figuring on maximum yields.

	Pounds per acre per year removed.	
	Sulphur.	Phosphorus.
Cereal grains (wheat, corn, oats, etc.)	4-9	10-17
Potato	32.6	17
Alfalfa hay	45.9	36
Timothy hay	15.2	12
Clover hay	13.1	20
Cabbage	40	13

In the average soil there are but few years' supply of either sulphur or phosphorus, and both must be added consistently if fertility is to be permanently maintained.

Taking all these facts together, it appears that the question of sulphur fertilization is quite as serious as phosphorus fertilization, and one fact makes it appear much more so—the great rate at which sulphur leaches out of the soil.

Aside from farm manure, a century ago marls and gypsum were the main fertilizers. No doubt the weakest point in this old system was deficiency of phosphorus. Now rock phosphates supply this deficiency, and a balanced ration of natural rock fertilizers is possible—limestone, gypsum, and rock phosphate.

Let us assume, as is rightly assumed in the Illinois system of permanent fertility, that nitrogen is supplied by growing clover or some other legume in the rotation, and that potash is supplied where soils are occasionally deficient in it or when crops with high demand for it are grown. The Illinois system, combined use of ground limestone and ground rock phosphate, lacks one element of permanence and must ultimately fail. It does not supply sulphur, and will finally lead to a deficiency of this element.

The main advantage of the natural rock system is the fact that more than twice as much sulphur and phosphorus can be purchased per unit cost than is possible with acid phosphate.

AS A PRESERVER OF MANURE.

Gypsum preserves the nitrogen of manure by transforming the volatile ammonia to nonvolatile ammonium sulphate or otherwise tying it up. The pungent ammonia odor prevalent about a horse stable is evidence of the escape of ammonia into the air. Finely ground gypsum should be applied to the manure in the stall two or three times a day at the rate of 3 to 5 pounds per animal per day.

Various experiments indicate that the nitrogen preserved by gypsum, when it is properly used on manure, is worth two or three times the cost of the gypsum when both are figured at current market prices.

In addition, of course, both the calcium and the sulphur of the gypsum are added to the soil with the manure and have great fertilizer value, especially on such crops as clover, alfalfa, cabbage, and potatoes.

AS A SOIL STIMULANT.

Gypsum renders the nitrogen of the soil more available by stimulating the activity of the bacteria that transform the organic nitrogen of the soil into nitrates, the form available for crops. Due to the products of the activity of these organisms and to other effects of gypsum, the solubility and availability of the potash and phosphates of the soil are increased. Gypsum is therefore good for gardens and truck crops where the plant foods need to be ready in great abundance to permit rapid growth. Most of these crops also use much sulphur which the gypsum will supply. It will also prove valuable for crops of high potash needs (potatoes, tobacco, sugar beets, etc.) by rendering the high potash content of the soil more available.

AS A SPECIFIC FOR BLACK ALKALI.

Gypsum is a specific for black alkali. It transforms the harmful sodium carbonate of the black alkali into harmless calcium carbonate and into the less harmful sodium sulphate.

The foregoing article calls attention to an important use of gypsum which, according to the reports received by the Geological Survey, is declining. There is a prospect that by the dissemination of information on this subject the use of gypsum in agriculture may be very materially increased. Within the last few years field experiments conducted by the agricultural experiment stations of Ohio, Kentucky, Kansas, Wisconsin, Iowa, and Oregon and by the United States Department of Agriculture have shown that the application of sulphur to various soils in the form of calcium sulphate or gypsum has resulted in greatly increased yields of certain crops. Studies of the sulphur content of soils and the sulphur requirements of crops show that the application of gypsum to the soils in many parts of the United States would be beneficial.

The use of gypsum on peanuts is an old, established practice. In a restricted area in Virginia 20,000 to 30,000 tons of gypsum is used annually on this crop. Pulverized gypsum is applied to the foliage after blossoming and greatly increases the yield of tubers.

Notable results in alfalfa crops obtained in Oregon are described in Bulletin 163 of the Oregon Agricultural College Experiment Station, a report on sulphur as fertilizer for alfalfa in southern Oregon, by F. C. Reimer and H. V. Tartar, published in July, 1919. Other State experiment stations, including those of Ohio, Kentucky, Wisconsin, and Iowa, have studied the relation or effect of sulphur on soil and crops and published their results. It is possible that the small demand for agricultural gypsum in 1919 as compared with previous years was due mainly to high prices and freight rates, and that with lower prices and improved transportation the sale and use of agricultural gypsum will greatly increase.

Certainly it is very probable that on some soils the limiting factor in productiveness has been a lack of sulphur and that the application of superphosphate has resulted in good crops because of the sulphur rather than the phosphorus contained in the fertilizer. On such soils the cheaper agricultural gypsum or land plaster might yield as satisfactory results as the more expensive complete fertilizer. The needs of any soil can be determined by field tests, and fertilizer practice should be based on such tests. It may well be that a deeper study of soil needs by our growers of crops will show that in many places the element lacking to insure productiveness is sulphur, and that this lack can best be supplied by the application of agricultural gypsum.

MANUFACTURERS.

MANUFACTURERS OF GYPSUM PLASTER.

HEAD OFFICES.

Acme Cement Plaster Co., St. Louis, Mo.
Alabastine Co., Grand Rapids, Mich.
American Cement Plaster Co., Chicago, Ill.
American Gypsum Co., Port Clinton, Ohio.
Arizona Gypsum Plaster Co., Douglas, Ariz.
Best Bros. Keenes Cement Co., Medicine Lodge, Kans.
Cardiff Gypsum Plaster Co., Fort Dodge, Iowa.
Centerville Gypsum Co., Centerville, Iowa.
Colorado Portland Cement Co., Denver, Colo.
Connecticut Adamant Plaster Co. (importer), New Haven, Conn.
Dakota Plaster Co., Rapid City, S. Dak.
Ebsary Gypsum Co. (Inc.), 171 Court Street, Rochester, N. Y.
Empire Gypsum Co., Rochester, N. Y.
Globe Plaster & Mining Co., Kansas City, Mo.
Grand Rapids Plaster Co., Grand Rapids, Mich.
Jumbo Plaster & Cement Co., Sigurd, Utah.
J. B. King & Co. (importer), New York, N. Y.
Lycoming Calcining Co., Williamsport, Pa.
Nephi Plaster & Manufacturing Co., Salt Lake City, Utah.
Niagara Gypsum Co., Buffalo, N. Y.
Oklahoma Portland Cement Co., Denver, Colo.
Overland Cement Plaster Co., Laramie, Wyo.
Pacific Coast Gypsum Co., Tacoma, Wash.
Pacific Portland Cement Co., San Francisco, Calif.
Plymouth Gypsum Co., Fort Dodge, Iowa.
Rock Plaster Manufacturing Co. (importer), New York, N. Y.
Southern Gypsum Co., North Holston, Va.
Texas Cement Plaster Co., Oklahoma City, Okla.
Three Forks Portland Cement Co., Hanover, Mont.
United States Gypsum Co., Chicago, Ill.
Wasem Plaster Co., Fort Dodge, Iowa.
White Star Plaster Co., Moapa, Nev.

MANUFACTURERS OF GYPSUM PLASTER OPERATING MORE THAN ONE PLANT.

Acme Cement Plaster Co	Grand Rapids, Mich.
	Acme, Okla.
	Acme, Tex.
	Acme, N. Mex.
	Laramie, Wyo.
	Gypsum, Oreg.
American Cement Plaster Co	Akron, N. Y.
	Gypsum, Ohio.
	Grand Rapids, Mich.
	Fort Dodge, Iowa.
	Blue Rapids, Kans.
	Acme, Tex.

Colorado Portland Cement Co	Portland, Colo.
	Primm, Okla.
	Red Butte, Wyo.
Grand Rapids Plaster Co	Grand Rapids, Mich.
	Grandville, Mich.
United States Gypsum Co	Oakfield, N. Y.
	Plasterco, Va.
	Gypsum, Ohio.
	Alabaster, Mich.
	Grand Rapids, Mich.
	Fort Dodge, Iowa.
	Blue Rapids, Kans.
	Southard, Okla.
	Eldorado, Okla.
	Piedmont, S. Dak.
	Loveland, Colo.
	Arden, Nev.
	Amboy, Calif.

MANUFACTURERS OF KEENES CEMENT.

Acme Cement Plaster Co., 703 Frisco Building, St. Louis, Mo.
Best Bros. Keenes Cement Co., Medicine Lodge, Kans.
Nephi Plaster & Manufacturing Co., 322 Ness Building, Salt Lake City, Utah.
Pacific Portland Cement Co., 827 Pacific Building, San Francisco, Calif.
Texas Cement Plaster Co., Oklahoma City, Okla.
United States Gypsum Co., 205 West Monroe Street, Chicago, Ill.

MANUFACTURERS OF GYPSUM PLASTER BOARD AND WALL BOARD.

American Cement Plaster Co., 111 West Washington Street, Chicago, Ill.
Bell, H. W., & Co., 2592 Park Avenue, New York City.
Bestwall Manufacturing Co., 25 North Dearborn Street, Chicago, Ill.
Buttonlath Manufacturing Co., Vernon and Boyle avenues, Los Angeles, Calif.
Duffy, J. P., & Co., 51st Street and Second Avenue, Brooklyn, N. Y.
Gypsite Fireproofing Co., 2034 Dime Bank Building, Detroit, Mich.
Hercules Plaster Board Co., Hampton, Va.
Kelley Plaster & Plaster Board Co., 261 Central Avenue, Passaic, N. J.
Keyhole Plaster Lath Co., 148 Hooper Street, San Francisco, Calif.
King, J. B., & Co., 17 State Street, New York City.
New Jersey Adamant Manufacturing Co., 79 Passaic Avenue, East Newark, N. J.
Pacific Coast Gypsum Co., 403 Perkins Building, Tacoma, Wash.
Plymouth Gypsum Co., Fort Dodge, Iowa.
Rader, Gustav, 1105 Metropolitan Avenue, Brooklyn, N. Y.
Reeb, M. A., Corporation, 597 Michigan Avenue, Buffalo, N. Y.
Rock Plaster Manufacturing Co., 381 Fourth Avenue, New York City.
Schumacher Wall Board Co., 58th Street and San Pedro and Slauson avenues, Los Angeles, Calif.
Southern Gypsum Co., North Holston, Va.
United States Gypsum Co., 205 West Monroe Street, Chicago, Ill.

MANUFACTURERS OF GYPSUM BLOCK AND TILE.

Acme Cement Plaster Co., 703 Frisco Building, St. Louis, Mo.
Alabastine Co., Grand Rapids, Mich.
American Cement Plaster Co., 111 West Washington Street, Chicago, Ill.
Arizona Gypsum Co., Douglas, Ariz.
King, J. B., & Co., 17 State Street, New York, N. Y.
Nephi Plaster & Manufacturing Co., 322 Ness Building, Salt Lake City, Utah.
Plymouth Gypsum Co., Fort Dodge, Iowa.
Reeb, M. A., Corporation, 597 Michigan Avenue, Buffalo, N. Y.
United States Gypsum Co., 205 West Monroe Street, Chicago, Ill.

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MINERAL WATERS.

By Arthur J. Ellis.[1]

SCOPE OF REPORT.

The term mineral water as it is used in this report applies to water that is bottled and sold in its natural state or only slightly altered from its natural state. It includes (*a*) natural carbonated waters that have lost part of their carbon dioxide; (*b*) natural waters that have been artificially carbonated; and (*c*) waters from which iron has been removed. It does not include artificial waters or natural waters that have been essentially modified in chemical character. Waters that have been flavored, concentrated, fortified, diluted, or otherwise radically altered are therefore not included.

The statistics in this report refer only to domestic mineral waters that have been sold, imports being excepted. Water that is given away, including water furnished free for drinking or bathing to guests at hotels or to patients at sanitariums, has been omitted even where there are data available to show the quantity of water so used. Hence, as actual sales fall far short of the total quantity used, particularly of such waters as are drunk at fashionable resorts for their medicinal value, the totals do not represent the full magnitude of the trade.

Three uses of mineral waters are recognized in this report—table use, medicinal use, and use in the manufacture of soft drinks.

Distinction for statistical purposes between table and medicinal waters is entirely arbitrary. Most table waters are clear, sparkling, and without distinct mineral taste or odor. Some table waters are, however, more strongly mineralized than some medicinal waters, and many medicinal waters contain less mineral matter than certain city supplies. The distinction in this report between table waters and medicinal waters is based on the reports furnished by the owners and operators of springs, which state the uses for which the waters are sold. An operator's report is, in turn, based on his knowledge of the uses to which his customers put the water. The reports show that as many as 81 waters are sold in the United States for both table and medicinal purposes, and that 22 waters are sold for table use, medicinal use, and use in the manufacture of soft drinks. It is apparent, therefore, that although this classification is useful for statistical purposes, it does not correspond to fundamental differences in composition in the waters themselves.

[1] Mr. Ellis's untimely death occurred before this report was quite finished. The remaining details were completed by Miss B. H. Stoddard, of the United States Geological Survey, who compiled the statistical tables.—G. F. L.

USES OF MINERAL WATERS.

The figures in the following table are grouped according to uses of the water. As reported in this table 81 waters were sold in 1919 for both medicinal and table use and might properly be classed as table waters. These, together with the 274 waters that were sold exclusively for table use, made in all 355 table waters, as compared with 146 waters sold exclusively for medicinal use.

Number of springs supplying water of each class in 1919.

State.	Number of mineral waters.[a]	Sold for table use only.	Sold for medicinal use only.	Sold for both table and medicinal uses.	Used for soft drinks.	Used for soft drinks only.	Used for soft drinks and sold for table purposes.	Used for soft drinks and sold for medicinal purposes.	Used for soft drinks and sold for table and medicinal purposes.
Alabama	5		5						
Arkansas	7	1	4	2	1				1
California	37	18	15	3	9	1	6		2
Colorado	9	2	5	2	4		2	1	1
Connecticut	28	27	1		7		7		
District of Columbia	1	1							
Florida	5	2	2	1					
Georgia	9	5	2	2					
Illinois	6	3	1	2	2		2		
Indiana	10	2	4	4					
Iowa	5	2	1	1	4	1	2		1
Kansas	8	4	4		2		2		
Kentucky	10	1	6	2	2	1			1
Louisiana	1		1						
Maine	18	10	3	5	1				1
Maryland	8	8			3		3		
Massachusetts	38	26		7	15	5	6		4
Michigan	10	8	1	1					
Minnesota	12	11			8	1	7		
Mississippi	7		7						
Missouri	26	4	15	6	3	1	2		
Montana	3	2		1					
Nebraska	2		1		1	1			
Nevada	1	1			1		1		
New Hampshire	3	2	1		2		2		
New Jersey	14	12	1	1	6		5		1
New Mexico	2	1		1	1				1
New York	44	33	7	4	7		6	1	
North Carolina	9	2	5	2					
North Dakota	3	2			1	1			
Ohio	24	16	4	2	3	2	1		
Oklahoma	9	5	2	2	1		1		
Oregon	3	2		1	2		1		1
Pennsylvania	28	17	5	5	8	1	4	1	2
Rhode Island	6	6			2		2		
South Carolina	8	2	3	3	1			1	
South Dakota	3	3			2		2		
Tennessee	14	2	9	3					
Texas	18	1	15	1	1	1			
Vermont	5	1		3	1	1			
Virginia	30	10	13	7	3		2		1
Washington	2	1			1	1			
West Virginia	5	3	1	1	1		1		
Wisconsin	29	14	2	5	19	8	6	1	4
Wyoming	2	1		1	1				1
	527	274	146	81	126	26	73	5	22

[a] Equivalent to the number of active springs.

SOURCES OF MINERAL WATERS.

The mineral waters sold in the United States are for the most part derived from natural springs. Many, however, are obtained from wells, and some from streams. No distinction is made in this report between mineral water flowing or pumped from a natural spring and that flowing or pumped from a dug, bored, driven, or drilled well, but wherever the available information permits the sources are given their proper designations in the tables as springs or wells.

MINERAL-WATER TRADE IN 1919.

OUTPUT AND VALUE.

The number of mineral springs utilized commercially was smaller in 1919 than in 1918, as was also the quantity of water sold from them. The total value of the water, however, showed a small increase.

New York ranked first and Wisconsin second in quantity and Wisconsin first and New York second in value of mineral waters sold for all purposes; they were followed in order of value by California, Maine, Indiana, New Jersey, Virginia, and Ohio. Massachusetts ranked first in the consumption of mineral waters for soft drinks; Indiana was first and California and New York were second and third, respectively, in value of medicinal waters. In value of table waters Wisconsin, in first place, and New York, in second place, were followed in order by California, Maine, New Jersey, Ohio, Michigan, and Minnesota. More than 25 springs were active in each of 8 States, more than 1,000,000 gallons of mineral water were sold in each of 13 States, and the value of the water sold amounted to more than $100,000 in each of 12 States.

Sales were reported from 527 springs in 1919, as compared with 569 springs in 1918. No reports of mineral-water sales were received from Arizona, Delaware, Idaho, or Utah, and less than three commercially productive springs each were reported from the District of Columbia, Louisiana, Nebraska, Nevada, New Mexico, Washington, and Wyoming; three or more springs were productive in every other State in the Union. Sales exceeded 5,000,000 gallons in New York and Wisconsin, and the total value of the water was more than $1,400,000 in Wisconsin and more than $800,000 in New York.

As shown in the accompanying table, 90 per cent of all the mineral waters sold in the United States in 1919 came from 21 States; all other States than those mentioned in the following table furnished less than 1 per cent each.

Not all of this water was consumed in the United States, a considerable quantity being exported, but no separate statistics of exports are available.

Mineral waters sold in the leading States and the percentages, by States, of the total sold in the United States in 1919.

State.	Quantity (gallons).	Approximate percentage of total.	State.	Quantity (gallons).	Approximate percentage of total.
New York	6,537,966	17	Pennsylvania	872,595	2
Wisconsin	5,113,289	13	South Dakota	785,404	2
Minnesota	2,731,967	7	Tennessee	752,837	2
California	2,693,165	7	Maine	728,606	2
Ohio	2,341,853	6	Indiana	538,294	1
Massachusetts	1,630,216	4	Montana	499,225	1
Michigan	1,570,906	4	Kansas	394,625	1
Virginia	1,418,528	4	Colorado	391,851	1
Oklahoma	1,368,375	4			
New Jersey	1,244,983	3		34,992,495	90
Connecticut	1,216,184	3	All other States	3,704,785	10
Arkansas	1,084,373	3			
Maryland	1,077,253	3		38,697,280	100

Mineral waters sold in the United States in 1918 and 1919.

State.	Commercial springs.	Quantity sold (gallons).	Average price per gallon (cents).	Value of medicinal waters.	Value of table waters.	Total value.
1918.						
Alabama	7	6,315	29	$1,688	$120	$1,808
Arkansas	8	863,142	8	62,031	8,595	70,626
California	38	2,399,144	18	140,808	292,202	433,010
Colorado	10	319,542	25	34,284	47,083	81,367
Connecticut	27	1,364,443	5	12,073	60,454	72,527
Florida	5	164,630	6	4,105	8,778	12,883
Georgia	10	314,388	9	5,940	21,870	27,810
Illinois	13	921,953	5	1,337	42,111	43,448
Indiana	10	555,076	32	161,964	17,467	179,431
Iowa	4	87,703	4	2,479	1,458	3,937
Kansas	9	403,862	19	56,994	18,365	75,359
Kentucky	11	255,852	16	29,800	12,197	41,997
Maine	21	829,338	32	67,670	198,498	266,168
Maryland	8	1,089,966	9	3,000	97,575	100,575
Massachusetts	43	1,999,592	6	6,034	119,174	125,208
Michigan	9	1,216,882	11	783	128,809	129,592
Minnesota	16	2,248,731	4	183	98,976	99,159
Mississippi	7	175,533	27	47,539		47,539
Missouri	26	306,299	13	30,137	8,341	38,478
Montana	3	193,557	5	26	8,886	8,912
Nebraska	3	1,080	14	15	140	155
New Hampshire	3	182,326	5		8,256	8,256
New Jersey	13	1,134,848	10	25	110,125	110,150
New York	50	5,887,746	10	135,437	431,473	566,910
North Carolina	10	65,422	12	5,382	2,792	8,174
North Dakota	3	530,000	3		13,700	13,700
Ohio	24	2,771,485	5	6,151	144,560	150,711
Oklahoma	8	1,166,485	2	4,000	16,249	20,249
Oregon	4	13,550	13	125	1,700	1,825
Pennsylvania	30	1,400,456	9	10,896	112,540	123,436
Rhode Island	6	365,705	8		30,729	30,729
South Carolina	7	279,300	18	48,988	2,210	51,198
South Dakota	3	454,865	4	4	17,265	17,269
Tennessee	13	990,027	5	10,413	42,954	53,367
Texas	18	544,183	15	80,553		80,553
Vermont	4	95,700	18	8,300	8,790	17,090
Virginia	35	1,745,105	10	48,379	125,533	173,912
West Virginia	8	301,883	11	8,831	23,214	32,045
Wisconsin	32	6,630,725	18	39,737	1,153,608	1,193,345
Wyoming	4	41,335	13	1,525	3,988	5,513
Other States [a]	6	391,548	4	1,500	13,080	14,580
	569	40,709,722	11	1,079,136	3,453,865	4,533,001

[a] Includes Delaware, District of Columbia, Louisiana, Nevada, New Mexico, and Washington.

Mineral waters sold in the United States in 1918 and 1919—Continued.

State.	Commercial springs.	Quanity sold (gallons).	Average price per gallon (cents).	Value of medicinal waters.	Value of table waters.	Total value.
1919.						
Alabama	5	4,694	33	$1,548	....	$1,548
Arkansas	7	1,084,373	5	42,301	$8,059	50,360
California	37	2,693,165	14	120,852	245,145	365,997
Colorado	9	391,851	21	38,309	42,778	81,087
Connecticut	28	1,216,184	5	100	61,050	61,150
Florida	5	192,935	6	1,522	10,540	12,062
Georgia	9	364,310	11	2,855	36,427	39,282
Illinois	6	364,934	6	131	21,020	21,151
Indiana	10	538,294	34	161,948	19,547	181,495
Iowa	5	39,661	14	2,570	3,133	5,703
Kansas	8	394,625	18	57,160	12,322	69,482
Kentucky	10	213,436	18	31,666	6,210	37,876
Maine	18	728,606	42	79,520	229,940	309,460
Maryland	8	1,077,253	10	....	105,397	105,397
Massachusetts	38	1,630,216	7	6,236	105,977	112,213
Michigan	10	1,570,906	8	60	132,252	132,312
Minnesota	12	2,731,967	4	....	113,776	113,776
Mississippi	7	124,788	23	29,126	....	29,126
Missouri	26	212,871	19	34,797	4,844	39,641
Montana	3	499,225	1	547	6,264	6,811
New Hampshire	3	197,012	5	1	8,940	8,941
New Jersey	14	1,244,983	12	31	143,272	143,303
New York	44	6,537,966	12	92,298	723,317	815,615
North Carolina	9	62,925	17	6,475	4,420	10,895
North Dakota	3	110,000	1	....	1,100	1,100
Ohio	24	2,341,853	6	8,503	134,467	142,970
Oklahoma	9	1,368,375	3	2,877	38,948	41,825
Oregon	3	2,600	44	120	1,020	1,140
Pennsylvania	28	872,595	10	3,859	79,724	83,583
Rhode Island	6	317,571	8	....	26,039	26,039
South Carolina	8	348,242	11	33,799	5,091	38,890
South Dakota	3	785,404	3	....	23,961	23,961
Tennessee	14	752,837	7	32,225	22,034	54,259
Texas	18	328,913	16	60,067	58	60,125
Vermont	5	107,600	15	8,125	7,630	15,755
Virginia	30	1,418,528	10	58,611	84,588	143,199
West Virginia	5	271,907	12	10,410	23,386	33,796
Wisconsin	29	5,113,289	28	43,056	1,403,311	1,446,367
Other States [a]	11	440,386	3	3,200	9,294	12,494
	527	38,697,280	13	974,905	3,905,281	4,880,186

[a] Includes District of Columbia, Louisiana, Nebraska, Nevada, New Mexico, Washington, and Wyoming

CONDITION OF TRADE.

The total quantity of mineral waters sold in 1919 was less than in any year since 1903 and yet the total value was more than it was in 1918, the increase being approximately 8 per cent. The decrease in sales of mineral waters during the war period is shown in the following table:

Mineral waters sold in the United States, 1913–1919.

Year.	Commercial springs.	Quantity sold (gallons).	Value.	Average price per gallon (cents).
1913	838	57,867,399	$5,631,391	10
1914	829	54,358,466	4,892,328	9
1915	812	52,113,503	5,138,794	10
1916	802	55,928,461	5,735,035	10
1917	717	46,784,419	4,931,710	11
1918	569	40,709,722	4,533,001	11
1919	527	38,697,280	4,880,186	13

Comparative production of mineral waters, 1918 and 1919.

State.	1918			1919				Increase or decrease in quantity sold.		Increase or decrease in value of product.	
	Commercial springs.	Quantity sold (gallons).	Value.	Commercial springs.	Quantity sold (gallons).	Value.	Increase or decrease in number of springs.	Gallons.	Per cent.	Dollars.	Per cent.
Alabama	7	6,315	$1,808	5	4,694	$1,548	− 2	− 1,621	− 26	− 260	− 14
Arkansas	8	863,142	70,626	7	1,084,373	50,360	− 1	+ 221,231	+ 26	− 20,266	− 29
California	38	2,399,144	433,010	37	2,693,165	365,997	− 1	+ 294,021	+ 12	− 67,013	− 15
Colorado	10	319,542	81,367	9	391,851	81,087	− 1	+ 72,309	+ 23	− 280	− 0.34
Connecticut	27	1,364,443	72,527	28	1,216,184	61,150	+ 1	− 148,259	− 11	− 11,377	− 16
Delaware	1	(a)	(a)	....	....	....	− 1	(a)	−100	(a)	−100
District of Columbia	1	(a)	(a)	1	(a)	(a)	......	(a)	(a)	(a)	(a)
Florida	5	164,630	12,883	5	192,935	12,062	......	+ 28,305	+ 17	− 821	− 6
Georgia	10	314,388	27,810	9	364,310	39,282	− 1	+ 49,922	+ 16	+ 11,472	+ 41
Illinois	13	921,953	43,448	6	364,934	21,151	− 7	− 557,019	− 60	− 22,297	− 51
Indiana	10	555,076	179,431	10	538,294	181,495	......	− 16,782	− 3	+ 2,064	+ 1
Iowa	4	87,703	3,937	5	39,661	5,703	+ 1	− 48,042	− 55	+ 1,766	+ 45
Kansas	9	403,862	75,359	8	394,625	69,482	− 1	− 9,237	− 2	− 5,877	− 8
Kentucky	11	255,852	41,997	10	213,436	37,876	− 1	− 42,416	− 17	− 4,121	− 10
Louisiana	1	(a)	(a)	1	(a)	(a)	......	(a)	(a)	(a)	(a)
Maine	21	829,338	266,168	18	728,606	309,460	− 3	− 100,732	− 12	+ 43,292	+ 16
Maryland	8	1,089,966	100,575	8	1,077,253	105,397	......	− 12,713	− 1	+ 4,822	+ 5
Massachusetts	43	1,999,592	125,208	38	1,630,216	112,213	− 5	− 369,376	− 18	− 12,995	− 10
Michigan	9	1,216,882	129,592	10	1,570,906	132,312	+ 1	+ 354,024	+ 29	+ 2,720	+ 2
Minnesota	16	2,248,731	99,159	12	2,731,967	113,776	− 4	+ 483,236	+ 21	+ 14,617	+ 15
Mississippi	7	175,533	47,539	7	124,788	29,126	......	− 50,745	− 29	− 18,413	− 39
Missouri	26	306,299	38,478	26	212,871	39,641	......	− 93,428	− 31	+ 1,163	+ 3
Montana	3	193,557	8,912	3	499,225	6,811	......	+ 305,668	+158	− 2,101	− 24
Nebraska	3	1,080	155	2	(a)	(a)	− 1	(a)	(a)	(a)	(a)
Nevada	1	(a)	(a)	1	(a)	(a)	......	(a)	(a)	(a)	(a)
New Hampshire	3	182,326	8,256	3	197,012	8,941	......	+ 14,686	+ 8	+ 685	+ 8
New Jersey	13	1,134,848	110,150	14	1,244,983	143,303	+ 1	+ 110,135	+ 10	+ 33,153	+ 30
New Mexico	1	(a)	(a)	2	(a)	(a)	+ 1	(a)	(a)	(a)	(a)
New York	50	5,887,746	566,910	44	6,537,966	815,615	− 6	+ 650,220	+ 11	+248,705	+ 44
North Carolina	10	65,422	8,174	9	62,925	10,895	− 1	− 2,497	− 4	+ 2,721	+ 33
North Dakota	3	530,000	13,700	3	110,000	1,100	......	− 420,000	− 79	− 12,600	− 92
Ohio	24	2,771,485	150,711	24	2,341,853	142,970	......	− 429,632	− 16	− 7,741	− 5
Oklahoma	8	1,166,485	20,249	9	1,368,375	41,825	+ 1	+ 201,890	+ 17	+ 21,576	+107
Oregon	4	13,550	1,825	3	2,600	1,140	− 1	− 10,950	− 81	− 685	− 38
Pennsylvania	30	1,400,456	123,436	28	872,595	83,583	− 2	− 527,861	− 38	− 39,853	− 32
Rhode Island	6	365,705	30,729	6	317,571	26,039	......	− 48,134	− 13	− 4,690	− 15
South Carolina	7	279,300	51,198	8	348,242	38,890	+ 1	+ 68,942	+ 25	− 12,308	− 24
South Dakota	3	454,865	17,269	3	785,404	23,961	......	+ 330,539	+ 73	+ 6,692	+ 39
Tennessee	13	990,027	53,367	14	752,837	54,259	+ 1	− 237,190	− 24	+ 892	+ 2
Texas	18	544,183	80,553	18	328,913	60,125	......	− 215,270	− 40	− 20,428	− 25
Vermont	4	95,700	17,090	5	107,600	15,755	+ 1	+ 11,900	+ 12	− 1,335	− 8
Virginia	35	1,745,105	173,912	30	1,418,528	143,199	− 5	− 326,577	− 19	− 30,713	− 18
Washington	1	(a)	(a)	2	(a)	(a)	+ 1	(a)	(a)	(a)	(a)
West Virginia	8	301,883	32,045	5	271,907	33,796	− 3	− 29,976	− 10	+ 1,751	+ 5
Wisconsin	32	6,630,725	1,193,345	29	5,113,289	1,446,367	− 3	−1,517,436	− 23	+253,022	+ 21
Wyoming	4	41,335	5,513	2	(a)	(a)	− 2	(a)	(a)	(a)	(a)
Other States [b]	....	391,548	14,580	....	440,386	12,494	......	+ 6,423	+ 1	− 7,754	− 38
	569	40,709,722	4,533,001	527	38,697,280	4,880,186	−42	−2,012,442	− 5	+347,185	+ 8

[a] Included under "Other States."
[b] Includes in 1918: Delaware, District of Columbia, Louisiana, Nevada, New Mexico, and Washington. in 1919: District of Columbia, Louisiana, Nebraska, Nevada, New Mexico, Washington, and Wyoming.

RANGE OF PRICE.

Effort has been made in compiling the following table, which gives the quantity and value of mineral waters sold within certain ranges of price during 1918 and 1919, to eliminate freight and marketing charges and the value of returnable containers, and thus to give the net value of the waters at their sources.

Range of price per gallon of mineral water, 1918 and 1919.

Price per gallon (in cents).	Number of springs.	Quantity sold (gallons).	Value.	Percentage of number of springs.	Percentage of total quantity.	Percentage of total value.
1918.						
Not more than 2	20	2,249,978	$39,575	4	5.5	0.9
More than 2 and not more than 5	115	12,240,608	459,269	21	30.1	10.0
More than 5 and not more than 10	222	17,248,581	1,390,842	40	42.3	31.0
More than 10 and not more than 20	89	4,507,057	681,890	16	11.1	15.0
More than 20 and not more than 30	38	518,147	134,732	7	1.3	3.0
More than 30 and not more than 50	36	3,095,801	1,189,595	7	7.6	26.1
More than 50 and not more than 100	25	701,049	467,502	4	1.7	10.3
More than 100	8	148,501	169,596	1	.4	3.7
	a 553	40,709,722	4,533,001	100	100.0	100.0
1919.						
Not more than 2	17	4,742,442	74,409	3	12	1
More than 2 and not more than 5	94	10,989,256	459,747	19	28	9
More than 5 and not more than 10	190	14,883,577	1,231,386	38	38	25
More than 10 and not more than 20	90	3,714,484	556,737	18	10	11
More than 20 and not more than 30	43	789,386	190,013	9	2	4
More than 30 and not more than 50	38	1,677,624	662,088	8	4	13
More than 50 and not more than 100	23	1,891,339	1,691,981	4	4	34
More than 100	6	9,172	13,825	1	2	3
	b 501	38,697,280	4,880,186	100	100	100

a Exclusive of 16 springs whose waters are used exclusively in the manufacture of soft drinks.
b Exclusive of 26 springs whose waters are used exclusively in the manufacture of soft drinks.

Practically four-fifths of the mineral waters sold brought prices ranging from half a cent to 10 cents a gallon during 1913, 1914, 1915, 1916, 1917, 1918, and 1919. The quantity sold for more than 30 cents a gallon was 9.2 per cent of the total in 1919, as compared with 9.7 per cent in 1918. The water from 301 springs was sold for 10 cents or less a gallon, and the water from 6 springs was sold for more than $1 a gallon. The average price per gallon in 1919 was 13 cents.

SOFT DRINKS.

Returns show that the quantity of mineral water used in the manufacture of soft drinks in 1919 was less than in 1918. The gross distribution of the consumption during 1919 is indicated in the following table. Massachusetts heads the list with a consumption greater than 1,900,000 gallons, and Wisconsin follows with about 750,000 gallons. In addition to Massachusetts and Wisconsin 11 states reported consumption exceeding 100,000 gallons each, and 26 other States reported a combined consumption of 702,457 gallons. This recorded consumption does not represent the total production of soft drinks in the United States, as most of them are compounded with municipal and private supplies not classified as mineral waters.

Mineral waters used in the manufacture of soft drinks in 1919.

Rank.	State.	Quantity (gallons).	Rank.	State.	Quantity (gallons).
1	Massachusetts	1,970,073	9	New York	271,636
2	Wisconsin	747,061	10	Ohio	245,800
3	Pennsylvania	623,676	11	Connecticut	208,515
4	South Carolina	420,000	12	California	167,843
5	Nebraska	400,000	13	Texas	100,292
6	Colorado	354,965		Other States	702,457
7	Iowa	321,500			
8	Minnesota	285,757			6,819,575

IMPORTS.

The total imports of natural mineral waters entered for consumption in the United States in 1919, as reported by the Bureau of Foreign and Domestic Commerce, Department of Commerce, amounted to 193,933 gallons, valued at points of shipment at $112,732, the average price per gallon being 58 cents. During the entire year 1,237,730 pounds of mineral salts obtained by evaporation from natural mineral waters were imported for consumption in this country. These imports were valued at $12,339.

Mineral waters imported for consumption in the United States, 1915–1919.

Year.	Quantity (gallons).	Value.	Price per gallon (cents).
1915	1,528,181	$551,648	36
1916	1,553,199	624,302	40
1917	618,405	268,665	43
1918 January to June	288,701	138,671	48
1918 July to December [a]	200,786	102,970	51
1919 [a]	193,933	112,732	58

[a] Natural mineral waters exclusively. Figures for first half of 1918 and for all preceding years include artificial mineral waters and imitation mineral waters, in addition to natural mineral waters.

The following table shows the general imports by principal countries. The figures include both natural and artificial mineral waters.

Mineral waters imported into the United States in 1919.

[General imports.]

Country.	Quantity (gallons).	Value.	Country.	Quantity (gallons).	Value.
Austria-Hungary	6,876	$2,164	Italy	13,095	$7,234
Australia	27	17	Japan	576	225
Canada	294	159	Netherlands	624	625
Cuba	18	38	Panama	3	3
France	121,164	64,212	Spain	3,567	3,788
Germany	105,348	54,394			
Greece	303	427		251,895	133,286

"General imports" and "imports for consumption" for any period will differ to the extent that the value of entries for warehouse for the period differs from the value of withdrawals from warehouse for consumption. The term "entry for consumption" is the technical name of the import entry made at the customhouse and implies that the goods have been delivered into the custody of the importer and that the duties have been paid on the dutiable portion.

EXPORTS.

Large quantities of a few domestic waters are exported, but no statistics regarding such shipments are available. The quantity and the value of these waters are included in the statistics of production for the United States.

MINERAL-WATER TRADE BY STATES.

ALABAMA.

Returns from Alabama indicate that the mineral-water trade in 1919 was about 26 per cent less in quantity than it was in 1918. The sales amounted to 4,694 gallons, and the value of the output was $1,548, the average price per gallon increasing from 29 cents to 33 cents. Two springs that were active in 1918 reported no sales in 1919. Three resorts accommodating about 160 guests and two bathing establishments were maintained. No mineral waters were used in the manufacture of soft drinks.

Sources of mineral waters sold in Alabama in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Bladon Springs	Choctaw	Bladon Springs		
Healing Springs	Washington	Healing Springs		
Luverne Mineral Springs	Crenshaw	Luverne		
Matchless Mineral Water Well	Butler	Greenville	Southeast	3
White Sulphur Well	Clarke	Jackson	do	1

ARKANSAS.

The sales of mineral waters in Arkansas during 1919 were 1,084,373 gallons, as reported from seven active springs, an increase in quantity of about 26 per cent over the output in 1918. The average price of the water, however, decreased from 8 cents to 5 cents, and the total value of the output amounted to $50,360, which was about 29 per cent less than the total value of sales in 1918. The decrease in value was for waters sold for both table and medicinal purposes.

From two springs which reported in 1918 no figures were obtainable in 1919, and one spring which did not report in 1918 reported sales in 1919.

About 60 guests, exclusive of Eureka (Springs) and Hot Springs, were accommodated, in addition to which 50,000 gallons of mineral water was used in the manufacture of soft drinks, as compared with 100,000 gallons used for this purpose in 1918.

Sources of mineral waters sold in Arkansas in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Arsenic Springs	Garland	Hot Springs		
Chewaukla Mineral Springs	do	do		
De Soto Spring	do	do		
Happy Hollow Springs	do	do	Northeast	1
Mountain Valley Springs	do	Mountain Valley	West	1½
Ozarka Springs	Carroll	Eureka Springs	East	1½
Raleigh Springs	Pulaski	Little Rock	Southwest	2¼

CALIFORNIA.

The output of mineral waters in California in 1919 showed an increase of about 12 per cent in quantity and a decrease of about 15 per cent in value as compared with the output in 1918.

The total quantity sold was 2,693,165 gallons. Medicinal waters sold for $120,852 and table waters for $245,145—a total of $365,997, the average price being 14 cents.

In 1919 reports were received from five springs from which no sales were made in 1918. One of these—Deer Lick Springs—reported sales for the first time. Mineral-water baths were maintained at 14 springs, and 12 resorts, accommodating about 2,800 guests, were operated. In the manufacture of soft drinks, 167,843 gallons of mineral water was used.

Mineral waters sold in California, 1915–1919.

Year.	Commercial springs.	Quantity sold (gallons).	Value.	Average price per gallon (cents).
1915	50	2,789,871	$532,817	19
1916	55	2,651,471	503,775	19
1917	52	2,566,491	455,360	18
1918	38	2,399,144	433,010	18
1919	37	2,693,165	365,997	14

Sources of mineral waters sold in California in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Alhambra Springs	Contra Costa	Martinez	Southwest	6
Alma Spring	Santa Clara	Alma	South	1
Arrowhead Springs	San Bernardino	Arrowhead Springs		
Barcal Spring	Sonoma	Preston	Northeast	1
Bartlett Spring	Lake	Bartlett Springs		
Bimini Hot Springs	Los Angeles	Los Angeles	West	3
Boyes Hot Springs	Sonoma	Boyes Springs		
Busch Springs	Mendocino	Potter Valley	Northwest	7½
Bythinia Well	Santa Barbara	Santa Barbara	West	4½
Castle Rock Mineral Springs	Shasta	Castella	East	1
Crystal Spring	Los Angeles	Los Angeles	Northwest	1½
Deer Lick Springs	Trinity	Knob	North	6½
Dollar Mountain Medical Springs	Lake	Middletown		
Elliotta Springs	Riverside	Riverside	North	1½
Elysian Spring	Los Angeles	Los Angeles		
Grizzly Springs	Lake	Wilbur Springs	West	4½
Holly Spring	Los Angeles	Los Angeles	Northwest	10
Iaqua Medicinal Spring	Humboldt	Eureka		
Lepori Vichy Springs	Napa	Napa	Northeast	3½
McGlashan Mineral Spring	Placer	Truckee	South	5¾
Magnesia	Sonoma	The Geysers		
Marin Mountain Spring	Marin	Sausalito		
Mok-Hill Mineral Spring	Calaveras	Mokelumne Hill	East	¼
Napa Rock and Priest-Napa Soda Springs	Napa	Soda Valley[a]		
Napa Soda Springs	do	Napa Soda Springs		
Polk Springs	Tehama	Butte Meadows	West	14
Pope Mineral Springs	Napa	Pope Valley	Southwest	6
Radium Sulphur Springs	Los Angeles	Los Angeles	Northwest	6
Richardson Springs	Butte	Chico	Northeast	12
Shanghai Spring	Marin	Sausalito	Northwest	3
Shasta Spring	Siskiyou	Shasta Springs		
Tamalpais Spring	Marin	San Rafael	Northwest	¼
Valley Springs	Calaveras	Valley Springs	Northeast	½
Veronica Medicinal Springs	Santa Barbara	Santa Barbara	West	4
Walters Mineral Springs	Napa	Pope Valley	Northeast	6
Wheelers Hot Springs	Ventura	Wheeler Springs		$\frac{1}{8}$
Witter Medical Springs	Lake	Witter Springs		

[a] Not a post office.

COLORADO.

In 1919 Colorado showed an increase, about 23 per cent, in the quantity of mineral waters sold for the first time since 1911. There was a slight decrease in the total value, from $81,367 in 1918 to $81,087 in 1919. The sales of medicinal waters increased from $34,284 in 1918 to $38,309 in 1919, and the sales of table waters decreased from $47,083 in 1918 to $42,778 in 1919.

Reports were received from nine active springs. Four bathing establishments were maintained—the same number as in 1918—and three resorts, accommodating about 1,800 guests. In the manufacture of soft drinks 354,965 gallons of water was used, as compared with 176,831 gallons in 1918.

Mineral waters sold in Colorado, 1915–1919.

Year.	Commercial springs.	Quantity sold (gallons).	Value.	Average price per gallon (cents).
1915	14	858,185	$63,104	7
1916	12	542,185	120,509	22
1917	12	442,815	65,169	15
1918	10	319,542	81,367	25
1919	9	391,851	81,087	21

Sources of mineral waters sold in Colorado in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Boulder Springs	Boulder	Crisman [a]	East	½
Canon City Soda Springs	Fremont	Canon City		
Clark Magnetic Mineral Well	Pueblo	Pueblo	South	1
Green Mineral Well	Fremont	Canon City		
Manitou, Navajo, Cheyenne, and Shoshone Springs.	El Paso	Manitou		
Pueblo Mineral Springs	Pueblo	Pueblo		
Ute, Ouray, Little Chief, and Geyser Iron Springs.	El Paso	Manitou		
Waunita Hot Springs	Gunnison	Waunita Hot Springs		
Yampa Hot Springs	Garfield	Glenwood Springs	North	½

[a] Not a post office.

CONNECTICUT.

The output of mineral waters in Connecticut decreased about 11 per cent in quantity and 16 per cent in value in 1919; the average price was about 5 cents. The returns for 1918 showed a very decided increase in the value of medicinal waters—from $3,127 in 1917 to $12,073—and a decrease—from $100,851 in 1917 to $60,454 in 1918—in the value of table waters sold. In 1919 a decrease of $11,973 in the sales of medicinal waters and an increase of $596 in the sales of table waters were reported.

Silver Spring reported for the first time. Oak Spring is now called Silver Rock Spring. Twenty-eight active springs reported, or one more than in 1918. No resorts or mineral-water baths were reported.

About 208,515 gallons of mineral waters was used in the manufacture of soft drinks, a decrease of 70,148 gallons from the quantity used in 1918.

Mineral waters sold in Connecticut, 1915-1919.

Year.	Commercial springs.	Quantity sold (gallons).	Value.	Average price per gallon (cents).
1915	38	1,774,213	$101,970	6
1916	34	2,837,878	133,768	5
1917	31	1,964,096	103,978	5
1918	27	1,364,443	72,527	5
1919	28	1,216,184	61,150	5

Sources of mineral waters sold in Connecticut in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Bailey Natural Spring	Fairfield	Danbury	West	2
Beaver Spring	New Haven	Ansonia	East	1
Camp Meeting Spring	do	Milford	Northwest	2½
Cherry Hill Spring	do	Highwood	North	2
Crystal Spring	Middlesex	Middletown	Northwest	2½
Do	New Haven	Derby	North	1¼
East Hill Spring	do	do		
Elco Springs	Hartford	Bristol	West	1½
Glacier Spring	Fairfield	Fairfield	Northwest	3½
Granite Rock Spring	Middlesex	Higganum	Southeast	1
Gra-Rock Spring	Hartford	Canton	Southwest	¼
Hermitage and Rockledge Springs.	New Haven	New Haven	Northeast	4
Highland Spring	Middlesex	Meriden	do	4
Hillside Spring	New Haven	do	West	1½
Hosmer Mountain Spring	Windham	Willimantic		
Indian Spring	Fairfield	Shelton	West	⅓
Live Oak Spring	New Haven	Meriden	Southeast	¾
Mammanasco Spring	Fairfield	Ridgefield	Northwest	4
Pequabuck Mountain Spring	Hartford	Bristol	West	2
Pequot Mineral Spring	New London	Old Mystic		
Pequot Spring	Hartford	Glastonbury	Northeast	1
Richardson Spring	Litchfield	Torrington	Southwest	1½
Rock Spring	Fairfield	Bridgeport	Northwest	3½
Silver Rock Spring	Middlesex	Middletown		
Silver Spring	New London	Berlin		3
Stafford Spring	Tolland	Stafford Springs	Southwest	1/10
Varuna Spring	Fairfield	Stamford	North	6
Venture Rock Spring	New London	Stonington	Southeast	4

DISTRICT OF COLUMBIA.

One spring in the District of Columbia reported sales in 1919, namely, Red Oak Spring, near Langdon.

FLORIDA.

Returns from Florida showed an increase of 17 per cent in quantity and a decrease of 6 per cent in value of mineral waters sold in 1919, as compared with 1918. Five springs were active in 1919, the same number as in 1918.

The total output was 192,935 gallons, valued at $12,062. The average price per gallon was 6 cents.

Three bathing establishments and three resorts, accommodating 725 persons, were maintained.

Sources of mineral waters sold in Florida in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Espiritu Santo Springs	Pinellas	Safety Harbor		
Good Hope Mineral Wells	Duval	Jacksonville	Northwest	6
Newport Sulphur Spring	Wakulla	Newport	South	1
Purity Springs	Hillsborough	Tampa	North	6
Quisisana Spring	Clay	Green Cove Springs	East	1/10

GEORGIA.

The sales of mineral waters in Georgia increased 16 per cent in quantity and 41 per cent in value in 1919, and the price per gallon rose to 11 cents. The sales were 364,310 gallons, valued at $39,282. One bathing establishment and two resorts, accommodating 750 guests, were maintained at springs. Three springs active in 1918 were idle in 1919; and two springs from which no reports were received in 1918 were active in 1919.

Sources of mineral waters sold in Georgia in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Benscot Mineral Springs	Cobb	Austell	Northwest	3/4
Bowden Spring	Douglas	Lithia Springs		
Catoosa Springs	Catoosa	Tunnel Hill	North	3
Crystal Mineral Springs	Chatham	Savannah		6
Flake Spring	Richmond	Gracewood	Southwest	2½
High Rock Spring	Fulton	Atlanta	East	3
Jay Bird Spring	Dodge	Helena	North	7
White Oak Mineral Well	Bibb	Macon	West	4
Windsor Spring	Richmond	Gracewood	West	3

ILLINOIS.

The sales of mineral waters in Illinois decreased 60 per cent in quantity and 51 per cent in value in 1919. The total sales were 364,934 gallons, valued at $21,151, of which $131 was received for medicinal waters and $21,020 for table waters. Seven springs active in 1918 reported no sales for 1919.

The quantity of mineral waters used in the manufacture of soft drinks decreased from 32,668 to 18,598 gallons. One resort accommodating about 150 guests and two mineral-water bathing establishments were maintained.

Mineral waters sold in Illinois, 1915–1919.

Year.	Commercial springs.	Quantity sold (gallons).	Value.	Average price per gallon (cents).
1915	23	1,559,489	$75,290	5
1916	21	1,777,741	94,056	5
1917	16	1,370,461	66,042	5
1918	13	921,953	43,448	5
1919	6	364,934	21,151	6

Sources of mineral waters sold in Illinois in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Gravel Springs	Morgan	Jacksonville	Northwest	5
Minerva Mineral Spring	McHenry	Cary Station	Southwest	1/8
Na-mo-no-ma; Old Ironsides; Springs	Pope	Dixon Springs	Northwest	
Ripley Mineral Spring	Brown	Ripley	do	2
Sanicula Mineral Spring	La Salle	Ottawa		

INDIANA.

Indiana sold 538,294 gallons of mineral waters in 1919—3 per cent less than in 1918—valued at $181,495. The average price per gallon increased from 32 to 34 cents. Ten springs reported sales in 1919 the same as in 1918. Five bathing establishments and four resorts, accommodating about 900 guests, were maintained.

Sources of mineral waters sold in Indiana in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Blue Cast Well	Allen	Woodburn		
Bronson Well	Vigo	Terre Haute	East	
Carlson's Mineral Springs	La Porte	La Porte	North	8
Cartersburg Spring	Hendricks	Cartersburg		
Greenwood Spring	Allen	Fort Wayne		
Holman Mineral Well	Montgomery	Crawfordsville	Southwest	1¼
McCullough Springs	Gibson	Oakland City	South	1¼
Mount Jackson Mineral Well	Marion	Indianapolis	West	4
Pluto, Proserpine, and Bowles Springs	Orange	French Lick	North	
White Crane Well	Dearborn	Dillsboro	West	1

IOWA.

The reported output of mineral waters in Iowa during 1919 was 39,661 gallons, sold for $5,703, as compared with 87,703 gallons, sold for $3,937, in 1918. These figures correspond to a decrease in quantity of 55 per cent and to an increase in value of 45 per cent. The average price increased from 4 to 14 cents. More than 300,000 gallons of mineral waters was used in the manufacture of soft drinks. No mineral-water bathing establishments were maintained, but one resort accommodating about 100 persons was operated.

Sources of mineral waters sold in Iowa in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Crystal Spring	Emmet	Estherville	Southwest	1
Fry's Well	Jasper	Colfax	Northeast	
Grand Hotel Mineral Spring	do	do		
Hawkeye Hygeia Well	Woodbury	Sioux City	West	
Lime Rock	Dubuque	Dubuque	North	3

KANSAS.

The mineral-water business in Kansas showed a decrease in 1919 in both quantity and value. The total sales amounted to 394,625 gallons, or 2 per cent less than in 1918, and were valued at $69,482, or 8 per cent less than in 1918. The average price per gallon dropped from 19 to 18 cents. Three mineral-water bathing establishments accommodated 65 guests at two resorts. In addition to the quantity reported sold, 26,200 gallons of mineral waters was used in the manufacture of soft drinks.

Sources of mineral waters sold in Kansas in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Abilena Wells	Dickinson	Abilene		
Aganippe Spring	Montgomery	Independence	Southeast	4¾
Blasing's Springs	Riley	Manhattan	do	12
Crystal Springs	Montgomery	Coffeyville	Northeast	1½
Nature's Best Wells	Summer	Conway Springs	Southwest	½
Sycamore Mineral Springs	Brown	Morrill	Northwest	4¾
Viola Springs	Sedgewick	Viola	North	5
Waconda Springs	Mitchell	Waconda Springs	South	

KENTUCKY.

The reports for 1919 show a decline in both the quantity and the value of mineral waters sold in Kentucky. The total sales amounted to 213,436 gallons, valued at $37,876, corresponding to decreases of 17 per cent in quantity and 10 per cent in value. The average price increased from 16 to 18 cents. Two springs which marketed water in 1918 reported no sales in 1919; and one spring idle in 1918 reported sales in 1919; thus the total number of active springs was 10.

One resort, accommodating 110 guests, exclusive of the capacity of Dawson Springs, and 3 mineral-water bathing establishments were maintained. In addition to this 76,900 gallons of mineral water was used in making soft drinks.

Sources of mineral waters sold in Kentucky in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Anita Springs	Oldham	La Grange	Southwest	1
Cole's Lexington Lithia Springs	Fayette	Lexington	North	2
Doom's Wells	Hopkins	Dawsonsprings		
Hamby's Well	do	do	South	
H. and H. Well	do	do		
Kentucky Carlsbad Spring	Grant	Dry Ridge	West	$\frac{1}{8}$
Kentucky Mineral Well	Taylor	Campbellsville	South	5
Redden's Wells	Hopkins	Dawsonsprings	East	$\frac{1}{6}$
Robson Spring	Campbell	Fort Thomas		
Royal Magnesian Spring	Oldham	La Grange	West	1

LOUISIANA.

Krotz Springs, Krotz Springs, St. Landry Parish, was the only one in the State for which sales were reported in 1919 The water was sold for medicinal purposes.

MAINE.

The output of mineral water in Maine was 728,606 gallons, valued at $309,460; the number of active springs decreased from 21 to 18. The average price per gallon was 42 cents. Three springs active in 1918 reported no sales in 1919; three springs from which no reports were received were omitted; one spring from which no report was received was estimated; and three springs which reported no sales in 1918 were active in 1919.

The mineral water used in Maine in the manufacture of soft drinks was 590 gallons, a decrease of 69,606 gallons from the quantity used in 1918. One resort for guests was maintained, but no bathing establishments using mineral water were reported.

Mineral waters sold in Maine, 1915–1919.

Year.	Commercial springs.	Quantity sold (gallons).	Value.	Average price per gallon (cents.)
1915	24	1,115,648	$338,003	30
1916	24	1,038,861	353,792	34
1917	24	1,014,084	343,587	34
1918	21	829,338	266,168	32
1919	18	728,606	309,460	42

Sources of mineral waters sold in Maine in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Baker Puritan Spring	York	Old Orchard	Northwest	1½
Forest Springs	Kennebec	Gardiner	Southwest	6
Glenrock Cold Spring	Androscoggin	Greene	South	2
Hanover Spring	Oxford	Hanover	Northwest	¾
Keystone Mineral Spring	Androscoggin	Poland		
Mount Desert Spring	Hancock	Northeast Harbor	North	1
Mount Kebo Spring	do	Bar Harbor		
Mount Zircon Spring	Oxford	Rumford Falls		
Mystic Spring	York	Saco		
Oak Grove Spring	Penobscot	Brewer	Northeast	1
Paradise Spring	Cumberland	Brunswick		
Paradise No. 2 Spring	do	do		
Poland Mineral Spring	Androscoggin	Poland	do	½
Purity Spring	Cumberland	West Scarboro	Southwest	1½
Rocky Hill Spring	Somerset	Fairfield	North	2
Skowhegan Crystal Spring	do	Skowhegan		1
Underwood Spring	Cumberland	Portland	Northeast	7
Wawa Lithia Spring	York	Moody	South	¼

MARYLAND.

Reports for 1919 show a decrease of 1 per cent in quantity and an increase of 5 per cent in value of mineral water sold in Maryland. There was an increase in 1918 of 5 per cent in quantity and 16 per cent in value. The total sales in 1919 amounted to 1,077,253 gallons, valued at $105,397. The output was all table water. In addition to the quantity reported sold, 91,359 gallons was used in the manufacture of soft drinks, as compared with 119,642 gallons in 1918. No resorts or bathing establishments using mineral water were maintained.

Mineral waters sold in Maryland, 1915–1919.

Year.	Commercial springs.	Quantity sold (gallons).	Value.	Average price per gallon (cents).
1915	10	1,433,406	$105,581	7
1916	9	1,312,788	99,020	8
1917	7	1,036,045	86,938	8
1918	8	1,089,966	100,575	9
1919	8	1,077,253	105,397	10

Sources of mineral waters sold in Maryland in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Big Rock Spring	Frederick	Thurmont	West	1
Brooklandwood Spring	Baltimore	Lutherville	do	2½
Buena Vista Spring	Washington	Edgemont		
Caton Spring	Baltimore	Catonsville	East	1
Chattolanee Springs	do	Garrison	Southeast	1
Green Spring	Washington	Big Spring	Southwest	2
Mardela Mineral Spring	Wicomico	Mardela Springs		
Rock Crystal Spring	Baltimore	Baltimore	West	4

MASSACHUSETTS.

Returns from Massachusetts for 1919 indicate a decrease of 18 per cent in quantity and 10 per cent in value of mineral waters sold. The average price per gallon increased from 6 to 7 cents. The sales amounted to 1,630,216 gallons, valued at $112,213. In addition to the quantity reported as sold, 1,970,073 gallons was used in the manufacture of soft drinks, as compared with 1,819,246 gallons in 1918.

Four springs active in 1918 reported no sales in 1919; four springs active in 1918 were not heard from in 1919; and three springs from which no reports were received in 1918 were active in 1919. One small resort was maintained, and one mineral-water bathing establishment was reported.

Mineral waters sold in Massachusetts, 1915–1919.

Year.	Commercial springs.	Quantity sold (gallons).	Value.	Average price per gallon (cents).
1915	48	3,872,192	$184,133	5
1916	51	3,124,096	128,478	4
1917	48	2,908,638	139,075	5
1918	43	1,999,592	125,208	6
1919	38	1,630,216	112,213	7

Sources of mineral waters sold in Massachusetts in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Abbotts Spring	Essex	Methuen	East	2½
Avonia Spring	Norfolk	Weymouth		
Ballardvale Springs	Essex	North Wilmington	Northeast	2
Belmont Crystal Spring	Middlesex	Belmont	do	1½
Burnham Spring	Essex	Methuen		
Cascella Springs	Hampden	Palmer		
Chapman's Crystal Mineral Spring.	Middlesex	Stoneham		
Chelmsford Spring	Hampden	Chelmsford	Southwest	1
Crystal Spring	Essex	West Peabody	Northwest	½
Deep Glen Spring	do	West Lynn	North	1½
El-Azhar Spring	Middlesex	Tyngsboro	East	3
Goulding Spring	Plymouth	Whitman	West	1
Great Radium Springs	Berkshire	Pittsfield	Northwest	2½
Holyoke Spring	Essex	West Lynn		
King Philip Spring	Plymouth	Mattapoisett	North	2
Klines Spring	Essex	Lawrence		
Milton Spring	Norfolk	Milton		
Monatiquot Spring	do	South Braintree	East	1
Mount Blue Mineral Spring	Plymouth	North Scituate	West	5
Mount Holyoke Spring	Hampshire	South Hadley		
Mount Pleasant Spring	Middlesex	Lowell	Southwest	2½
New Abbott Spring	Essex	Methuen	West	2½
Nobscot Mountain Spring	Middlesex	Framingham		
Old Homestead Springs	Essex	Lawrence		
Pearl Hill Spring	Worcester	Fitchburg	East	1½
Pepperell Spring	Middlesex	Pepperell	North	2
Pocahontas Spring	Essex	Lynnfield Center	do	1
Polar Spring	Worcester	Spencer	Northeast	2
Puritan Spring	Essex	Andover	South	1½
Purity Spring	do	Danvers	Southeast	2
Do	Middlesex	Chelmsford	North	2½
Robbins Spring	do	Arlington Heights	Southwest	1½
Sand Spring	Berkshire	Williamstown		
Shawmut Spring	Norfolk	East Milton	Southwest	1¼
Simpson Spring	Bristol	South Easton	South	1¾
Sterling Spring	Essex	West Lynn	West	3
Whitman Spring	Plymouth	Whitman	North	
Wilbraham Spring	Hampden	Wilbraham	West	

MICHIGAN.

The total sales of mineral waters in Michigan in 1919 was 1,570,906 gallons, as compared with 1,216,882 in 1918, an increase of 29 per cent; and the total value was $132,312, as compared with $129,592 in 1918. The sales of table waters amounted to $132,252, and medicinal waters netted only $60. One spring active in 1918 was not heard from in 1919 and has been considered idle, and two springs from which no reports were received in 1918 reported sales in 1919; thus the number of active springs increased from 9 to 10. Two resorts accommodating 1,000 guests were maintained, and one bathing establishment was operated.

Mineral waters sold in Michigan, 1915–1919.

Year.	Commercial springs.	Quantity sold (gallons).	Value.	Average price per gallon (cents).
1915	19	913,765	$72,711	8
1916	18	996,875	108,867	11
1917	12	1,069,164	105,641	10
1918	9	1,216,882	129,592	11
1919	10	1,570,906	132,312	8

Sources of mineral waters sold in Michigan in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Andrews Magnetic Mineral Spring.	Gratiot	Saginaw West Side		
Arctic Spring	Kent	Grand Rapids	Northwest	½
Deep Springs	Wayne	Northville		
Mount Clemens Well	Macomb	Mount Clemens		
Ogemaw Spring	Ogemaw	Maltby	South	½
Panacea Spring	Macomb	Mount Clemens		
Ponce de Leon Spring	Kent	Grand Rapids	South	6
Silver Springs	Wayne	Northville		
Sultana Mineral Spring	Van Buren	West Hartford		
Victory Springs	Macomb	Mount Clemens		

MINNESOTA.

According to reports received from 12 active springs in Minnesota, the sales of mineral waters in that State increased 21 per cent in quantity and 15 per cent in value in 1919. The total output was 2,731,967 gallons, valued at $113,776. The entire output was table water. The average price per gallon was 4 cents.

Glen Springs reported sales for the first time. Two mineral-water bathing establishments were operated at springs. In addition to the sales reported 285,757 gallons was used in the manufacture of soft drinks.

Mineral waters sold in Minnesota, 1915–1919.

Year.	Commercial springs.	Quantity sold (gallons).	Value.	Average price per gallon (cents).
1915	17	3,493,887	$136,259	4
1916	18	4,188,434	145,582	3
1917	17	3,004,546	109,964	4
1918	16	2,248,731	99,159	4
1919	12	2,731,967	113,776	4

Sources of mineral waters sold in Minnesota in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Campbells Spring	Ottertail	Fergus Falls		
Clear Spring	Hennepin	Hopkins	West	5
Glen Springs	do	Excelsior		
Glenwood-Inglewood Spring	do	Minneapolis	West	2½
Indian Medical Spring	Sherburne	Elk River		
Highland Spring	Ramsey	St. Paul	Southeast	3
Ogahmah Spring	Pennington	Thief River Falls		
Owens Spring	Pope	Glenwood	North	1
Pokegama Spring	Becker	Detroit	East	2
Red Star Springs	Stearns	Cold Spring	Northeast	¼
Rock Spring	Scott	Shakopee		
Silver Spring	Lyon	Marshall		
Do	Bigstone	Ortonville	North	
Ward Springs	Todd	Ward Springs	South	1

MISSISSIPPI.

The mineral-water business in Mississippi, which decreased in 1918, underwent a further decrease of 29 per cent in quantity and 39 per cent in value in 1919, the sales reported being 124,788 gallons, all classed as medicinal water, valued at $29,126, as compared with 175,533 gallons, valued at $47,539, in 1918. The price per gallon decreased from 27 to 23 cents. One spring active in 1918 reported no sales in 1919, and one spring idle in 1918 reported sales in 1919. Two mineral-water bathing establishments and four resorts, accommodating about 500 guests, were maintained at springs.

Sources of mineral waters sold in Mississippi in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Allison's Wells	Madison	Way	East	1
Arundel Spring	Lauderdale			
Brown's Wells	Copiah	Hazlehurst	West	10
Morris Mineral Spring	Jasper	Vosburg	North	¼
Red Spring	Montgomery	Stewart	Southwest	3
Robinson Spring	Madison	Pocahontas		Near.
Stafford Spring	Jasper	Vosburg	East	2

MISSOURI.

The decrease in the sales of mineral waters in 1918 in Missouri was followed by a further decline in the output in 1919 of 31 per cent in quantity, but an increase of 3 per cent in value. The total output for 1919 was 212,871 gallons, valued at $39,641. The average price per gallon increased from 13 to 19 cents. In addition to the quantity reported as sold, 37,706 gallons was used in the manufacture of soft drinks, an increase over the quantity reported for 1918 of 23,919 gallons. Reports for 1919 were received from 26 active springs, the same number as in 1918. Two resorts, exclusive of those at Excelsior Springs, and three mineral-water bathing establishments were operated.

Sources of mineral waters sold in Missouri in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
B. B. Spring	Pike	Bowling Green		
Belcher Artesian Well	St. Louis	St. Louis		
Bokert Springs	Jefferson	De Soto	West	4
Chalybeate Spring	Lawrence	Paris Springs		
Chouteau Springs	Cooper	Boonville	Southwest	10
Crystal Mineral and Saline Soda Wells.	Clay	Excelsior Springs		
Cusenbary Spring	Jackson	Mount Washington		
Eldorado Aperient Water Well.	Cedar	Eldorado Springs		
Excelsior Saline Well	Clay	Excelsior Springs		
Fonzo Spring	Pike	Bowling Green		
Grand River Mineral Spring	Mercer	Mercer	Northwest	5½
Hornet Spring	Pike	Bowling Green		
Jackson Spring	Jackson	Mount Washington	North	⅝
Laxative Mineral Well	Cedar	Eldorado Springs		
Natrona Wells	Clay	Excelsior Springs	Northeast	¼
Old Orchard Mineral Spring	St. Louis	Webster		
Park Spring	Cedar	Eldorado Springs		
Regent, Siloam, Soterian, Sulpho-Saline Springs.	Clay	Excelsior Springs		
Salax Well	do	do		
Soda Saline Well	Clay	Missouri City		
Sweet Spring	Saline	Sweet Springs	South	1
White Spring	Jackson	Independence		

MONTANA.

The sales from three springs reporting from Montana in 1919 were 499,225 gallons, valued at $6,811. This represented an increase in quantity in 1919 of 158 per cent and a decrease in value of 24 per cent. The same springs active in 1918 reported for 1919.

Mineral-water bathing establishments were maintained at one of these springs, and one resort accommodating 100 guests was reported. Practically all the water was sold for table use.

Sources of mineral waters sold in Montana in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Alhambra Hot Springs	Jefferson	Alhambra		
Lissner Mineral Spring	Lewis and Clark	Helena	Southeast	¾
Rock Creek	Carbon	Red Lodge		

NEBRASKA.

Reports were received from two springs in Nebraska in 1919—Brown Park Mineral Springs and Curo Mineral Springs. One bathing establishment was maintained at one of the springs, and a small resort was operated.

NEVADA.

One spring in Nevada reported sales of mineral waters in 1919, the entire output being sold for table use.

The spring is called Diamond Spring, Reno, Washoe County.

NEW HAMPSHIRE.

Returns from New Hampshire indicate an increase in both quantity and value of mineral water marketed in 1919. The total sales in 1919 were 197,012 gallons, as compared with 182,326 gallons in 1918, and the total value of the output was $8,941, as compared with $8,256 in 1918. Almost the entire output was classified as table water. The average price per gallon remained the same, 5 cents. One spring active in 1918 was not heard from in 1919 and was omitted; and another spring from which no report of sales was received in 1918 was active in 1919. No new springs were reported. In addition to the mineral water sold 84,200 gallons was used in the maufacture of soft drinks, as compared with 377,403 gallons in 1918, a decrease of 78 per cent.

Sources of mineral waters sold in New Hampshire in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Granite State Springs	Rockingham	Atkinson Depot	Northeast	¼
Laconia Spring	Belknap	The Weirs		
Wilton Mineral Spring	Hillsborough	Wilton		

NEW JERSEY.

The sales of mineral waters in New Jersey increased from 1,134,848 gallons in 1918 to 1,244,983 gallons in 1919, a gain in quantity of nearly 10 per cent and in value from $110,150 to $143,303, or about 30 per cent. The average price per gallon was 12 cents. Most of the output was classified as table water. In addition to the water reported as sold, 88,176 gallons was used in the manufacture of soft drinks, as compared with 47,264 gallons used in that business in 1918. No new springs were reported; one spring from which no sales were reported in 1918 was active in 1919, and the output of two springs not heard from in 1919 was estimated. No mineral-water baths nor resorts were reported to have been maintained.

Mineral waters sold in New Jersey, 1915–1919.

Year.	Commercial springs.	Quantity sold (gallons).	Value.	Average price per gallon. (cents).
1915	13	1,479,479	$116,226	8
1916	15	1,580,028	130,993	8
1917	14	1,283,157	115,188	9
1918	13	1,134,848	110,150	10
1919	14	1,244,983	143,303	12

Sources of mineral waters sold in New Jersey in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Alpha Spring	Union	Springfield	Southwest	3½
Belmar Spring	Bergen	Ridgewood	South	1
Cold Indian Spring	Monmouth	Asbury Park	West	3½
Culm Rock Spring	Somerset	Pluckemin		
Echo Spring	Mercer	Trenton	North	5
Grey Rock Artesian Well	do	do		
Indian Spring	Morris	Rockaway		
Indian Lady Hill Springs	Monmouth	Asbury Park		
Kalium Spring	Camden	Collingswood	Southeast	½
Kanouse-Oakland Spring	Bergen	Oakland	West	1
Pilgrim Spring	do	Ridgefield Park		
Rock Spring	Essex	West Orange		
Washington Rock Spring	Somerset	Plainfield		
Watchung Spring	do	do	North	2½

NEW MEXICO.

Reports of sales of mineral waters in New Mexico in 1919 were received from Aztec Mineral Springs, near Taylor Springs, Colfax County, and Coyote Spring, Bernalillo County, 12 miles east of Albuquerque.

NEW YORK.

The State of New York in 1919 ranked first in number of active mineral springs, first in total quantity of mineral waters sold, second in total value of sales and in value of table waters, third in value of medicinal waters, and ninth in consumption of mineral waters for the manufacture of soft drinks. Comparison of figures for 1919 with those of 1918 shows an increase of 11 per cent in quantity and of 44 per cent in value. Most of the water was sold for table use. In 1919 there were 44 active springs, as against 50 in 1918. An additional quantity of 271,636 gallons was used in the manufacture of soft drinks in 1919. Two mineral-water bathing establishments were operated in 1919. Two springs from which no reports were received were estimated.

Mineral waters sold in New York, 1915–1919.

Year.	Commercial springs.	Quantity sold (gallons).	Value.	Average price per gallon (cents).
1915	75	8,411,616	$711,697	8
1916	68	7,746,490	697,650	9
1917	65	7,819,314	562,874	7
1918	50	5,887,746	566,910	10
1919	44	6,537,966	815,615	12

Sources of mineral waters sold in New York in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Arlington Spring	Dutchess	Arlington	North	3
Baldwin Mineral Spring	Cayuga	Cayuga	Northeast	2
Carrier Spring	St. Lawrence	Potsdam		
Cascadian Spring	Rockland	Grand View		
Chester Crest Spring	Westchester	Mount Vernon	North	1
Clinton Mineral Spring	Oneida	Franklin Springs	South	½
Clysmic Spring	Ulster	Ellenville		½
Coesa Spring	Saratoga	Saratoga Springs	Southwest	2½
Cold Spring	St. Lawrence	Starlake	South	½
Comstock Well	Saratoga	Ballston Spa	Northeast	½
Crystal Springs	Oneida	Whitesboro	Southwest	¼
Deer Run Springs	Chautauqua	Dunkirk	South	2
Eagle Spring	Greene	Lanesville	Northeast	3
Elixir Spring	Ulster	Clintondale		
Elk Spring	Erie	Lancaster	East	2
Ferndell Spring	Saratoga	Saratoga Springs	Southwest	2
Flint Spring	Rensselaer	West Sand Lake		
Franklin Lithia Spring	Oneida	Franklin Springs	South	¼
Gardner White Sulphur Springs	Schoharie	Sharon Springs	North	⅛
Geyser Spring	Saratoga	Saratoga Springs	Southwest	2
Glen Alex Spring	Oneida	Washington Mills	East	$\frac{7}{10}$
Gramatan Spring	Westchester	Bronxville	East	½
Granite Spring	do	Granite Springs		
Great Bear Springs	Oswego	Fulton	South	5
Greendale Crystal Springs	Columbia	Greendale	East	3
Hathorn No. 2	Saratoga	Saratoga Springs	Southwest	4¾
Ideal Spring	Rensselaer	Troy		
Lithia Polaris and Adirondack Springs.	Oneida	Boonville	South	2
Mammoth Spring	Rensselaer	West Sand Lake	West	2
Mohawk Spring	Montgomery	Amsterdam		
Plymouth Spring	Rensselaer	Troy	South	3
Risley Cold Springs	Oneida	New York Mills		
Saratoga Vichy Spring	Saratoga	Saratoga Springs		
Shell Rock Spring	Suffolk	Rensselaer	South	4
Sparkling Spring	Erie	Buffalo		
Split Rock Lithia Spring	Oneida	Franklin Springs	South	¼
Standard Spring	Rensselaer	Troy		
Table Rock Mineral Spring	Monroe	Honeoye Falls	Northwest	1½
Taconic Spring	Dutchess	Beacon	Southeast	2½
Tréspur Artesian Well	Cortland	McGraw	Southwest	⅛
Victoria No. 2 Spring	Saratoga	Saratoga Springs		
Vita Spring	Washington	Fort Edward	Southeast	1½
Westmoreland Mineral Spring	Oneida	Westmoreland	Northeast	½
White Bear Spring	Genesee	Batavia	East	3

NORTH CAROLINA.

The sales of mineral waters in North Carolina showed a decrease in 1919 of 4 per cent in quantity and an increase of 33 per cent in value. The average price per gallon increased from 12 to 17 cents. The sales amounted to 62,925 gallons, valued at $10,895, as compared with 65,422 gallons, valued at $8,174, in 1918. One spring from which no report of sales was received in 1918 was active in 1919; and two springs active in 1918 reported no sales in 1919. Four resorts, accommodating about 600 guests, and two establishments for bathing in mineral water were maintained at springs.

Sources of mineral waters sold in North Carolina in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
All Healing Spring	Alexander	Taylorsville	West	6
Derita Calcic Spring	Mecklenburg	Derita	East	1
Haywood White Sulphur Springs.	Haywood	Waynesville		
Huckleberry Springs	Durham	West Durham	Southwest	2
Moores Springs	Stokes	Moores Springs		
Rivermont Carbonated Spring	Durham	West Durham	Southwest	3½
Seven Springs	Wayne	Sevensprings	West	½
Shelby Lithia Springs	Cleveland	Shelby	North	3
Vade Mecum Spring	Stokes	Vade Mecum		

NORTH DAKOTA.

Reports of sales were received from three active springs in North Dakota—the same number as in 1918—which showed a decrease in sales of 79 per cent in quantity and of 92 per cent in value. The total output was 110,000 gallons, valued at $1,100, as compared with 530,000 gallons, valued at $13,700 in 1918. In addition to the quantity reported as sold, 5,000 gallons was used in the manufacture of soft drinks, a very considerable decrease from 30,000 gallons, the quantity used in 1918.

Sources of mineral waters sold in North Dakota in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Granite Spring	Ward	Minot		
Kenmare Spring	do	Kenmare		
Stony Creek Well	Burke	Bowbells	East	1¼

OHIO.

Returns from Ohio in 1919 showed a decrease in the sales of mineral waters of 16 per cent in quantity and of 5 per cent in value. The total output was 2,341,853 gallons, valued at $142,970, as compared with 2,771,485 gallons, valued at $150,711, in 1918. The average price per gallon rose to 6 cents. The mineral water used in the manufacture of soft drinks increased from 145,000 gallons to 245,800 gallons. Two springs active in 1918 reported no sales in 1919; and two springs from which no sales were reported in 1918 were active in 1919. Two resorts, accommodating about 160 guests, and one mineral-water bathing establishment were maintained.

Mineral waters sold in Ohio, 1915–1919.

Year.	Commercial springs.	Quantity sold (gallons).	Value.	Average price per gallon (cents).
1915	36	3,504,343	$133,416	4
1916	37	4,102,922	161,160	4
1917	31	3,113,093	136,710	4
1918	24	2,771,485	150,711	5
1919	24	2,341,853	142,970	6

Sources of mineral waters sold in Ohio in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Alba Springs	Cuyahoga	West Park		
Beech Rock Spring	Muskingum	Zanesville		
Bellmore Spring	Columbiana	Signal		
Collingwood Well	Lucas	Toledo		
Crystal Springs	Licking	Newark	North	2
Deerfield Mineral Springs	Portage	Deerfield		
Elm Meade Spring	Trumbull	Youngstown	Northwest	4
Fargo Mineral Springs	Ashtabula	Ashtabula	Southeast	¼
Fisher's Magnesia Mineral Spring.	Franklin	Columbus		
Gibson Spring	Mahoning	Youngstown	South	1
Glenwood Mineral Spring	Ross	Chillicothe	West	8
La France Spring	Lucas	Toledo	do	4½
Minnehaha Spring	Cuyahoga	West Park		
Oak Place Spring	Summit	Akron		
Oak Ridge Mineral Springs	Sandusky	Greenspring		
Peerless and Puritas Springs	Cuyahoga	West Park		
Pine Tree Spring	Lake	Willoughby	Southeast	2
Puritas Spring	Cuyahoga	Berea		
Purity Spring	do	South Euclid		
Riblet Health Spring	Mahoning	Youngstown		
Sand Rock Mineral Well	Stark	Canton	Southeast	2
Sulphur Lick Springs	Ross	Chillicothe		
Tallewanda Mineral Springs	Preble	College Corner	Northwest	1
Wheeler Mineral Springs	Mahoning	Youngstown	East	

OKLAHOMA.

The output of mineral water in Oklahoma in 1919 was 1,368,375 gallons, valued at $41,825, as compared with 1,166,485 gallons, valued at $20,249, in 1918. These figures indicate an increase of 17 per cent in quantity and of 107 per cent in value. In addition to the quantity sold, 20,141 gallons of mineral water was consumed in the manufacture of soft drinks. One spring active in 1918 was not heard from in 1919; another from which no report of sales was received in 1918 was active in 1919. No bathing establishments or resorts were reported to have been maintained.

Sources of mineral waters sold in Oklahoma in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Bromide Spring	Murray	Sulphur		
Excelsior Well	Oklahoma	Oklahoma City		
Everpure Well	do	do	Northeast	
Kalium Well	Comanche	Faxon	West	1½
Lewis Lithia Wells	Oklahoma	Oklahoma City		
Sparkling Water Well	Pottawatomie	Shawnee	West	1
Standard Wells	Tulsa	Tulsa	Southeast	(a)
White Sulphur Spring	Creek	Sapulpa	Southwest	(a)
Works Excelsior Mineral Well	Stephens	Comanche	do	1

a Post office at springs or springs situated in town.

OREGON.

Returns for 1919 show a decrease of 81 per cent in quantity and 38 per cent in value of mineral waters sold in Oregon. The sales were 2,600 gallons, valued at $1,140, as compared with 13,550 gallons, valued at $1,825, in 1918. The average price per gallon increased from 13 to 44 cents. One spring which was active in 1918 reported no sales in 1919; thus the number of active springs was reduced from 4 to 3. One resort accommodating about 40 guests and two mineral-water bathing establishments were maintained. In addition to the water reported sold, 8,150 gallons was used in the manufacture of soft drinks, an increase of 2,100 gallons over the quantity used for this purpose in 1918.

Sources of mineral waters sold in Oregon in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Calapooya Springs	Lane	Cottage Grove	South	12
Sam-O Spring	Baker	Baker	Northeast	1½
White Pelican Spring	Klamath	Klamath Falls	East	1½

PENNSYLVANIA.

The returns from Pennsylvania indicate a decrease of 38 per cent in quantity and 32 per cent in value of mineral water sold in 1919, as compared with 1918. The price per gallon increased from 9 to 10 cents. The total output was 872,595 gallons, valued at $83,583. The sales of table water amounted to $79,724, and $3,859 was reported from sales of medicinal water. In addition, 623,676 gallons was used in the manufacture of soft drinks, an increase as compared with 1918 of 159,844 gallons.

Twenty-eight springs were active in 1919, a decrease of two. Five springs which marketed water in 1918 were inactive in 1919; three others which were inactive in 1918 reported sales in 1919; and the output of two springs was estimated. Three resorts accommodating 550 guests were maintained. No mineral-water bathing establishments are reported to have been operated.

Mineral waters sold in Pennsylvania, 1915–1919.

Year.	Commercial springs.	Quantity sold (gallons).	Value.	Average price per gallon (cents).
1915	47	2,136,218	$174,798	8
1916	42	1,671,637	145,133	9
1917	41	1,603,090	147,021	9
1918	30	1,400,456	123,436	9
1919	28	872,595	83,583	10

Sources of mineral waters sold in Pennsylvania in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Battering Ram Spring	Luzerne	Berwick	East	1½
Carnegie Alkaline Mineral Springs.	Allegheny	Carnegie		
Chadwick Mineral Well	Crawford	Cambridge Springs		
Cloverdale Well	Cumberland	Newville	Northwest	2½
Cold Spring	Lebanon	Lotell		
Dark Hollow Spring	Allegheny	Oakmont	East	1½
De Profundus Spring	Crawford	Saegerstown		
East Brook Spring	Lawrence	East Brook		
Ephrata Mountain Crystal Spring.	Lancaster	Ephrata		2
Franklin Lithia Well	Crawford	Cambridge Springs		
Glen Summit Spring	Luzerne	Wilkes-Barre	South	9
Gray Mineral Spring	Crawford	Cambridge Springs		
Great Oak Spring	Chester	Pottstown	Southwest	5
Harrison Valley Mineral Well	Potter	Harrison Valley		
Jordan Mineral Spring	Allegheny	Presto	North	1
Juniata Springs	Blair	Altoona	do	3
Kecksburg Mineral Springs	Westmoreland	Mammoth	do	1
Keystone Spring	Bucks	Taylorsville		
Mount Laurel Spring	Berks	Temple	East	1
Original Magnesia Springs	Crawford	Cambridge Springs		
Pavilion Spring	Berks	Wernersville	South	1¾
Polar Spring	Bucks	Morrisville	West	1
Puritas Spring	Erie	Erie		
Ross Common Springs	Monroe	Windgap	North	3
Thurstons Carbonate Springs	Crawford	Meadville	East	1¼
West Nanticoke Artesian Well	Luzerne	West Nanticoke		
Whannis Lithia Springs	Venango	Franklin	East	$2\frac{4}{10}$
White Star Spring	Northampton	Easton	South	4

RHODE ISLAND.

Rhode Island in 1919 reported sales from six springs amounting to 317,571 gallons, valued at $26,039. The average price per gallon was 8 cents. The water was sold exclusively for table use, and in addition 50,901 gallons was used in the manufacture of soft drinks, as against 37,833 gallons used for this purpose in 1918. The sales in 1918 amounted to 365,705 gallons, valued at $30,729. Thus there was a decrease of about 13 per cent in quantity and 15 per cent in value in 1919.

Sources of mineral waters sold in Rhode Island in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Berry Spring	Providence	Pawtucket	Southeast	1½
Girard Spring	do	do	West	3
Holley Mineral Spring	do	Woonsocket		
Ochee Spring	do	Providence	West	3½
Prophet Spring	do	do	Northwest	2
Queen City Spring Water Spring	do	do		

SOUTH CAROLINA.

The sales of mineral water in South Carolina during 1919 amounted to 348,242 gallons, valued at $38,890, as compared with 279,300 gallons, valued at $51,198, in 1918. These changes are equivalent to an increase of 25 per cent in quantity and a decrease of 24 per cent in value. Seventy-four per cent of the output was sold for medicinal use. One spring active in 1918 was not heard from in 1919; and one spring idle in 1918 was active in 1919. One resort accommodating 350 guests was maintained. In addition to the mineral water reported sold, 420,000 gallons was used in the manufacture of soft drinks.

Sources of mineral waters sold in South Carolina in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Economy Spring	York	Kings Creek	East	2½
Glendale Mineral Spring	Bamberg	Bamberg	Southwest	4
Glenn Springs	Spartanburg	Glenn Springs		
Healing Springs	Barnwell	Blackville		
Mansfield Mineral Springs	Spartanburg	Spartanburg	Northeast	4
Mertins Crystal Springs	Aiken	Augusta	do	5
Shivar Spring	Fairfield	Shelton	East	1
Whitestone Mineral Spring	Spartanburg	Spartanburg	South	4

SOUTH DAKOTA.

Three springs in South Dakota reported sales in 1919 which amounted to 785,404 gallons, valued at $23,961, as compared with 454,865 gallons, valued at $17,269, in 1918, an increase of 73 per cent in quantity and 39 per cent in value. The average price per gallon declined from 4 to 3 cents. All this water was sold for table use, and 11,260 gallons in addition was used in the manufacture of soft drinks. No resorts or bathing establishments were maintained.

Sources of mineral waters sold in South Dakota in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Culbert Spring	Brown	Aberdeen	Southwest	2
Milbank Well	Grant	Milbank	North	
Spring Brook Spring	Roberts	Sisseton	Southeast	¾

TENNESSEE.

The mineral-water trade of Tennessee showed a decrease in 1919 of 24 per cent in quantity and an increase of 2 per cent in value. The average price per gallon increased from 5 to 7 cents.

The total output for 1919 was 752,837 gallons, valued at $54,259, as compared with 990,027 gallons, valued at $53,367, in 1918. The sales of medicinal waters amounted to $32,225 and of table waters to $22,034. One spring active in 1918 was not heard from in 1919 and was omitted; and two springs idle in 1918 reported sales in 1919. Five resorts, accommodating about 1,000 guests, were maintained.

Mineral waters sold in Tennessee, 1915–1919.

Year.	Commercial springs.	Quantity sold (gallons).	Value.	Average price per gallon (cents).
1915	23	703,566	$39,304	6
1916	20	799,346	48,416	6
1917	19	758,193	47,362	6
1918	13	990,027	53,367	5
1919	14	752,837	54,259	7

Sources of mineral waters sold in Tennessee in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Buena Vista Springs	Davidson	Nashville		
Bush Epsom Lithia Wells	do	do		
Hamilton Springs	Wilson	Lebanon	West	6
Horn Springs	do	Hornsprings		
Larkin Spring	Davidson	Madison		
Lockeland Spring	do	Nashville	East	3
Pioneer Springs	do	do	South	5
Red and Black Boiling Springs	Macon	Red Boiling Springs		
Rhea Springs	Rhea	Rhea Springs		
Sunrise Springs	Cheatham	Ashland City	South	2
Tate Spring	Grainger	Tate	East	1¾
Thompson Spring	Davidson	Nashville		
Whittle Springs	Knox	Knoxville	North	3
Wright's Epsom Lithia Spring	Hawkins	Mooresburg	Northwest	1

TEXAS.

There was a decrease in the sales of mineral waters in Texas in 1919 of about 40 per cent in quantity and 25 per cent in value, only water valued at $58 being reported as sold for medicinal use. The total sales amounted to 328,913 gallons, valued at $60,125. In addition, about 100,292 gallons of mineral water was consumed in the manufacture of soft drinks, an increase of 70,566 gallons over the quantity used for the same purpose in 1918.

No new springs were reported. One spring active in 1918 reported no sales in 1919; and one spring idle in 1918 was active in 1919. Two resorts, accommodating about 225 guests, and one mineral-water bathing establishment were reported.

Sources of mineral waters sold in Texas in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office. (miles).
Aqua Vitae Wells	Nacogdoches	Nacogdoches		
Austin Well	Palo Pinto	Mineral Wells		
Brock's Mineral Wells	Denton	Denton	South	2½
Capps Mineral Wells	Gregg	Longview		
Crazy and Gibson Wells	Palo Pinto	Mineral Wells		
Hefner Wells	Lamar	Blossom	West	¼
Lamar Wells	Palo Pinto	Mineral Wells		
Marlin Hot Wells	Falls	Marlin		
Mangum Wells	Eastland	Mangum		
Maurice Wells	do	do		
Mitchell Well		Greenville	South	2
Riviere Mineral Wells	Smith	Tyler	North	1
Roach Mineral Well	Titus	Cookville	Southwest	4
Sour Well	Hopkins	Sulphur Springs	West	¾
Texas Carlsbad Wells	Palo Pinto	Mineral Wells		
Tioga Mineral Wells	Grayson	Tioga		
Weatherby Wells	Nacogdoches	Garrison		
Wizard Wells	Jack	Wizard Wells		

VERMONT.

The mineral-water trade in Vermont in 1919 was about 12 per cent greater in quantity and 8 per cent less in value than in 1918. The total sales were 107,600 gallons, valued at $15,755, as compared with 95,700 gallons, valued at $17,090, in 1918. The average price per gallon fell from 18 to 15 cents. In addition to the mineral water reported sold, about 60,000 gallons was used in the manufacture of soft drinks, or about twice the quantity used for the same purpose in 1918. Two resorts, accommodating 250 guests, and two mineral-water bathing establishments were maintained. The same springs active in 1918 reported sales in 1919, and one spring which was idle in 1918 was active in 1919.

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Sources of mineral waters sold in Vermont in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Alburg Springs	Grand Isle	Alburg		
Clarendon Nitrogen and North springs.	Rutland	West Rutland	South	4
Cold Spring	do	Wells	East	½
Equinox Mountain Spring	Bennington	Manchester	West	3

VIRGINIA

Returns from Virginia show that in 1919 the sales of mineral waters in that State decreased 19 per cent in quantity and 18 per cent in value. The total output was 1,418,528 gallons, valued at $143,199, as compared with 1,745,105 gallons, valued at $173,912, in 1918. The average price was 10 cents per gallon. In addition to the water reported as sold 28,951 gallons was used in the manufacture of soft drinks, a decrease of 94 per cent from the quantity used for this purpose in 1918.

Five springs active in 1918 reported no sales in 1919; two springs active in 1918 were not heard from in 1919; and two springs idle in 1918 reported sales in 1919. Ten resorts, accommodating about 1,700 guests, and five mineral-water bathing establishments were maintained at springs.

Mineral waters sold in Virginia, 1915–1919.

Year.	Commercial springs.	Quantity sold (gallons).	Value.	Average price per gallon (cents).
1915	50	3,027,528	$237,818	8
1916	50	2,313,616	248,906	11
1917	41	2,518,050	237,788	9
1918	35	1,745,105	173,912	10
1919	30	1,418,528	143,199	10

Sources of mineral waters sold in Virginia in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Alleghany Spring	Montgomery	Alleghany Springs		
Bear Lithia Spring	Rockingham	Elkton		
Beaufont Spring	Chesterfield	Richmond	South	3½
Blue Ridge Springs	Botetourt	Blue Ridge Springs		
Broad Rock Spring	Chesterfield	Richmond	Southeast	1¼
Buckhead Springs	do	Buckhead Springs		
Buffalo Mineral Springs	Mecklenburg	Buffalo Lithia Springs		
Carter Springs	Pittsylvania	Danville	Northwest	3
Chlorinated Calcic Spring	Norfolk	Norfolk	do	3
Coppahaunk Mineral Spring	Surry	Waverly	Southwest	2
Craig Healing Springs	Craig	Newcastle		
Crockett Arsenic Lithia Springs	Montgomery	Crockett Springs		
Farmville Lithia Springs	Cumberland	Farmville	North	¼
Fonticello Spring	Chesterfield	Richmond	Southwest	1
Granite Mineral Spring	do	do		
Healing Springs	Bath	Healing Springs	Southwest	¼
Jeffress Lithia Silica Well	Mecklenburg	Jeffress	East	1/10
Kayser Springs	Augusta	Staunton	Southwest	1½
Lithia Magnesia Springs	Franklin	Rockymount	West	1
Massanetta Spring	Rockingham	Harrisonburg	East	4
Mico Well	Alexandria	Alexandria	do	¾
Nye Lithia Springs	Wythe	Wytheville	do	2
Paeonian Springs	Loudoun	Paeonian Springs	South	
Pickett's Radio-active Spring	Prince Edward	Warsham	East	1½
Rockbridge Alum Springs	Rockbridge	Rockbridge Alum Springs.		
Rubino Healing Springs	Bath	Healing Springs	Southwest	½
Seawright Spring	Augusta	Fort Defiance		3
Trepho Mineral Spring	Surry	Claremont	East	1
Virginia Etna Springs	Roanoke	Vinton	West	½
Wyrick Mineral Spring	Wythe	Crockett	Southwest	1

WASHINGTON.

Reports of sales of mineral waters in Washington were received from two springs only. They are called Artesian Mineral Well, Yakima, Yakima County, and Klickitat Mineral Spring, Klickitat, Klickitat County.

WEST VIRGINIA.

The output of mineral waters in West Virginia in 1919 amounted to 271,907 gallons, valued at $33,796, as compared with 301,883 gallons, valued at $32,045, in 1918. This change is equivalent to a decrease of about 10 per cent in quantity and an increase of 5 per cent in value. In addition to the quantity of water sold, 30,000 gallons was used in the manufacture of soft drinks. Three springs active in 1918 were not heard from in 1919 and were omitted; thus the number of active springs in 1919 was five. One resort, accommodating about 120 guests, and one mineral-water bathing establishment were operated at springs.

Sources of mineral waters sold in West Virginia in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Hamlett Sulphur Well	Monroe	Alderson	West	
Manacca Irondale Spring	Preston	Independence		3
Pence Spring	Summers	Pence Springs	North	½
Vigora Spring	Ohio	Wheeling	East	1
Walnut Hill Spring	Kanawha	Charleston	Northwest	1½

WISCONSIN.

The sales of mineral waters in Wisconsin decreased in quantity and increased in value in 1919. The total output was 5,113,289 gallons, valued at $1,446,367, as compared with 6,630,725 gallons, valued at $1,193,345, in 1918. These figures represent a decrease of 23 per cent in quantity and an increase of 21 per cent in value. The sales of table waters amounted to $1,403,311 and of medicinal waters to $43,056. The average price per gallon rose from 18 to 28 cents. In addition to the water reported as sold, 747,061 gallons was used in the manufacture of soft drinks. Wisconsin ranked first in total value of mineral waters sold in 1919, and second in consumption of mineral waters for the manufacture of soft drinks. One resort accommodating 120 guests was maintained, but no bathing establishment was operated at springs. Two springs temporarily idle in 1918 were active in 1919; three springs active in 1918 reported no sales in 1919; three springs active in 1918 were not heard from in 1919; and Sparkling Spring Water Spring reported sales for the first time.

Mineral waters sold in Wisconsin, 1915–1919.

Year.	Commercial springs.	Quantity sold. (gallons).	Value.	Average price per gallon (cents).
1915	36	4,861,734	$1,051,405	22
1916	36	7,696,813	1,507,679	20
1917	36	6,296,634	1,362,498	22
1918	32	6,630,725	1,193,345	18
1919	29	5,113,289	1,446,367	28

Sources of mineral waters sold in Wisconsin in 1919.

Spring or well.	Location.			
	County.	Nearest post office.	Direction from post office.	Distance from post office (miles).
Allouez Spring	Brown	Green Bay	Southeast	1
Almanaris Spring	Waukesha	Waukesha	North	1
Arbutus Natural Mineral Spring	Oconto	Oconto	Northwest	2½
Arcadian Spring	Waukesha	Waukesha		
Bay City Springs	Ashland	Ashland	East	1¼
Bethania Spring	Polk	Osceola	Southwest	1½
Bethesda Spring	Waukesha	Waukesha	do	1
Chippewa Springs	Chippewa	Chippewa Falls	South	1
Clinton Spring	Milwaukee	Wauwatosa	Southwest	2
Clysmic Spring	Waukesha	Waukesha		
Crystal Spring	Sheboygan	Sheboygan	Northwest	3
Do	Waupaca	Waupaca	Southeast	1
Darlington Mineral Spring	Lafayette	Darlington	West	½
Famous Spring	Waukesha	Menomonee Falls	South	
Hydrox Spring	Jefferson	Palmyra		
Lebenswasser Spring	Brown	Green Bay		
Maribel Mineral Spring	Manitowoc	Maribel	Northeast	2¼
Nee-Ska-Ra Spring	Milwaukee	Wauwatosa	do	1
Roxo Spring	Waukesha	Waukesha	East	1
Sheridan Mineral Spring	Walworth	Lake Geneva	Northeast	1½
Silurian and Waukesha AAAA Springs.	Waukesha	Waukesha	East	
Soda Lithia Spring	do	Menomonee Falls	South	4
Solon Springs	Douglas	Douglas	do	1
Sparkling Springs	Kenosha	Kenosha	Northwest	1¼
Sulphur Mineral Springs	Winnebago	Oshkosh	North	3
Waukesha Fox Head Spring	Waukesha	Waukesha	South	⅔
White and Still Rock Springs	do	do		1½
Wilnette Spring	Racine	Racine	West	1¼

WYOMING.

Sales from two springs were reported from Wyoming in 1919. They are called Big Horn Hot Springs, Hot Springs, Thermpolis County, and Paulson Well, Saratoga, Carbon County.

SAND AND GRAVEL.

By R. W. Stone.

PRODUCTION.

The sand and gravel produced in the United States in 1919, according to reports received by the United States Geological Survey from producers, amounted to 70,576,407 short tons, an increase of 8,751,981 tons, or 14 per cent, over the production in 1918. The quantity of glass sand, molding sand, and fire sand was less than in 1918, and the quantity of grinding, engine, and filter sand was practically the same in both years; building sand and paving sand, however, were in greater demand in 1919 than in 1918, and, with railroad ballast and gravel, they account for practically all the increase.

The total value of all the sand and gravel produced in 1919 was $45,951,556, as compared with $37,927,079 in 1918.

The following table summarizes the sand and gravel industry for the last five years. It shows at a glance the quantity of material, so far as reported to the United States Geological Survey, that has been transported each year. There is no way to tell how much has been moved by wagon or auto-truck and how much by railroad. It is worthy of note, however, that nearly 1½ million tons annually is used on rails to increase traction. The importance of this sand, listed as engine sand and used both above and below ground on steam and electric railways for hauling passengers and freight is little appreciated. There is no equally cheap substitute, and without this sand many a train would be unable to move.

Sand and gravel produced in the United States, 1915–1919, by kinds, in short tons.

Kind.	1915	1916	1917	1918	1919
Glass sand	1,884,044	2,018,317	1,942,675	2,172,887	1,827,409
Molding sand	3,585,746	4,662,649	4,660,968	4,910,178	3,774,612
Building sand	22,921,426	27,193,462	25,374,987	19,686,885	21,969,736
Grinding and polishing sand	969,718	1,370,354	1,179,190	975,265	988,240
Fire or furnace sand	529,887	426,654	604,035	472,733	355,458
Engine sand	1,560,201	1,383,034	1,410,222	1,462,465	1,481,481
Paving sand	3,381,717	3,998,548	4,348,474	2,722,144	4,431,306
Filter sand	(a)	76,053	62,170	51,111	58,342
Other sands	1,109,250	1,834,907	1,262,785	666,152	1,083,152
Railroad ballast	2,688,766	13,649,827	10,260,999	8,064,505	8,715,842
Gravel	37,972,548	32,477,927	25,312,820	20,640,101	25,890,829
Total	76,603,303	89,091,732	76,419,325	61,824,426	70,576,407

a Filter sand included under "Other sands" prior to 1916.

The demand for sand and gravel was heavier in the latter part of 1919 than in the first half of the year, but car shortage and labor shortage curtailed the output. The opinions of 610 out of an approximate total of 1,200 producers in the five leading States—Illinois, Michigan, New York, Ohio, and Pennsylvania—give some insight into the trend of business. Of these producers 42 per cent reported that their trade was better, 26 per cent said that trade was about the same, and 32 per cent said that they had less business. In New York and Pennsylvania the number of producers who reported trade better and worse was the same, and those in the two States who reported no change were about 20 per cent of those who expressed an opinion. As a matter of fact, the quantity of sand and gravel produced in New York was a little less and the value a little greater in 1919 than in 1918, and in Pennsylvania there was a decrease in both quantity and value.

It must be admitted that the statistics of the sand and gravel industry are incomplete, for there are many small producers whose names are not known to the Geological Survey. This will always be the case, because there are thousands of unrecorded small building operations in the villages and hamlets and on the farms of every State the sand and gravel for which are procured locally and not furnished by a regular dealer. The aggregate quantity of the material so produced must be large. The list of producers maintained by the Geological Survey is always increasing, however, and a small percentage of the output reported each year is always that of producers whose output had not previously been recorded. Therefore as the list of producers increases the statistics each year more nearly represent the actual output of the industry.

The tables in this report have been prepared by Mrs. L. M. Beach, of the United States Geological Survey.

Sand and gravel produced in the United States in 1918 and 1919, by States and uses.

1918.

State.	Glass sand.		Molding sand.		Building sand.		Grinding and polishing sand.		Fire or furnace sand.		Engine sand.	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons)	Value.	Quantity (short tons).	Value.
Alabama			119,975	$47,037	230,481	$128,806			(a)	(a)	(a)	(a)
Arizona												
Arkansas	(a)	(a)	(a)	(a)	82,602	49,479	(a)	(a)			(a)	(a)
California	(a)	(a)	14,834	20,695	486,862	169,110			(a)	(a)	34,577	$7,911
Colorado			(a)	(a)	62,197	25,033			(a)	(a)	(a)	(a)
Connecticut			2,081	1,625	109,979	67,990	(a)	(a)				
Delaware			5,874	4,727	64,594	49,312					(a)	(a)
Florida			(a)	(a)	32,869	13,227	(a)	(a)				
Georgia	6,862	$6,864	35,001	12,705	187,171	75,253	(a)	(a)	(a)	(a)	15,121	3,800
Hawaii					(a)	(a)						
Idaho												
Illinois	760,835	1,273,804	885,617	658,205	1,832,195	756,888	46,450	$139,390	88,800	$58,925	107,041	31,589
Indiana	46,681	13,500	298,934	135,605	1,061,189	308,461	34,624	8,988			117,599	34,022
Iowa	(a)	(a)	29,219	13,469	903,425	391,120	6,926	2,761	(a)	(a)	33,283	14,748
Kansas					682,525	238,535					49,749	17,848
Kentucky	(a)	(a)	45,129	46,030	326,237	249,674	(a)	(a)	(a)	(a)	3,593	2,294
Louisiana	(a)	(a)			188,035	85,056	(a)	(a)			750	575
Maine					12,532	6,906					(a)	(a)
Maryland	(a)	(a)	(a)	(a)	795,848	395,155	(a)	(a)			38,384	61,065
Massachusetts	(a)	(a)	58,768	50,614	620,262	507,278	23,807	36,397	(a)	(a)	14,488	6,638
Michigan			116,485	55,255	433,497	174,888	(a)	(a)	(a)	(a)	5,174	1,322
Minnesota			14,614	14,790	291,196	149,809	(a)	(a)	8,359	1,610	13,470	6,729
Mississippi					113,043	58,115					12,140	4,642
Missouri	141,062	202,763	116,671	65,111	546,986	213,321	(a)	(a)	(a)	(a)	32,793	21,143
Montana					4,177	4,964						
Nebraska					773,049	204,657					14,912	2,181
Nevada	(a)	(a)									(a)	(a)
New Hampshire					2,525	934						
New Jersey	139,992	242,762	442,007	626,637	1,748,576	690,209	47,824	121,022	62,185	100,857	56,543	40,925
New Mexico					(a)	(a)						
New York			519,681	770,512	1,997,091	581,835			(a)	(a)	73,603	41,668
North Carolina			(a)	(a)	91,959	35,721					(a)	(a)
North Dakota												
Ohio	130,359	277,475	857,481	1,493,541	1,722,737	1,062,108	64,694	229,131	109,680	273,821	59,300	36,843
Oklahoma	(a)	(a)	(a)	(a)	232,692	111,235					(a)	(a)
Oregon			(a)	(a)	44,901	36,125						

a Included in "Undistributed."

Sand and gravel produced in the United States in 1918 and 1919, by States and uses—Continued.

1918—Continued.

State.	Glass sand.		Molding sand.		Building sand.		Grinding and polishing sand.		Fire or furnace sand.		Engine sand.	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
Pennsylvania	450,880	$1,065,162	1,158,715	$953,886	1,537,984	$1,529,133	460,047	$881,799	143,932	$211,330	354,190	$543,453
Rhode Island												
South Carolina			(a)	(a)	55,434	34,648						
South Dakota					10,046	7,496						
Tennessee	(a)	(a)	33,016	18,688	494,540	333,573			(a)	(a)	33,221	17,454
Texas	(a)	(a)	(a)	(a)	221,285	105,227					25,622	8,729
Utah					(a)	(a)					(a)	(a)
Vermont			(a)	(a)	3,691	1,133	38,390	6,579				
Virginia	(a)	(a)	12,148	15,691	771,832	395,511	(a)	(a)	(a)	(a)	92,634	39,085
Washington					49,165	42,122					(a)	(a)
West Virginia	399,936	942,331	(a)	(a)	190,838	192,840	8,641	17,466	(a)	(a)	132,717	128,199
Wisconsin	(a)	(a)	107,782	90,658	615,584	251,870	(a)	(a)			59,893	7,254
Wyoming					(a)	(a)					(a)	(a)
Undistributed	96,280	185,067	36,146	26,384	55,054	37,799	243,862	115,529	59,777	54,854	81,668	29,944
	2,172,887	4,209,728	4,910,178	5,121,865	19,686,885	9,772,556	975,265	1,559,062	472,733	701,400	1,462,465	1,110,061

a Included in "Undistributed."

Sand and gravel produced in the United States in 1918 and 1919, by States and uses—Continued.

1918—Continued.

State.	Paving sand.		Filter sand.		Other sands.		Railroad ballast sand and gravel.		Gravel.		Total.	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons.)	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
Alabama	(a)	(a)	2,978	$3,585			165,131	$82,980	149,278	$122,953	712,787	$406,933
Arizona	(a)	(a)					(a)	(a)			3,722	5,920
Arkansas	(a)	(a)					105,484	7,118	18,513	21,192	230,239	107,290
California	457,255	$134,724			11,501	$2,007	563,117	116,879	1,431,647	589,766	3,011,842	1,070,441
Colorado	(a)	(a)					24,265	4,282	65,412	50,056	172,472	90,657
Connecticut	(a)	(a)							(a)	(a)	140,383	99,233
Delaware	13,440	8,839	794	397					(a)	(a)	103,299	76,322
Florida	(a)	(a)	(a)	(a)			(a)	(a)	(a)	(a)	158,489	48,768
Georgia	(a)	(a)							18,500	19,900	270,071	121,655
Hawaii											(a)	(a)
Idaho									(a)	(a)	(a)	(a)
Illinois	54,925	39,937	72	360	23,233	20,772	914,418	255,675	1,641,820	744,579	6,355,406	3,980,124
Indiana	195,344	62,091	150	110	95,002	23,798	1,382,741	362,604	1,553,351	770,238	4,785,615	1,719,417
Iowa	62,577	30,202	10,686	5,649	33,357	11,277	397,795	71,356	524,541	361,200	2,004,444	904,307
Kansas	(a)	(a)							(a)	(a)	761,110	264,073
Kentucky							142,978	24,861	284,261	203,188	818,471	557,548
Louisiana	(a)	(a)	200	80	(a)	(a)	41,964	13,600	788,068	493,776	1,024,498	595,682
Maine							1,740	895	21,051	23,320	35,623	31,421
Maryland	(a)	(a)			(a)	(a)	(a)	(a)	876,964	768,182	1,759,419	1,303,780
Massachusetts	54,263	24,665	2,445	3,535	42,485	30,139	3,451	1,804	346,661	455,830	1,170,562	1,133,884
Michigan	237,317	89,430			6,163	3,048	161,552	18,314	1,741,681	869,316	2,837,371	1,239,874
Minnesota	5,350	4,700	(a)	(a)	(a)	(a)	263,087	22,873	355,851	232,097	1,150,660	492,232
Mississippi			135	75			681,508	93,135	392,689	190,686	1,199,515	346,653
Missouri					(a)	(a)	359,404	46,639	439,281	138,562	1,743,616	772,753
Montana					(a)	(a)	331,280	54,394	12,140	14,616	348,347	74,474
Nebraska	50,587	16,537			4,939	689	54,054	8,005	77,777	46,569	975,318	278,638
Nevada							6,714	1,048	(a)	(a)	25,325	3,943
New Hampshire	2,468	749					916	471	117,831	14,849	123,743	17,003
New Jersey	180,280	104,976	13,859	37,399	(a)	(a)	(a)	(a)	880,746	493,720	3,579,862	2,462,864
New Mexico									(a)	(a)	(a)	(a)
New York	131,276	77,170	(a)	(a)	52,335	26,738	(a)	(a)	1,386,092	673,448	4,172,733	2,176,472
North Carolina	(a)	(a)					(a)	(a)	250,418	128,415	458,578	209,553
North Dakota									(a)	(a)	(a)	(a)
Ohio	326,281	183,565	1,183	2,957	47,430	30,723	1,148,286	323,291	1,533,809	1,026,146	6,001,240	4,939,604
Oklahoma					(a)	(a)	(a)	(a)	85,276	39,745	383,747	215,862

a Included in "Undistributed."

Sand and gravel produced in the United States in 1918 and 1919, by States and uses—Continued.

1918—Continued.

State.	Paving sand.		Filter sand.		Other sands.		Railroad ballast sand and gravel.		Gravel.		Total.	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons.)	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
Oregon	50,047	$26,640			(a)	(a)	81,316	$16,408	297,151	$113,954	473,745	$193,559
Pennsylvania	348,039	406,932			76,050	$77,658			1,772,840	1,538,487	6,302,677	7,207,810
Rhode Island									(a)	(a)	(a)	(a)
South Carolina	(a)	(a)	1,000	$800	140	70			4,627	3,016	76,297	49,374
South Dakota	3,769	1,982					181,619	17,347	34,353	21,537	229,787	48,362
Tennessee	(a)	(a)			(a)	(a)	39,935	16,719	377,425	246,299	986,801	639,373
Texas	(a)	(a)	(a)	(a)			322,176	90,398	568,705	288,679	1,175,426	519,446
Utah	(a)	(a)			(a)	(a)	20,054	1,660	98,480	61,063	184,719	103,873
Vermont	(a)	(a)					104	54	726	280	47,059	10,462
Virginia	(a)	(a)			(a)	(a)	(a)	(a)	389,635	276,312	1,331,123	764,618
Washington	251,292	96,716					172,342	14,606	434,428	177,932	908,102	332,141
West Virginia	40,222	29,824							124,309	117,811	904,148	1,438,887
Wisconsin	121,142	56,738			34,660	18,345	229,977	22,910	1,000,961	361,967	2,170,312	809,884
Wyoming							3,000	200	495,976	48,888	502,746	50,293
Undistributed	136,270	63,908	17,609	20,030	238,857	108,531	264,097	81,711	46,824	42,499	12,977	11,087
	2,722,144	1,460,325	51,111	74,977	666,152	353,795	8,064,505	1,772,237	20,640,101	11,791,073	61,824,426	37,927,079

a Included in "Undistributed."

Sand and gravel produced in the United States in 1918 and 1919, by States and uses—Continued.

1919.

State.	Glass sand.		Molding sand.		Building sand.		Grinding and polishing sand.		Fire or furnace sand.		Engine sand.	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
Alabama			99,753	$59,653	255,520	$123,553					(a)	(a)
Arizona					(a)	(a)						
Arkansas	(a)	(a)	(a)	(a)	128,989	82,441	(a)	(a)			(a)	(a)
California	(a)	(a)	(a)	(a)	764,214	339,907					(a)	(a)
Colorado			(a)	(a)	89,936	45,191			(a)	(a)	(a)	(a)
Connecticut			1,918	2,474	192,753	127,469						
Delaware			(a)	(a)	2,544	1,315			(a)	(a)	(a)	(a)
Florida					74,980	47,955	(a)	(a)			(a)	(a)
Georgia	(a)	(a)	66,981	34,784	246,711	116,627	(a)	(a)			14,341	$4,988
Hawaii					(a)	(a)						
Idaho					(a)	(a)						
Illinois	521,286	$886,707	482,219	338,893	2,187,682	1,027,452	28,885	$82,303	44,421	$30,474	83,596	25,028
Indiana	88,030	27,338	572,292	243,199	1,093,836	434,085	(a)	(a)	(a)	(a)	191,227	65,884
Iowa			6,405	14,318	913,400	531,596	(a)	(a)	(a)	(a)	39,891	9,230
Kansas					855,077	465,300					35,217	15,073
Kentucky	(a)	(a)	15,622	24,767	423,350	320,871	(a)	(a)	(a)	(a)	(a)	(a)
Louisiana	(a)	(a)			183,419	96,000					(a)	(a)
Maine					17,168	8,598						
Maryland	(a)	(a)	(a)	(a)	873,952	685,403			(a)	(a)	(a)	(a)
Massachusetts	(a)	(a)	10,610	9,092	500,237	480,314	(a)	(a)	(a)	(a)	(a)	(a)
Michigan	(a)	(a)	124,006	66,877	539,800	251,733	(a)	(a)	(a)	(a)	6,958	2,268
Minnesota			6,751	9,328	343,537	186,353	(a)	(a)	(a)	(a)	(a)	(a)
Mississippi					120,187	68,181					(a)	(a)
Missouri	135,683	209,938	85,732	73,178	656,827	194,996	175,513	163,858	(a)	(a)	22,543	21,376
Montana					12,080	14,662	(a)	(a)			(a)	(a)
Nebraska			(a)	(a)	790,316	299,337					(a)	(a)
Nevada												
New Hampshire					2,803	3,403						
New Jersey	121,799	225,036	501,583	583,656	1,640,704	763,896	43,097	79,048	63,232	93,447	90,789	63,837
New Mexico											(a)	(a)
New York			418,319	609,730	1,974,827	705,603	(a)	(a)	(a)	(a)	43,102	24,997
North Carolina			(a)	(a)	80,942	28,445	(a)	(a)	(a)	(a)	(a)	(a)
North Dakota					(a)	(a)						
Ohio	79,580	191,565	689,555	1,137,356	2,063,918	1,173,324	32,469	107,733	56,955	127,185	55,868	31,515
Oklahoma	(a)	(a)			343,867	210,052					(a)	(a)
Oregon			(a)	(a)	163,574	157,396						

a Included in "Undistributed."

Sand and gravel produced in the United States in 1918 and 1919, by States and uses—Continued.

1919—Continued.

State.	Glass sand.		Molding sand.		Building sand.		Grinding and polishing sand.		Fire or furnace sand.		Engine sand.	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
Pennsylvania	325,810	$797,068	512,862	$712,460	1,517,957	$1,289,827	483,307	$804,108	121,737	$129,984	294,927	$456,604
Rhode Island			(a)	(a)	(a)	(a)						
South Carolina			(a)	(a)	107,784	89,219						
South Dakota					59,286	50,920						
Tennessee	(a)	(a)	16,605	16,631	351,134	285,015	(a)	(a)	(a)	(a)	33,893	21,526
Texas	(a)	(a)	(a)	(a)	430,413	269,455	(a)	(a)	(a)	(a)	49,791	17,611
Utah					(a)	(a)					(a)	(a)
Vermont			4,012	2,919	(a)	(a)	44,241	9,106				
Virginia			7,817	12,377	685,988	453,701	(a)	(a)	(a)	(a)	86,944	35,543
Washington			(a)	(a)	122,930	66,151					9,724	6,446
West Virginia	407,918	933,863	(a)	(a)	176,829	218,700	(a)	(a)	(a)	(a)	148,237	147,973
Wisconsin	(a)	(a)	121,742	159,106	859,020	455,948	(a)	(a)			46,335	7,796
Wyoming					(a)	(a)						
Undistributed	147,303	321,856	29,828	43,192	121,245	126,270	180,728	80,679	69,113	54,947	228,098	185,160
	1,827,409	3,593,371	3,774,612	4,153,990	21,969,736	12,296,664	988,240	1,326,835	355,458	436,037	1,481,481	1,142,855

State.	Paving sand.		Filter sand.		Other sands.		Railroad ballast sand and gravel.		Gravel.		Total.	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
Alabama	(a)	(a)					349,401	$116,690	78,962	$99,215	785,479	$400,338
Arizona	(a)	(a)					(a)	(a)			(a)	(a)
Arkansas	(a)	(a)			(a)	(a)	382,661	93,769	281,880	163,724	871,328	406,802
California	520,296	$196,852	(a)	(a)	30,098	$17,852	571,402	111,231	1,242,220	684,256	3,168,517	1,426,517
Colorado	16,233	9,895							127,508	91,105	248,483	154,978
Connecticut	(a)	(a)							62,279	80,264	261,815	212,286
Delaware	15,753	7,737							(a)	(a)	34,843	19,404
Florida					(a)	(a)	(a)	(a)	(a)	(a)	271,794	164,101
Georgia	21,284	12,320			(a)	(a)			(a)	(a)	362,487	181,844
Hawaii									(a)	(a)	(a)	(a)
Idaho									(a)	(a)	(a)	(a)

Illinois	173,054	107,127	(a)	(a)	8,008	12,048	1,378,321	548,249	2,184,361	1,189,813	7,093,333	4,252,094
Indiana	453,487	242,779			509,107	128,445	1,013,950	306,340	2,256,905	1,226,863	6,187,741	2,680,968
Iowa	165,597	86,235	20,242	$13,224	134,828	65,315	50,394	19,712	755,289	636,497	2,093,471	1,383,764
Kansas	(a)	(a)			(a)	(a)			59,304	24,720	954,121	507,642
Kentucky	(a)	(a)			(a)	(a)	(a)	(a)	673,567	349,359	1,151,297	744,073
Louisiana									586,295	508,196	772,943	605,401
Maine	(a)	(a)							28,924	30,521	46,296	39,319
Maryland	(a)	(a)			(a)	(a)			792,716	985,686	1,747,587	1,800,882
Massachusetts	261,237	478,669			(a)	(a)	(a)	(a)	489,937	730,485	1,381,555	1,839,435
Michigan	204,045	75,228			9,446	3,220	67,916	21,861	2,639,483	1,378,929	3,772,535	1,944,143
Minnesota	162,985	87,344	(a)	(a)	(a)	(a)	129,649	21,544	603,200	546,121	1,304,395	905,341
Mississippi	(a)	(a)					517,913	88,837	983,405	487,271	1,624,538	645,795
Missouri					(a)	(a)	167,232	33,078	419,674	176,203	1,665,295	873,333
Montana					(a)	(a)	(a)	(a)	40,835	51,887	159,564	71,736
Nebraska	76,117	34,138			29,797	6,482	39,418	17,424	271,611	197,659	1,211,395	556,080
Nevada					(a)	(a)	(a)	(a)			70,569	7,011
New Hampshire	(a)	(a)			(a)	(a)	(a)	(a)	322,001	62,188	333,073	70,174
New Jersey	281,124	149,842	15,842	23,580	36,457	30,880			915,599	563,050	3,710,226	2,576,272
New Mexico	(a)	(a)			(a)	(a)			(a)	(a)	(a)	(a)
New York	51,865	36,013	(a)	(a)	(a)	(a)	(a)	(a)	1,441,161	842,758	3,987,987	2,246,880
North Carolina	(a)	(a)	(a)	(a)			310,404	59,018	179,882	157,511	600,887	266,631
North Dakota									(a)	(a)	(a)	(a)
Ohio	444,161	260,330			19,703	22,715	1,344,800	427,846	1,652,970	1,121,823	6,439,979	4,601,392
Oklahoma	(a)	(a)	(a)	(a)	(a)	(a)			79,445	48,852	467,482	304,029
Oregon	30,753	27,002			(a)	(a)	146,417	21,363	452,346	296,415	797,288	506,526
Pennsylvania	646,816	562,114	(a)	(a)	12,165	11,376			1,783,625	1,129,028	5,699,306	5,892,679
Rhode Island	(a)	(a)							(a)	(a)	8,950	11,142
South Carolina	(a)	(a)	(a)	(a)			(a)	(a)	(a)	(a)	298,787	157,220
South Dakota	(a)	(a)					510,893	127,386	77,763	51,584	648,939	231,390
Tennessee	41,178	33,325					(a)	(a)	452,051	324,954	1,006,708	734,212
Texas	(a)	(a)			(a)	(a)	317,630	110,014	806,273	562,939	1,673,119	991,798
Utah	(a)	(a)			(a)	(a)	138,314	16,082	153,163	110,628	383,372	190,606
Vermont							(a)	(a)	3,901	794	52,323	12,861
Virginia	(a)	(a)			(a)	(a)	(a)	(a)	677,355	787,414	1,565,592	1,349,148
Washington	283,391	98,989					242,375	58,250	573,331	306,226	1,231,814	536,132
West Virginia	143,754	146,557			(a)	(a)			299,535	293,188	1,183,606	1,750,201
Wisconsin	249,854	142,219			139,591	49,642	350,352	160,115	995,323	566,776	2,763,249	1,543,434
Wyoming									348,063	39,200	349,181	40,825
Undistributed	188,322	119,726	22,258	49,488	153,952	91,219	686,400	232,244	98,687	66,722	133,158	114,717
	4,431,306	2,914,441	58,342	86,292	1,083,152	439,194	8,715,842	2,591,053	25,890,829	16,970,824	70,576,407	45,951,556

[a] Included in "Undistributed."

IMPORTS.

The quantity of sand imported and entered for consumption in the United States in 1919 was 597,481 short tons, valued at $126,586, or 21 cents a ton. The total value of the imports in 1918 was $91,465 and in 1917 was $142,586. There is no record of the quantity of sand imported into the United States during the first half of 1918, but the imports during the last half of the year amounted to 284,036 short tons, valued at $46,910, an average price of 16½ cents a ton. Some of the sand imported was carried as ship's ballast and was entered at various ocean ports, but most of it was building sand brought in from Canada to localities near the border. For instance, Sandusky, Ohio, gets sand from Pelee Island, which is across the international boundary in Lake Erie.

EXPORTS.

The exports of sand and gravel have been negligible until recently. The largest quantity exported is that sent to Canada for use as building material. No information is at hand as to the kinds of sand sent to the other countries named in the following table. Much of it doubtless is building sand carried as ballast.

Value of sand and gravel exported from the United States in 1917–1919.

Destination.	1917	1918	1919
Canada	$415,699	$599,876	$347,578
Mexico	16,892	3,741	14,803
Panama	33,941	2,721	4,650
Japan	5,951	2,674	3,091
England	7,136	2,300	967
Cuba	1,743	1,788	2,438
Newfoundland	1,039	930	279
Brazil	226	393	40
China	217	132	130
Argentina	6	....	712
Other countries	11,401	4,859	7,382
	494,251	619,414	382,070

PRICES.

The average price per ton of all sand and gravel reported sold in the United States in 1919 increased from 61 to 65 cents. There was not, however, a general increase in prices, as the average prices of some kinds of sand decreased.

Average prices per short ton of sand and gravel marketed in the United States, 1915–1919.

Kind.	1915	1916	1917	1918	1919
Glass sand	$0.85	$0.97	$1.38	$1.94	$1.97
Molding sand	.59	.69	.92	1.04	1.10
Building sand	.30	.32	.39	.50	.56
Grinding and polishing sand	.46	.65	1.04	1.60	1.34
Fire, or furnace, sand	.34	.90	1.15	1.48	1.23
Engine sand	.32	.37	.59	.76	.77
Paving sand	.32	.36	.41	.54	.66
Filter sand	(a)	.90	.76	1.47	1.48
Railroad ballast	.13	.13	.17	.22	.30
Gravel	.25	.32	.46	.57	.66
All kinds	.30	.33	.46	.61	.65

a Figures not available.

The prices given in this table for each use were obtained by dividing the total value of the sand sold by the total number of tons sold. High-grade glass sand in certain localities brought $2.50 to $3 in 1919, but large quantities of low-grade silica sand used for making colored glass bottles and other cheap glass were dug from sand dunes by steam shovel and sold for less than 50 cents a ton; thus the average price was brought down to less than $2 a ton. Although building sand sold in some of the large eastern cities in 1919 around $1 to $2 a ton, this was exceptional, and sand for building purposes throughout most of the country, except in large cities, was sold for about 50 cents a ton.

The average price of most of the different sands listed in the table has either doubled or a little more than doubled in the last five years. The average price of grinding and polishing sand has nearly trebled, and that of fire or furnace sand has much more than trebled.

GLASS SAND.

PRODUCTION.

A total of 1,827,409 short tons of glass sand was produced in the United States in 1919, a decrease of 16 per cent from the output in 1918. The average price in 1919 was $1.97 a ton, an increase of 3 cents over that of 1918. The total value of all glass sand produced in 1919 was $3,593,371, a loss of nearly 15 per cent as compared with 1918. The accompanying table, showing the production of glass sand in the six principal producing States in 1918 and 1919, brings out the fact that the quantity produced was less in 1919 in each of the States except West Virginia, which made a gain. West Virginia was the only one of the six States, however, in which the average price per ton was less in 1919. Pennsylvania, New Jersey, and Missouri made nominal gains in average price per ton; Illinois increased 22 cents and Ohio 28 cents.

The quantity of glass sand reported as produced in Indiana was about 8,000 tons more than the production in Ohio. The Indiana material, however, was mostly of low-grade (dune sand) and was produced and sold at small cost, and the figures can not well be used in comparison with those of the six leading States in the production of high-grade glass sand.

Glass sand produced in six of the leading States in 1918 and 1919.

State.	1918			1919		
	Quantity (short tons).	Value.	Average price per ton.	Quantity (short tons).	Value.	Average price per ton.
Illinois	760,835	$1,273,804	$1.67	521,286	$886,707	$1.70
Missouri	141,062	202,763	1.44	135,683	209,938	1.55
New Jersey	139,992	242,762	1.73	121,799	225,036	1.85
Ohio	130,359	277,475	2.13	79,580	191,565	2.41
Pennsylvania	450,880	1,065,162	2.36	325,810	797,068	2.45
West Virginia	399,936	942,331	2.35	407,918	933,863	2.29

Glass sand produced in the United States, 1910–1919.

Year.	Quantity (short tons).	Value.	Average price per ton.
1910	1,461,089	$1,516,711	$1.04
1911	1,538,666	1,543,733	1.01
1912	1,465,386	1,430,471	.97
1913	1,791,800	1,895,991	1.06
1914	1,619,649	1,568,030	.97
1915	1,884,044	1,606,640	.85
1916	2,018,317	1,957,797	.97
1917	1,942,675	2,685,014	1.38
1918	2,172,887	4,209,728	1.94
1919	1,827,409	3,593,371	1.97

GLASS-SAND LOCALITIES.

The resources of the United States in sand suitable for making the more common kinds of glass are very great. Nineteen States produced glass sand in 1919, and it occurs in other States in numerous localities.

Localities where glass sand was reported as produced in 1919.

Arkansas: Guion.
California: Ione and Lake Majella.
Georgia: Lumber City.
Illinois: Millington, Oregon, Ottawa, Utica, and Wedron.
Indiana: Michigan City.
Kentucky: Lawton.
Louisiana: Le Blanc.
Maryland: Robinson.
Massachusetts: Cheshire.
Michigan: Rockwood.
Missouri: Crystal City, Festus, Gray Summit, Klondike, and Pacific.
New Jersey: Cedarville, Milltown, Pembryn, South River, South Vineland, and Williamstown Junction.
Ohio: Austintown, Barberton, Chalfants, Howard, Massillon, and Toboso.
Oklahoma: Hickory and Roff.
Pennsylvania: Derry, Dunbar, Falls Creek, Kennerdell, Lewistown, Mapleton, Newton Hamilton, Parrish, Ridgway, St. Marys, and Torpedo.
Tennessee: Lagrange.
Texas: Santa Anna.
West Virginia: Berkeley Springs, Great Cacapon, Greer, Imperial, Sturgisson, Terra Alta (Holmes Station), Thayer, and West Berkeley.
Wisconsin: Ripon.

BUILDING SAND.

The output of building sand in 1919, so far as reported to the Geological Survey, amounted to 21,969,736 short tons, valued at $12,296,664, an increase of more than 2,000,000 tons and $2,500,000 over the output of 1918. The six leading States in the production of building sand in 1919 were Illinois, Ohio, New York, New Jersey, Pennsylvania, and Indiana, in the order named. In total value of output, however, Pennsylvania led, the average price per ton in that State being 85 cents, which was much higher than that in any of the other leading States. The table shows an increase in average price per ton in each State except Ohio and Pennsylvania.

Building sand produced in the six leading States in 1918 and 1919.

State.	1918			1919		
	Quantity (short tons).	Value.	Average price per ton.	Quantity (short tons).	Value.	Average price per ton.
Illinois	1,832,195	$756,888	$0.41	2,187,682	$1,027,452	$0.47
Indiana	1,061,189	308,461	.29	1,093,836	434,085	.40
New Jersey	1,748,576	690,209	.39	1,640,704	763,896	.47
New York	1,997,091	581,835	.29	1,974,827	705,603	.36
Ohio	1,722,737	1,062,108	.62	2,063,918	1,173,324	.57
Pennsylvania	1,537,984	1,529,133	.99	1,517,957	1,289,827	.85

MOLDING SAND.

The quantity of molding sand produced in 1919 was about 1,100,000 tons less than in 1918, and the total value was nearly $1,000,000 less. The average price per ton, however, was higher than ever before, being $1.10. Some molding sand sold for well over $2 a ton, and the average price in Ohio was $1.65, but large quantities of sand were sold in Illinois and Indiana for very much less than $1 a ton. In fact, in Indiana particularly hundreds of thousands of tons of dune sand for steel molding were sold for much less than 50 cents a ton.

The very considerable reduction in quantity of molding sand produced in 1919 can doubtless be ascribed in part to the strike of the steel workers.

Molding sand produced in the six leading States in 1918 and 1919.

State.	1918			1919		
	Quantity (short tons).	Value.	Average price per ton.	Quantity (short tons).	Value.	Average price per ton.
Illinois	885,617	$658,205	$0.74	482,219	$338,893	$0.70
Indiana	298,934	135,605	.45	572,292	243,199	.42
New Jersey	442,007	626,637	1.42	501,583	583,656	1.16
New York	519,681	770,512	1.48	418,319	609,730	1.46
Ohio	857,481	1,493,541	1.74	689,555	1,137,356	1.65
Pennsylvania	1,158,715	953,886	.82	512,862	712,460	1.39

Molding sand produced in the United States, 1910–1919.

Year.	Quantity (short tons).	Value.	Average price per ton.
1910	3,636,167	$2,431,254	$0.67
1911	3,376,717	2,132,469	.63
1912	4,485,380	2,718,726	.61
1913	3,563,583	2,230,217	.63
1914	2,751,209	1,756,383	.64
1915	3,585,746	2,123,203	.59
1916	4,662,649	3,219,839	.69
1917	4,660,968	4,303,809	.92
1918	4,910,178	5,121,865	1.04
1919	3,774,612	4,153,990	1.10

OTHER SANDS.

Sand sold for uses not specifically designated in the foregoing tables amounted in 1919 to 1,083,152 short tons, valued at $439,194. Most of this quantity—509,107 tons, valued at $128,445, or 25 cents a ton—was dune sand, dug along the shore of Lake Michigan in northern Indiana and used for filling, probably to fill swampy land or to grade around the great manufacturing plants along the lake shore.

Under this heading is included also sand sold for fertilizer filler for bedding in stock cars, for use in mechanical toys, for use by blacksmiths in welding iron and soft steel, for testing sand for laboratory determinations, and for miscellaneous purposes. One producer reported a few tons sold as "propagating sand," by which is probably meant sand for use in greenhouses to start seedlings.

ASSOCIATIONS OF SAND AND GRAVEL PRODUCERS.

The organization of the sand and gravel producers in various parts of the country is progressing rapidly as the benefits of such action are recognized. The association of men engaged in any industry helps the advancement of that industry. Cooperation works for the common good. Mutual benefits are derived from getting together and understanding the other man's problems. Individuals can do little to protect their business from discriminatory regulations, but a solid association of producers united on a proposition can get results.

The National Association of Sand and Gravel Producers was organized in 1911 for the purpose of obtaining mutual benefits, including equitable rates from the railroads. An appreciation of the benefits procured by such organizations has resulted in the formation of several State and regional or local associations. The associations known to the Geological Survey are as follows:

- American Sand Association (composed of producers of silica and molding sand in eastern Ohio and western Pennsylvania), Pittsburgh, Pa.
- Arkansas Valley Association of Mineral Aggregate Producers, Tulsa, Okla.
- Chicago Sand & Gravel Producers' Association, 1406 City Hall Square Building, Chicago, Ill.
- Georgia Sand & Gravel Producers' Association, Atlanta, Ga.
- Great Lakes Sand & Gravel Producers' Association, Sandusky, Ohio.
- Illinois Association of Sand & Gravel Producers, Lincoln, Ill.
- Indiana Sand & Gravel Producers' Association, 122 East Ohio Street, Indianapolis, Ind.
- Iowa Sand & Gravel Producers' Association, Des Moines, Iowa.
- Missouri Valley Association of Mineral Aggregate Producers, 706 American Bank Building, Kansas City, Mo.
- National Association of Sand & Gravel Producers, 702 City Trust Building, Indianapolis, Ind.
- Nebraska Aggregates' Association, Omaha, Nebr.
- Pennsylvania Sand & Gravel Producers' Association, 1101 Diamond Bank Building, Pittsburgh, Pa.
- Silica Sand Association of Illinois, Central Life Building, Ottawa, Ill.
- Wisconsin Mineral Aggregate Association, 332 First National Bank Building, Milwaukee, Wis.

TECHNICAL JOURNALS.

The technical journals that give considerable space to the sand and gravel industry are:

- Cement, Mill, and Quarry, 542 Monadnock Block, Chicago, Ill.
- Pit and Quarry, Rand-McNally Building, Chicago, Ill.
- Rock Products, 542 South Dearborn Street, Chicago, Ill.

GEMS AND PRECIOUS STONES.

By B. H. Stoddard.

PRODUCTION.

The value of gems and precious stones produced in the United States in 1919 was $111,763, as against $106,523 in 1918—an increase of about 5 per cent.

For three years preceding 1917 the production of precious stones in the United States steadily increased, but in 1917 and 1918 it decreased. The scarcity and high price of labor seem to have been the chief causes of the decline in operations. Recent information of renewed activity in gem mining, however, indicates that within a few years the industry in this country will regain its pre-war status.

Increases in the production of tourmaline, turquoise, quartz, garnet, spinel, variscite, jet, and fossil coral were reported. Tourmaline showed the greatest increase in value, from $6,206 in 1918 to $17,700 in 1919; quartz ranked second, with an increase of $2,421; and turquoise was third, with an increase of $2,083. Variscite, jet, fossil coral, garnet, and spinel showed increases of less than $1,000 each.

The production of jet in Utah was renewed after many years of inaction.

Arkansas is credited with all the diamonds reported as produced in the United States in 1919; Michigan with all the chlorastrolite, datolite, fossil coral, and gem hematite; and Texas with all the meerschaum.

Decreased production was reported for several minerals, especially opal, which showed the largest decrease in value. Topaz showed a decline, due to the fact that none of this mineral was reported from Maine or California, as in 1918; and among other minerals of which a decrease in production was reported were beryl, corundum, diamond, chlorastrolite, copper-ore gems, datolite, feldspar, hematite, lapis lazuli, rhodonite, spodumene, and thomsonite.

Value of precious stones produced in the United States, 1913–1919.

	1913	1914	1915	1916	1917	1918	1919
Beryl	$1,615	$2,395	$1,675	$2,031	$2,178	$1,906	(a)
Copper-ore gems	2,350	1,280	1,120	1,713	2,857	2,299	(a)
Corundum	238,835	61,032	88,214	99,180	54,204	42,414	$40,304
Diamond	6,315	765	608	2,680	4,175	1,910	(a)
Feldspar	1,285	449	368	305	(b)	(b)	(b)
Garnet	4,285	1,760	4,523	1,542	624	1,277	1,630
Hematite	....	....	126	(b)	(b)	138	(b)
Jade	....	300	....	....	....	....	....
Opal	15,130	1,114	1,850	1,838	805	6,304	(a)

a Less than 3 producers; figures combined with others to avoid disclosing confidential information.
b Small production included under "miscellaneous gems."

Value of precious stones produced in the United States, 1913–1919—Continued.

	1913	1914	1915	1916	1917	1918	1919
Peridot	$375	$100	(a)	$455	(a)	$1,018	....
Pyrite	50	....	$1,042	2,075	(a)	(a)	....
Quartz	16,861	18,838	35,724	25,707	$28,273	15,211	$17,632
Rhodonite	165	1,050	85	(a)	(a)	515	160
Smithsonite	50	50	(a)	....	(a)	....	....
Spodumene	6,520	4,000	(a)	(a)	(a)	281	(a)
Thomsonite	....	21	(a)	47	(a)	(a)	(a)
Topaz	736	1,380	862	1,005	230	907	210
Tourmaline	7,630	7,980	10,969	50,807	12,452	6,206	17,700
Turquoise	8,075	13,370	11,691	21,811	14,171	20,667	22,750
Variscite	6,105	5,055	3,867	3,140	2,350	753	925
Vesuvianite	152	1,425	1,535	(b)	2,765	320	....
Beryl, copper-ore gems, diamond, opal	(b)	(b)	(b)	(b)	(b)	(b)	8,832
Miscellaneous gems	2,920	2,287	c 6,172	d 3,457	e 5,928	f 4,397	g 1,620
	319,454	124,651	170,431	217,793	131,012	106,523	111,763

a Small production included under "Miscellaneous gems."
b For value of production in this year, see p. 165.
c Includes apatite, calamine, chlorastrolite, crocidolite, datolite, fossil coral, Iceland spar, kyanite, lapis lazuli, obsidian, peridot, phenacite, rutile, smithsonite, spodumene (kunzite), staurolite, thomsonite, titanite, and zircon.
d Includes chlorastrolite, datolite, epidote, fossil coral, hematite, Iceland spar, kyanite, lazulite, obsidian, rhodonite, rutile, sepiolite, serpentine, spodumene, staurolite, and vesuvianite.
e Includes andalusite, chlorastrolite, datolite, epidote, feldspar, fossil coral, hematite, Iceland spar, lapis lazuli, obsidian, peridot, phenacite, pyrite, rhodonite, rutile, sepiolite, smithsonite, spodumene, staurolite, thomsonite, willemite, and zoisite.
f Includes andalusite, calamine, chlorastrolite, datolite, epidote, feldspar, fluorite, Iceland spar, lapis lazuli, mariposite, meerschaum, obsidian, phenacite, pyrite, satin spar (gypsum), staurolite, thomsonite, willemite, and zoisite.
g Includes chlorastrolite, datolite, feldspar, fossil coral, hematite, jet, lapis lazuli, meerschaum, spinel, spodumene (kunzite), thomsonite, and Iceland spar.

The value given in the table represents as nearly as possible the value of the rough material; the value of the cut and polished gems is several times greater. The completeness and accuracy of the statistics of production depend on the assistance rendered by the gem miners and dealers, and their help is greatly appreciated.

Persons and firms that have reported to the Geological Survey production of gems and precious stones in the United States, 1917–1919.

Name and address.	Mineral.
American Gem Mining Syndicate, 509 Merchants Laclede Building, St. Louis, Mo.	Corundum.
Arkansas Diamond Co., 201 West Second Street, Little Rock, Ark.	Diamond.
Frank C. Bailey, Big Arm, Mont.	Topaz.
Barber Jewelry Manufacturing Co., D. H. Kingsland, secretary, 36 Gold Street, New York City, N. Y.	Quartz.
Robert F. Bickford, Norway, Maine.	Tourmaline.
Carl Blatt, 800 Olive Street, St. Louis, Mo.	Quartz.
Otto Borreson, Hancock, Mich.	Thomsonite.
W. J. Brown, Happy Camp, Calif.	Rhodonite.
H. T. Buie, Murfreesboro, Ark.	Diamond.
F. F. Burr, Wayne, Maine	Amazon stone.
	Beryl.
	Quartz.
	Topaz.
	Tourmaline.
J. S. Callen, Lawyers' Block, San Diego, Calif.	Do.
R. H. Cartwright, Greycliff, Mont.	Iceland spar.
Dr. Homer Collins, 417 New Jersey Building, Duluth, Minn.	Chlorastrolite.
	Pyrite.
Eugene N. Crossett, South Acworth, N. H.	Hornblende in quartz.
Crystal Peak Gem Co., Florissant, Colo.	Amazon stone.
	Feldspar.
	Fluorite.
	Hematite.
	Opal.
	Phenacite.
	Quartz.
	Topaz.
F. S. Davis, 406 Charleston Building, San Francisco, Calif.	Quartz.
	Turquoise.
Elgin National Watch Co., Elgin, Ill.	Garnet.
	Sapphire.
J. D. Endicott, Canon City, Colo.	Beryl.
	Garnet.
	Miscellaneous gems.
	Opal.
	Quartz.
	Spodumene.
William Fliedner, R. D. 4, Box 42, Oroville, Calif.	Diamond.
F. H. L. Gutierrez, 1 Salinas Street North, Santa Barbara, Calif.	Opal.
W. C. Hart, 111 Narcissus Street, West Palm Beach, Fla.	Amazon stone.
	Calamine.
	Pyrite.
	Quartz.
	Topaz.
Francis Holstein, De Roche, Ark.	Quartz.

Persons and firms that have reported to the Geological Survey production of gems and precious stones in the United States, 1917–1919—Continued.

Name and address.	Mineral.
John F. Heeney, Reno, Nev.	Dumortierite in quartz. Vesuvianite.
T. J. & Thomas Homer, Lemon Cove, Calif.	Rhodonite.
J. B. Horne & Mrs. G. Jordan, Searchlight, Nev.	Turquoise.
E. A. Howard, Cave Creek, Ariz.	Quartz.
H. Johnson, 565 South Ionia Avenue, Grand Rapids, Mich.	Chlorastrolite. Thomsonite.
Ben Jutz, Cherokee, via Oroville, Calif.	Diamond. Quartz.
M. L. Keith, 65 Court Street, Auburn, Maine.	Beryl. Quartz. Tourmaline.
J. B. Kiernan, Beatty, Nev.	Opal.
Kimberlite Diamond Mining & Washing Co., St. Louis, Mo.	Diamond.
C. G. King, Manassa, Colo.	Turquoise.
J. J. Kinrade, 628 Montgomery Street, San Francisco, Calif.	Copper ore gems. Lapis lazuli. Olivine. Opal. Quartz. Rhodonite. Topaz. Turquoise. Variscite. Vesuvianite.
William Kley, 1608 Tremont Street, Denver, Colo.	Turquoise.
Henry Lindemann, 1520 Champa Street, Denver, Colo.	Beach pebbles. Copper ore gems. Garnet. Quartz. Turquoise.
Luminous Compass Co., E. N. Kramer, 617 Washington Street, Cedarburg, Wis.	Garnet. Quartz.
Don Maguire, 549 Twenty-fifth Street, Ogden, Utah.	Garnet. Jet. Quartz. Variscite.
G. H. Marcher, 411 Douglas Building, Los Angeles, Calif.	Hematite. Lapis lazuli. Quartz. Spodumene. Tourmaline. Turquoise. Variscite.
W. R. McGaw, La Jolla, Calif.	Turquoise.
J. C. Melcher, La Grange, Tex.	Meerschaum. Opal. Quartz. Spinel. Topaz.
W. W. Mildrum Jewel Co., East Berlin, Conn.	Garnet. Quartz.
Montana Gem Shop, 109 South Sixth Street, Miles City, Mont.	Do.
E. G. Morrison, Shelby, N. C.	Beryl. Garnet. Quartz.
J. H. Mosher, Glendive, Mont.	Do.
F. M. Myrick, Johannesburg, Calif.	Do.
W. D. Nevel, Andover, Maine.	Do.
New Jersey Zinc Co., Franklin, N. J.	Willemite.
New Mine Sapphire Syndicate, Morley House, Holburn Viaduct, London, E. C., England.	Corundum (sapphire).
Occidental Gem Corporation, 343 Main Street, Salt Lake City, Utah.	Variscite.
Pearce Novelty Co., 405 Fidalgo Street, Seattle, Wash.	Quartz.
William B. Penniston, Ashland, Oreg.	Do.
Petoskey Steam Agate Works, I. A. Ponfield, Petoskey, Mich.	Fossil coral.
William Petry, 424 South Broadway, Los Angeles, Calif.	Turquoise.
Dr. J. P. Rowe, Missoula, Mont.	Iceland spar.
A. J. Rudinger, Trevilians, Va.	Quartz (amethyst).
F. J. Rynerson, 4088 First Street, San Diego, Calif.	Tourmaline.
George E. Schulze, 400 Elm Street, Calumet, Mich.	Chlorastrolite. Datolite. Hematite. Opal. Quartz. Thomsonite. Tourmaline.
Mrs. Samuel Scott, Custer, S. Dak.	Quartz.
Louis Sigmund, 819 North Main Street, Goldfield, Nev.	Turquoise.
Ambrose Smedley, Lima, Pa.	Andalusite. Beryl. Feldspar. Garnet. Quartz. Rutile.
Southwest Turquoise Co., 426 Metropolitan Building, Los Angeles, Calif.	Turquoise.
H. C. Stevens, 603 Sixth Street, Oregon City, Oreg.	Quartz.
L. W. Stilwell, Deadwood, S. Dak.	Do.
Sunset Gem Co., 313 Hinckley Building, Seattle, Wash.	Do.
A. L. Thomas, Newport, Oreg.	Do.
Virginia Fairy or Lucky Stone Co., Roanoke, Va.	Staurolite.
Ward's Natural Science Establishment, 84–102 College Avenue, Rochester, N. Y.	Opal. Pyrite. Quartz. Spodumene. Tourmaline. Vesuvianite.
S. L. Watkins, Pleasant Valley, Calif.	Beryl. Copper ore gems. Corundum. Epidote. Garnet. Mariposite. Obsidian. Pyrite. Quartz. Rhodonite. Spodumene. Tourmaline. Turquoise. Vesuvianite. Zoisite.
A. C. Weeks, P. O. Box 233, Santa Fe, N. Mex.	Turquoise.
Edw. R. Zalinski, Salt Lake City, Utah.	Variscite.

RANK OF STATES.

Montana led all other States in the value of precious stones produced in 1919, a position she has held since 1911. The output consisted of sapphire, quartz of several varieties, and Iceland spar. Montana was the only producer of corundum (sapphire) and Iceland spar in the United States in 1919.

Maine rose to second place in 1919, her increase being due chiefly to a larger production of tourmaline, which is spoken of at greater length in another part of the report. Beryl, of which she was the sole producer, and quartz, of the rock crystal and smoky varieties, were also reported.

Arizona ranked third, and her output was chiefly turquoise. Small quantities of copper-ore gems, garnet, and quartz were also reported.

Nevada dropped from second to fourth rank in 1919, and the total production decreased from $21,674 to $13,679.

California, which dropped from third to fifth place in 1919, produced chiefly quartz of several varieties, tourmaline, and turquoise. She also produced small quantities of lapis lazuli, rhodonite, spodumene, and variscite, of all of which, except variscite, she was the only producer.

Value of precious stones produced in 1919, by States.

Montana	$48,391
Maine	16,225
Arizona	13,745
Nevada	13,679
California	9,221
Oregon	3,025
Arkansas, Colorado, New Mexico, Utah [1]	5,762
Other States [2]	1,715
	111,763

IMPORTS.[2a]

The precious stones (excluding pearls) imported into the United States in 1919, as reported by the Bureau of Foreign and Domestic Commerce, Department of Commerce, were valued at $91,958,830, the highest value reported for the last 10 years. The value of the pearls produced is omitted from the total, for pearls are not a mineral but an animal product, being deposited in the shells of mollusks. They are lustrous calcareous concretions with animal membrane between successive layers, and they owe their beauty and value to their organic part; but as they are among the most desired of gems, their value is given in a separate column in the table of imports.

General imports and imports for consumption for any period will differ to the extent that the value of entries for warehouse for the period differs from the value of withdrawals from warehouse for consumption. The term "entry for consumption" is the technical name of the import entry made at the customhouse and implies that the goods have been delivered into the custody of the importer and that the duties have been paid on the dutiable portion. Some of them may be afterward exported.

[1] Production of each State more than $1,000 and less than $2,000.

[2] Michigan, New Hampshire, South Dakota, Texas, Washington, and Wyoming. Production of each State less than $1,000.

[2a] Statistics compiled by J. A. Dorsey, of the United States Geological Survey, from records of the Bureau of Foreign and Domestic Commerce.

Diamonds and other precious stones imported and entered for consumption in the United States, 1910–1919.

Year.	Diamonds.				Other stones not set.	Total, excluding pearls.	Pearls.
	Glazier's.	Dust and bort.	Rough or uncut.	Cut but not set.			
1910	$213,701	$54,701	$8,991,890	$25,593,641	$4,237,232	$39,091,165	$1,626,083
1911	199,930	110,434	9,654,219	25,676,302	3,820,703	39,461,588	1,384,376
1912	452,810	94,396	9,414,514	22,865,686	3,433,163	36,260,569	5,130,376
1913	471,712	100,704	12,268,543	24,812,604	2,805,963	40,459,526	5,002,624
1914	579,332	77,408	2,851,933	11,976,871	1,649,875	17,135,419	2,090,018
1915	366,793	75,944	7,020,646	13,177,919	1,078,391	21,719,693	4,513,909
1916	836,018	67,290	11,441,328	24,282,140	2,303,351	38,930,127	11,336,971
1917	1,098,102	349,746	13,092,855	18,421,838	1,883,810	34,846,351	4,947,509
1918	718,397	475,870	12,636,024	7,734,150	1,102,398	22,666,839	765,929
1919	984,381	1,420,442	20,306,758	64,085,610	5,161,639	91,958,830	11,008,973

Value of diamonds imported into the United States in the calendar years 1918 and 1919.

[General imports.]

Country.	1918		1919			
	Uncut.	Cut but not set.	Uncut.		Cut but not set.	
			Carats.	Value.	Carats.	Value.
Argentina					17	$2,933
Belgium			46	$2,913	13,133	1,793,815
Bolivia					5	1,745
Brazil	$444,465		13,940	529,272	298	27,969
British Guiana			588	29,613		
British South Africa	197,777		8,263	469,999	62	16,572
Canada	94	$852	1	22	681	59,600
Cuba	802				40	3,361
Denmark					991	23,627
England	11,924,482	1,308,941	245,207	17,921,148	66,758	6,664,911
France	163	170,441	857	22,818	8,995	2,033,268
Italy	14,618	1,749				
Mexico		1,100				
Netherlands	23,125	6,266,319	20,998	1,337,775	434,340	53,561,019
Panama					6	1,275
Siam			897	2,198		
Spain		2,454				
Switzerland		9,954			230	32,064
Turkey in Europe					3	788
	12,605,526	7,761,810	290,797	20,315,758	525,559	64,222,947

The very notable increase of about 200 per cent in the imports of dust and bort into the United States would seem to indicate a revival of exploratory drilling in the mining industry in this country, most of the bort being used for the cutting edges of diamond drills.

The diamond market in the United States had a profitable year in 1919, as is shown by the unprecedented increases in the imports of uncut and cut diamonds. Never before has the price of diamonds risen so high, and never before has the demand been so great. One partial explanation of the vast expenditures on luxuries is that the great wave of economy that spread over the whole country during the war was followed by a reaction, and that high wages have enabled the American people to spend large sums of money for jewelry and other luxuries.

The imports of pearls into this country in 1919 amounted to $11,008,973, the highest record for the last 10 years except that of 1916, when it reached $11,336,971.

CORUNDUM (SAPPHIRE).

The mine of the New Mine Sapphire Syndicate, in Fergus County, Mont., was handicapped in its operations in 1919 by the scarcity of miners and other laborers, and by a shortage of water, the supply of which gave out early in August, bringing operations to a close. The mine was active only about 10 weeks. During the year there was taken from the mine an exceptionally fine stone, which was cut and sold in Hatton Garden, London, for £400. It weighed 10 carats in the rough and cut a gem weighing 5 carats.

DIAMOND.

UNITED STATES.

ARKANSAS.

According to a report received from the Arkansas Diamond Co., Little Rock, Ark., which owns the Arkansas diamond mine, work was done there in 1919 only by the watchman, who took out casually a very few stones. Mr. Reyburn, president of the Arkansas Diamond Corporation, which now has control of the property, states[3] that the diamonds that have been recovered from the mine average in weight a little less than half a carat. Many of the stones are of the finest quality, and the few that have been cut are said to have made beautiful gems. The company, under the supervision of its chief engineer, S. H. Zimmerman, was in April, 1920, installing on the site a mill for testing the value of the property. The actual diamond area covers about 60 acres. The diamonds occur in peridotite, which is similar in its geologic characteristics to the diamond-bearing rock in South Africa.

The Kimberlite Diamond Mining & Washing Co., which holds a lease on the Mauney mine and owns the Ozark and Kimberlite mines, did not operate the mines in 1919, owing to the loss of its two plants by fire on January 13, 1919.

The American mine, which is owned by T. E. Fluornoy, was not operated.

No work was done at the Black Lick prospect, which is owned by the Grayson-McLeod Lumber Co.

According to the best information available, about 5,000 diamonds, mostly from the Arkansas, Ozark, and Mauney mines, have been found in Arkansas between the discovery in August, 1906, and the end of 1919. These included white, brown, and yellow stones, and their average weight was between 0.3 and 0.4 carat. The largest

[3] Reyburn, S. W., Diamonds in Arkansas: Eng. and Min. Jour., Apr. 24, 1920.

diamond yet discovered in the State was found in the Arkansas mine in May, 1917, and was a canary-colored octahedron weighing 17.85 carats.

CONDITION OF DIAMOND INDUSTRY.

Up to May, 1919, the United States was buying more precious stones than all the rest of the world put together. The demand for all grades of diamonds, from "chips" to stones of the finest quality, continues in excess of the offerings. The shortage of diamonds, which is general, is most marked in small stones. The output from the South African mines has not attained the level it reached in recent pre-war years, and as the diamond market is now under the control of a diamond-mining syndicate, the diamonds have been distributed on the rationing principle, which is varied by the syndicate according to circumstances. America, however, still probably absorbs her pre-war proportion of these diamonds, which was three-fourths of the total output.

According to the American Jeweler the price of diamonds has increased almost 100 per cent in the last year. A stone weighing 1 carat now brings $500 to $650, whereas last year plenty were to be had at $250. A perfect white stone is now worth at least $700 a carat, but it formerly sold at half that price. Diamonds have become so scarce that cutters consider themselves fortunate if they can get supplies enough to keep them going from day to day.

DIAMOND CUTTING IN THE UNITED STATES.

America is becoming more and more a diamond-cutting country, according to statements made by authorities in the diamond trade. In 1918 as many as 600 cutters were employed in the vicinity of New York, and they are said to be as efficient as their foreign competitors. Antwerp has heretofore been the center of the industry.

AFRICA.

UNION OF SOUTH AFRICA.

Diamonds sold in the Union of South Africa, 1918–19.

Province.	1918		1919	
	Carats sold.	Value.	Carats sold.	Value.
Transvaal	896,021.34	£1,603,449	873,680.71	£3,244,239
Cape Colony	1,526,487.25	4,870,980	1,553,652.75	8,639,580
Orange Free State	219,424.02	758,315	221,597.55	1,495,843
	2,641,932.61	7,232,744	2,648,931.01	13,379,662

There are no diamond mines or diggings in Natal.

It will be noted that the quantity of African diamonds sold in 1919 was practically the same as in 1918, and that the increased price per carat is therefore the sole reason for the very considerable increase in the total value.

Average price per carat of diamonds sold in Union of South Africa, 1911–1919.

Year.	Mine stones.		Alluvial stones.		All stones.	
	s.	d.	s.	d.	s.	d.
1911	32	11	111	1	35	1
1912	37	4	107	9	40	1
1913	41	2	108	9	43	8
1914	38	5	80	2	40	2
1915	47	0	80	4	52	11
1916	40	3	113	2	45	7
1917	45	11	113	10	51	1
1918	50	2	134	6	54	9
1919	87	3	261	6	101	0

The following table[4] shows the production of the five mines owned by the De Beers Consolidated Mines (Ltd.) for the three years ending June 30, 1919:

Diamonds produced by De Beers Consolidated Mines (Ltd.), 1916–1919.

Year.	Blue ground hoisted (loads).	Blue ground washed (loads).	Diamonds found (carats).	Price per carat.
De Beers mine.				
1916–17	0	0	41	(a)
1917–18	0	0	206	(a)
1918–19	0	0	94½	(a)
Kimberley mine.				
1916–17	0	0	b 76	(a)
1917–18	0	0	109¾	(a)
1918–19	0	0	147½	(a)
Wesselton mine.				
				s. d.
1916–17	1,814,393	1,669,104	455,665¾	53/ 9.27
1917–18	2,065,620	1,805,436	487,828¼	54/ 9.76
1918–19	1,035,311	1,657,146	403,039¾	69/11.79
Bultfontein mine.				
1916–17	2,092,267	1,761,756	675,401¾	46/ 11
1917–18	2,328,615	1,859,531	646,927½	49/ 9.62
1918–19	1,262,942	1,629,198	507,858¾	63/ 5.38
Dutoitspan mine.				
1916–17	135,650	1,957,335	c 377,571¼	106/11.93
1917–18	2,200,843	2,178,132	422,657¾	108/ 6.22
1918–19	1,389,883	1,066,465	180,983	139/ 9.77

a Value not given in company's report. b Includes 9½ carats of débris. c Includes 9 carats of débris.

[4] Taken from the report of the De Beers Co.

It is reported by the Premier Diamond Mining Co. (Ltd.) that the scarcity of native labor necessitated a curtailment of development work during the greater part of 1919. As the development of the mine was well advanced, however, at the end of the preceding financial year, this curtailment will not react unfavorably upon operations in the future, as there is still 32,500,000 loads of blue ground available above the present lowest working level.

Diamonds produced at the Premier mine for two years ending October 31, 1919.

Year.	Quantity (carats).	Value.
		£ s. d.
1917-18	851,573	1,203,903 15 2
1918-19	814,577	1,961,259 8 1

According to information received in this country [5] a flawless blue-white diamond, weighing 1,400 carats and valued at $500,000, was discovered on the property of this company near the point where the famous Cullinan diamond was found. It was later reported that this stone had been split into about a dozen fragments by the crushing machinery, whether by accident or not is not stated. The largest piece recovered is said to weigh 300 carats and is valued at approximately $220,000.

Acccording to the Financial Times the report of the New Jagersfontein Mining & Exploration Co. for the year ending March 31, 1919, is of more than ordinary interest, for although there was a falling off in the quantity of ground washed and in the number of carats of diamonds found, the total value of the stones produced was higher than that for 1918. No details are given of the value per carat of the various classes of stones. At a meeting at Kimberley the chairman stated that the fine blue-white stone weighing 388¼ carats found on the dump in January, 1919, was taken in the books at the end of March at the average cost of production, but has since been sold at a very high price.

NEW DIAMOND-MINING DISTRICT NORTH OF KIMBERLEY.

A new diamond-mining district [6] is said to have been discovered at Tlaring, near Taungs, in Bechuanaland, about 100 miles north of Kimberley. So great is the rush of prospective diggers from the Cape to the Zambesi and Mozambique, and even into the Kongo, that the Government has decided to lay out a township to receive the new community.

OPERATIONS ON VAAL RIVER.

A company called Deep Water Diamonds has been formed to recover diamonds from the bed of Vaal River, South Africa,[7] by means of an air-lock caisson or diving bell. According to a descrip-

[5] Jewelers' Circular, Dec. 24, 1919.
[6] Manufacturing Jeweler, vol. 66, No. 5, Jan. 29, 1920.
[7] Min. and Sci. Press, Dec. 6, 1919.

tion published by the South African Mining and Engineering Journal, Johannesburg, the bell of the caisson has a diameter of 15 feet, giving ample space for several men to work. The bell is specially designed for working in deep pools and can easily be shifted from one pool to another, as the whole structure is attached to pontoons that can float in shallow water from 12 to 18 inches deep. The bell is lowered into the water by means of water ballast, and the water is displaced by air pumped into the bell by compressed-air pumps. The interior is lighted by electricity and has a telephone and signals for communication. The gravel is hauled up by a compressed-air hoist and is handled by purely mechanical means once it enters the skip. The apparatus is designed to work in any depth of water less than 65 feet; the deepest pool in the Vaal in the dry season is only about 30 to 40 feet deep. On the deck there are boilers and a steam turbine for driving the machinery and an air-compressor for supplying air to the bell. There is a bin to accommodate the gravel brought up, a trommel for cleaning and classifying the soil, gravitators for separating the diamonds, and a sorting table. Previous attempts to obtain diamonds from the bed of Vaal River have been made by means of breakwaters and suction or bucket dredges, but the latter method is said to have proved unsuccessful because the bed of the river is a natural concrete of bowlders and clay. Recent advices indicate that the idea of recovering diamonds from Vaal River by means of a caisson is not new.

CONTROL OF SOUTH AFRICAN DIAMONDS.

The diamond-mining industry of South Africa has undergone a complete change of control, as is shown by the following notes extracted from the annual report of the De Beers Consolidated Mines (Ltd.) for 1919:

A conference of the four largest producers of diamonds, consisting of the German Southwest Africa, De Beers, Jagersfontein, and Premier companies, met in London in July, 1914, with the object of regulating the value of diamonds to be placed on the market and determining the quota of each participant in the total annual sales. After long and protracted negotiations lasting many days an agreement was arrived at among the producers and terms made with the syndicate for the marketing of the diamonds. Owing to the war all negotiations came to an end, but during 1916 the diamond market began to show signs of a return to life, and while the trade was slowly recovering the Union Government decided to place a large quantity of German Southwest Africa (Southwest Protectorate) diamonds on the market, for which it called for tenders in London and on the Continent. The syndicate, feeling that if those goods were forced on the dealers there would be a collapse, approached the De Beers Co. and suggested tendering on joint account. The proposition was accepted, and an arrangement was made on a profit-sharing basis for the purchase of the German Southwest diamonds until the conclusion of peace. In October, 1916, the syndicate came to terms with the Premier Co. for the purchase of its output, so that from February, 1917, the diamonds of the four big producers have been sold through one channel.

The prices are paid to the four producers in South and Southwest Africa every quarter and are based on the net average price realized by the syndicate for the respective quotas during the previous three months, less 5 per cent. The quotas were fixed as follows:

	Per cent.
De Beers Co	51
Southwest Protectorate producers	21
Premier Co	18
Jagersfontein Co	10

NOTES ON DIAMOND MINING IN SOUTH AFRICA.

The following is an extract from the annual report of the Department of Mines and Industries of the Union of South Africa in 1919:

The continued increase in the price of diamonds, which has been most striking, has naturally resulted in renewed activity in prospecting and in the working of alluvial fields.

Although the strict control now exercised over production and sale by agreement between the principal producers steadies the market and allows of a continual enhancement of price, it may be pointed out that high prices have their disadvantages. In most commodities, in which supply and demand balance each other, the sale value of the commodity can not get away very far from the cost of production, which thus acts as a stabilizer and insures a certain reasonable minimum below which prices can not readily fall. In the case of diamonds the sale value of the big producers is at present far above the cost of production. This large margin enables a number of smaller producers whose costs are considerably higher to work also at a profit. A slight contraction of the market then becomes disastrous to these producers; and at all times the knowledge that the large producers can, if need be, place diamonds on the market at a much lower price is an element of danger. The security rests, of course, in the monopoly of control, and as long as this is maintained the position is safe. A further danger lies, however, in the possibility of the discovery of important new mines. With such great activity in prospecting as is now prevalent, such a discovery is by no means to be looked upon as impossible. It is unlikely that all the large diamond pipes already known are the only ones that exist. If other large and valuable pipes are discovered, they will be a disturbing element in the market until they also come within the monopoly of control.

GOLD COAST COLONY.

The discovery of a new diamond field in the Gold Coast Colony by the director of the Gold Coast Geological Survey, Mr. Kitson, is reported in Commerce Reports for December 15, 1919, which quotes a report published in the Gold Coast Government Gazette. The diamonds vary greatly in size. The largest found are about the size of a split pea; large numbers of them range in size from a large pinhead to a grain of millet; and many are still smaller. Of one lot of 175 stones the weight of the largest is about a carat; of the average stones of medium size 28 weigh one carat; and of the next grade there are 36 to the carat. The whole 175 stones weigh $4\frac{13}{32}$ carats. Many of the diamonds are beautifully perfect crystals, colorless and transparent. The commonest forms are the octahedron and the rhombic dodecahedron. A few are of pale-yellow, blue, green, gray, and brown tints; others are colorless, but with small dark inclusions. Cleavage plates of octahedra occur in fair numbers, indicating that the original crystals were much larger than any of those found. The Board of Trade Journal states that their value is from $2.50 to $3 a carat for the smaller grades, $4.25 a carat for the medium grade, and $7.25 to $8 a carat for the larger grade. These prices are for mixed samples, including stones of all qualities. Some of the largest stones, however, are worth $17 to $19.50 a carat.

More than 600 diamonds were found merely by panning during the time the surrounding locality was being tested with regard to the origin and distribution of the diamond-bearing gravels. Sufficient work has not yet been done to prove the economic value of the discovery.

ENGLAND.

Prior to the war the industry of cutting diamonds was confined almost exclusively to Holland and Belgium, but endeavors were made some years before the war to add diamond cutting to the other industries of Birmingham, England. In face of great difficulties the effort was continued, and when Antwerp fell numbers of refugees from among the diamond cutters of that city were provided with means of pursuing their craft in Birmingham.[8]

Centers for the employment of disabled soldiers in the diamond-cutting industry have also been established at Brighton, Cambridge, and Wrexham (Wales).

SCOTLAND.

It was recently reported[9] that a diamond-cutting industry was about to be established at Fort William, in the northwestern part of Scotland. The director of training, Ministry of Pensions, at Fort William, is reported to have said that there were about 20,000 disabled soldiers who required to be retrained. Preparations for the establishment of the diamond-cutting industry are under way, and the plant was expected to be in operation early in the spring of 1920.

BRAZIL.

A corporation was recently organized in Rio de Janeiro[10] to develop the diamond mines at Moribeca and Boa Vista, in the region of Diamantina, State of Minas Geraes, Brazil.

EMERALD.

COLOMBIA.

The rediscovery of one of the lost emerald mines in Colombia, about 10 miles northeast of Bogota, has been reported. The rediscovered mine is called the Chivor. Flawless gems of a rich and vivid color, valued as high as $1,000 a carat, are said to have been found.

The following notes on the rediscovery of certain lost emerald mines in Colombia are taken from the Survey's report on gems and precious stones in 1910 by Douglas B. Sterrett:

> Emeralds were highly prized by the Indians of South America and were mined by them for centuries prior to the coming of the Spaniards in three districts of the present Republic of Colombia. These districts—Muzo, Cosquez,

[8] Commerce Repts., July 17, 1919.
[9] Idem, Apr. 3, 1919.
[10] Idem, Apr. 5, 1919.

and Somondoco—were widely separated. When the Spanish took possession of the country about 1555, the emerald mines also were taken up. Excessive cruelties were practiced by the Spanish mine workers on the Indians employed in the mines. The trouble was not averted by the importation of African negroes, and in the war of independence of 1816 the country was so desolated that the mines of Cosquez and Somondoco were entirely lost. From that time until recently the Colombian emeralds have been obtained only from Muzo.

A Colombian named Francisco Restrepo, guided by a few hints given in ancient Spanish parchment maps and with little or no knowledge of geology or emeralds, undertook the search for the lost emerald mines. In 1896 he found traces of ancient workings and later the large workings of the lost mines. The mines are situated on a sectional ridge of the great eastern range of the Andes Mountains, at an elevation of about 9,000 feet above sea level. An old ditch 12 to 15 miles long, with reservoirs above the mines, was found. The great open cuts and tunnels were scattered over an area 6 miles long east and west and 3 miles wide north and south. Some of the working faces of these mines measure 700 to 300 meters on steep slopes; of this about 100 meters is emerald-bearing and the rest nonproductive. The emerald region is covered by forest and jungle, which doubtless conceal other workings in the region.

JET.

UTAH.

The production of jet in Utah in 1919, though small, is somewhat significant for the reason that no other production of this mineral has been reported to the Geological Survey for several years. The demand for jet had decreased considerably up to 1918, but the mortality caused by the recent war revived the demand for jet ornaments, and it may gain some vogue after years of disuse. The locality in which the mineral was found is described by Don Maguire, of Ogden, Utah, as lying south of Dirty Devil River, in a spur of the north base of the Henry Mountains, Wayne County, and also just across the line in Garfield County. The jet occurs in masses from 4 to 15 inches long and as much as 6 inches wide and from 1 to 4 inches thick. The material takes a durable blue-black polish, is not liable to crack or check after mounting, and is said to be suitable for cutting into scarf pins or cuff-button settings or necklaces.

OPAL.

UNITED STATES.

During 1919 a large flawless black opal, $3\frac{15}{16}$ inches long, $3\frac{1}{8}$ inches wide, and $1\frac{3}{16}$ inches thick, free from matrix, weighing 16.95 troy ounces, was exhibited to the Secretary of the Interior. This new gem, which is remarkable for its iridescence, was pronounced by G. P. Merrill, curator of precious stones in the United States National Museum, the finest and most beautiful he had ever seen. This very remarkable opal was found more than two years ago and is held by its owners to be worth $250,000. They have not made public the locality where it was found.

NEVADA.

In Humboldt County, Nev., writes H. P. Whitlock,[11] there have recently been brought to light some wonderful fossil remains of trees. These are remarkable not merely because they are trees, but because

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[11] Jewelers' Circular, Feb. 4, 1920, p. 189.

the stone by which the wood has been replaced is the much-sought opal. A series of these Nevada wood-opal replacements has been put on view in the Morgan Hall of Minerals, in the American Museum of Natural History, New York, where all steps in the process of the transformation of wood to opal may be seen. A unique specimen is of dark smoky color which, when it catches the light at a certain angle, reflects a dull glow of red and orange, almost as if there still burned in it some of the fires of the extinct volcano which was perhaps the first factor in its metamorphosis.

MEXICO.

Opal mining in the vicinity of Queretaro, Mexico, in a district that has for many years furnished nearly all the opals sold in the Republic, showed renewed activity in 1919. Most of the gems are sent to dealers in Mexico City, who in turn ship them to the United States.

NEW SOUTH WALES.

The discovery of black opal at Tintenbar, about 7 miles from Ballina, New South Wales,[12] caused much local excitement and a rush of applicants for miners' rights and permission to enter private lands. The Melbourne Age states that nearly a hundred claims have already been pegged. The geologic formations in the locality are slates and sandstones capped by basaltic lava flows, of which there are at least three. The opal consists of loose pieces, ranging in size from that of a pea up to that of a good-sized walnut, which are found in the soil and in highly decomposed volcanic rock at depths ranging from 3 to 6 feet. It is evident that the opal occurs as the filling of cavities in the volcanic rock and that it can probably be worked at a profit only where the containing rock has been softened by weathering.

Up to September, 1919, most of the opal found was of the transparent variety, but black opal of a very different type from the Lightning Ridge stone is also obtained.

QUARTZ.

CALIFORNIA.

Rose quartz has been found in mining feldspar,[13] 5 miles from Hale Station, on the line of the Lemon Cove & Visalia Electric Railroad (Southern Pacific), shipping point Exeter, Tulare County, Calif. The operators are Lawton & Cone, 503 Market Street, San Francisco.

MAINE.

Large quantities of pure, colorless quartz, gems from which are very brilliant and flawless, are reported by Mr. Robert F. Bickford, Norway, Me., to have been obtained from the Mount Apatite feldspar quarry owned by the Greenlaw Corporation. One large piece of smoky quartz cut a 2½ or 3 inch ball, and another specimen, without flaws, measured 6 inches in length and 2½ inches in diameter.

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[12] Commerce Repts., Jan. 29, 1920.
[13] Information furnished by C. G. Yale, of the U. S. Geological Survey.

TOPAZ.

IDAHO.

White topaz is reported to have been discovered by Mrs. Emma Mikesell at City of Rocks, about 5 miles northeast of Moulton, Cassia County, Idaho. The mineral is said to resemble diamond closely and has been cut into stones of 1 to 3 carats. Some stones that have been exhibited by the owner of the claims are exceptionally clear and will cut glass like a high-priced diamond. Miles E. North and C. C. Young, of Reno, Nev., propose to operate the properties.

TOURMALINE.

MAINE.

Mr. Robert F. Bickford, Norway, Maine, reports that new pockets of tourmaline were opened at the feldspar property on Mount Apatite owned by the Greenlaw Corporation. One oblong emerald stone weighing 10½ carats and several weighing more than 6 carats each were cut from the material taken out. Some of the material is perfect and of fine color.

Other minerals that have been found on this property are dark-pink lepidolite, talclike altered pink and blue tourmaline, cookeite, and other alteration products of original lithia minerals. A pink beryl crystal was also discovered.

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FOREIGN GRAPHITE.

By Arthur H. Redfield.

INTRODUCTION.

Early in the war period graphite took its place among the so-called war minerals—that is, minerals of which a constant supply was vital to the continuance of war-time industries and of the normal industrial life of the Nation. Even before the United States entered the war the importance of graphite as a cardinal material of war time had been recognized by Allies and Central Powers alike. Efforts were made to conserve existing supplies of graphite, to obtain new supplies from foreign and domestic sources, to maintain the production of mines in operation, and to promote the exploitation of newly discovered deposits. Under the stimulus of the war demand countries previously known as producers of graphite increased their output, and other countries entered the field. The demand for crucible steel and for brass, aluminum, and alloys of various types increased the need of crystalline graphite for crucibles. Increased requirements of foundry graphite were a natural consequence of the expansion of the metallurgic industries. The shortage of oils and fats, especially among the Central Powers, had to be met to a large extent by the use of graphite lubricants.

Three-fourths of the graphite, crystalline, amorphous, and artificial, consumed in the United States is normally imported from foreign countries. In 1913, which may be taken as a typical pre-war year, the United States obtained from outside sources 28,879 short tons (26,198 metric tons) of graphite, or 76.4 per cent of the total of 37,779 short tons (34,272 metric tons) consumed in that year. In 1919 after stimulated domestic production to meet war demands had subsided, the imports amounted to 26,626 short tons (24,155 metric tons), constituting 71.0 per cent of a total consumption of 37,501 short tons (34,020 metric tons). Foreign deposits of graphite will therefore command the interest of consumers in the United States.

Ceylon, French Indo-China, Mexico, Canada, and Madagascar (by way of France) were the principal sources of graphite imported into the United States in1919. Chosen supplied only a small quantity, by way of Japan. From Ceylon the United States obtains crystalline graphite used in making crucibles; other crystalline graphite is obtained from Madagascar, Canada, and recently from French Indo-China. Mexico and Chosen supply amorphous graphite used in making lead pencils, foundry facings, and lubricants.

WORLD'S PRODUCTION.

The overproduction of graphite stimulated by war demands reached its culmination in 1917 and had already begun to show its effect in lower prices and a diminished output in 1918. The cessation of hostilities late in 1918 completed the break of the world market.

Canceled orders stagnated the market in Madagascar. The high quality of Ceylon plumbago did not avail to maintain the demand. The removal of the import restrictions of the United States Government could not create a market in the face of untoward conditions. Graphite production in 1919 was universally depressed. The available statistics show for practically all the producing countries a decrease in output that in several countries spells the paralysis of the industry. Ceylon and Madagascar, where the production is controlled largely by small native operators, show a marked sensitiveness to conditions of the world market. Chosen, fortified by a stable Japanese demand, does not appear to have suffered to the same extent, so far as her exports show, although the price dropped sharply. (See fig. 2.)

The following table shows the world's production of natural graphite for the calendar years 1913 to 1919, inclusive, so far as figures are available. Official figures have been used as far as possible, and the unofficial figures used are from presumably reliable sources. Estimated figures are indicated as such. Differences between statistics in this table and the corresponding figures cited in previous publications of the United States Geological Survey are due generally to the substitution of later and more accurate data for preliminary figures available at the time of the earlier publications.

World's production of natural graphite, 1913–1919, in metric tons.

	1913	1914	1915	1916	1917	1918	1919
United States: [a]							
Amorphous	2,035	1,565	1,071	2,378	7,530	5,951	3,065
Crystalline	2,297	2,368	3,209	4,959	4,801	5,834	3,668
Canada [a]	1,961	1,495	2,391	3,588	3,369	2,826	1,199
Mexico [c]	4,023	3,865	1,525	4,836	6,869	5,080	4,995
Brazil [c]	2½	....	2	1	15	45	2
Austria and Styria	17,282	11,062	14,815	[b] 21,000	[b] 18,000	17,415	[b] 17,000
Bohemia and Moravia	32,175	26,973	20,231	26,313	29,073	27,355	31,234
France	1,194	300	....	....	1,650	2,132	375
Germany	12,057	13,619	17,292	30,574	42,825	64,080	(d)
Italy	11,145	8,567	6,176	8,182	12,117	11,653	7,626
Spain	....	....	30	1,240	1,980	710	1,958
Sweden	88	56	87	194	4	102	....
Ceylon [c]	28,996	14,463	22,173	33,956	27,572	15,701	6,504
French Indo-China [c]	....	....	....	....	8,000	15,000	(d)
British India	....	....	71	1,525	105	82	129
Japan	667	573	666	1,149	1,331	1,886	(d)
Chosen (Korea) [c]	14,543	9,149	7,044	16,963	16,183	13,659	[b] 12,000
Madagascar	7,997	11,232	15,940	26,524	35,000	16,000	2,000
Union of South Africa	35	31	37	55	78	72	78
Australia	....	7	71	72	89	208	102
	136,497½	105,325	112,831	183,509	216,591	205,791	....

[a] Shipments and sales. [b] Estimated. [c] Exports. [d] No data.

No attempt has been made to reduce into United States currency the values of the graphite produced. The universal inflation of national currencies during the war period, the vagaries of foreign exchange, and the artificial restrictions on trade, which prevented a free exchange of commodities, make any comparison of values between different countries or even different years in the same country of doubtful utility. Conversions of value from foreign into United States currency, whether made at the par rate of exchange or at the average rates for the respective years, are equally misleading and unsatisfactory. In view of these circumstances it has been considered better in this paper to express in United States currency

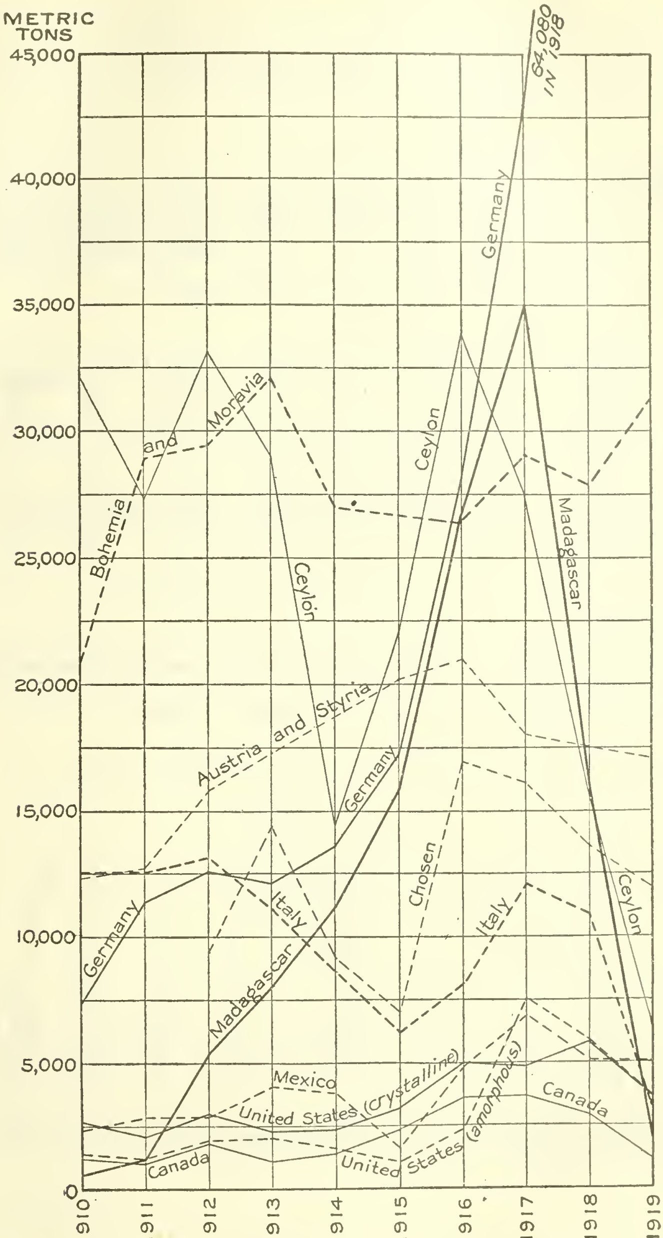

FIGURE 2.—Graph showing production of graphite in principal countries, 1910–1919.

only the values that represent actual quotations in the markets of this country.

Value of world's production of natural graphite, 1913–1919.

	Unit.								
	Name.	Par value in United States currency.	1913	1914	1915	1916	1917	1918	1919
United States [a]									
Amorphous.	Dollar	$1.00	39,428	38,750	12,358	20,723	73,481	69,455	47,716
Crystalline.	...do	1.00	254,328	285,368	417,273	914,748	1,094,398	1,454,799	731,141
Canada [a]	...do	1.00	90,282	107,203	124,233	325,362	402,892	248,970	92,241
Mexico [c d]	...do	1.00	198,000	190,075	75,000	230,000	285,568	134,183	135,464
Brazil [c]	Paper milreis.	.3244	1,300	....	500	1,612	16,760	39,257	2,160
Austria and Styria	Krone	.2026	821,544	623,671	956,947	[b]1,700,000	(e)	(e)	(e)
Bohemia and Moravia.	...do	.2026	1,162,263	(e)	(e)	(e)	(e)	(e)	(e)
France	Franc	.193	17,205	(e)	(e)	(e)	(e)	(e)	(e)
Germany	Mark	.238	266,000	426,700	1,003,625	3,100,307	3,631,332	4,405,502	(e)
Italy	Lira	.193	328,950	259,851	201,776	302,325	752,342	1,081,488	773,330
Spain	Peseta	.193	....	....	90	7,997	5,100	1,775	127,800
Sweden	Krona	.268	10,565	6,765	24,000	67,000	120	36.250	....
Ceylon [c]	Rupee	.3244	9,047,290	4,254,201	7,919,770	22,494,943	21,797,943	4,840,630	(e)
French Indo-China [c]	Piastre	.4825	....	....	....	....	(e)	(e)	(e)
British India	Rupee	.3244	....	....	2,370	22,667	8,205	5,410	12,285
Japan	Yen	.4985	31,898	24,492	32,352	52,014	75,727	104,507	(e)
Chosen (Korea) [c]	...do	.4985	248,858	192,187	202,691	576,792	1,526,133	1,264,483	560,893
Madagascar [c f]	Franc	.193	2,892,288	3,175,979	3,656,572	11,793,912	12,527,140	6,755,000	1,822,448
Union of South Africa.	Pound sterling.	4.8665	1,257	970	1,204	1,780	2,590	2,294	2,630
Australia	...do	4.8665	....	40	30	[b] 960	(e)	6,075	(e)

[a] Shipments and sales.
[b] Estimated.
[c] Exports.
[d] Values of exports of Mexican graphite, derived from United States customs statistics, are here given in United States dollars.
[e] No data.
[f] Quantities of graphite exported will be found under discussion of Madagascar.

Average exchange values of foreign coins cited in preceding table, 1913–1919. [a]

Coin.	Country.	1913	1914	1915	1916	1917	1918	1919
Milreis (paper).	Brazil	$0.324	$0.282	$0.248	$0.24	$0.256	$0.26	$0.26
Krone	Austria and Styria	.203	.1985	.156	.13	.118	(b)	(b)
	Bohemia and Moravia	.203	.1985	.156	.13	.118	(b)	(b)
Franc	France	.193	.1969	.182	.17	.174	.179	.1436
	Madagascar	.193	.1969	.182	.17	.174	.179	.1436
Mark	Germany	.238	.237	.209	.186	.178	(b)	(b)
Lira	Italy	.193	.1943	.16	.155	.128	.134	.1209
Peseta	Spain	.18	.19	.193	.201	.229	.252	.1958
Krona	Sweden	.268	.26	.254	.2925	.3208	.3355	.2550
Rupee	Ceylon	.324	.33	.332	.3285	.344	.364	(b)
	India	.324	.33	.332	.3285	.344	.364	(b)
Yen	Japan	.499	.499	.4954	.50575	.5133	.532	(b)
	Chosen	.499	.499	.4954	.50575	.5133	.532	(b)
Pound sterling.	Union of South Africa	4.87	5.011	4.7787	4.7595	4.7556	4.7554	4.464
	Australia	4.87	5.011	4.7787	4.7595	4.7556	4.7554	4.464

[a] Calculated principally from statistics of Federal Reserve Bulletin, quoted in Statistical Abstract of the United States, 1919, pp. 822–825.
[b] No data.

NORTH AMERICA.

CANADA.

The reduced demand for graphite after the signing of the armistice and during the succeeding year is illustrated in the production of Canada for 1919. The Quebec mines were idle throughout the year; those of Ontario produced only 1,322 short tons, as compared with 3,974 tons in 1918.

The United States is almost the sole consumer of Canadian graphite, importing 1,504 short tons (1,343 long tons) in 1919, as compared with 3,084 short tons (2,754 long tons) in 1918. The trend of Canadian production may be shown by the monthly imports into the United States during 1919.

Canadian graphite imported into the United States, 1919.[a]

Month.	Quantity (long tons).	Value.	Month.	Quantity (long tons).	Value.
January	286	$16,610	August	78	$5,276
February	25	1,051	September	136	10,881
March	74	11,443	October	87	10,333
April	18	2,002	November	253	18,482
May	32	2,491	December	252	17,305
June	97	4,863			
July	5	1,426		1,343	102,163

[a] Bureau of Foreign and Domestic Commerce, Dept. Commerce.

No artificial graphite was produced during 1919 by the International Acheson Graphite Co., of Niagara Falls, Ontario, whose output was 904 short tons in 1918. The production of this company for the last 10 years is given in the following table:

Artificial graphite manufactured in Canada, 1910–1919.[1]

	Pounds.		Pounds.
1910	2,442,166	1915	497,271
1911	2,172,098	1916	525,048
1912	2,302,625	1917	1,096,172
1913	2,184,472	1918	1,808,000
1914	1,234,239	1919	

MEXICO.

The Santa Maria mine, near La Colorada, Sonora, owned by the United States Graphite Co., of Saginaw, Mich., continued to be the only active producer of graphite in Mexico. The Mexican official statistics gave the output for 1919 as 5,012 metric tons, as compared with 6,191 metric tons in 1918. Shipments to the United States, the sole consumer of the Mexican graphite, as shown by the imports at Nogales, Ariz., for the year 1919, amounted to 4,995 metric tons (4,916 long tons), as against 5,080 metric tons (5,000 long tons) for the preceding year.

The trend of Mexican production is shown by the statement of imports into the United States during 1919.

[1] Report of mineral production in Canada, 1919, Dept. Mines, Mines Branch.

Mexican graphite imported into the United States, 1919.[a]

Month.	Quantity (long tons).	Value.	Month.	Quantity (long tons.)	Value.
January	574	$15,012	August	37	$1,348
February	1,298	36,351	September	....	....
March	1,868	46,727	October	76	3,211
April	737	20,418	November	87	3,325
May	88	3,132	December	38	1,404
June	113	4,536			
July	....	....		4,916	135,464

[a] Bur. Foreign and Domestic Commerce, Dept. Commerce.

SOUTH AMERICA.

BRAZIL.

Little graphite was mined in Brazil during 1919, so far as can be determined from the export statistics. Only 2,160 kilograms, valued at 2,160 paper milreis ($562), was exported in 1919, as compared with 44,553 kilograms, valued at 39,257 milreis ($10,207), in 1918.

No record of domestic production or consumption during 1919 is available at present (November, 1920).

CHILE.

The mining of graphite at Chehueque, in the Vallenar district, Province of Atacama, Chile, began shortly after the discovery of the deposits in 1917. Early in 1918 the Compañía Minera de Gráfito de Vallenar was reported to be actively exploiting these deposits and to have begun the sale of its product in carload lots in Santiago. No statistics are available to indicate the production, but beyond doubt it has been inconsiderable.

URUGUAY.

No record is available to date (November, 1920) of any active production of graphite in Uruguay during 1918 or 1919.

EUROPE.

AUSTRIA.

The Republic of Austria, sometimes called "German Austria," as delimited by the treaty of St. Germain September 10, 1919, consists of the former Provinces of Upper and Lower Austria and parts of Tyrol, Carinthia, and Styria. Of these only Lower Austria and Styria produce graphite. (See fig. 3.)

The production of graphite in Lower Austria and Styria rose from 12,356 metric tons in 1910 to 17,282 tons in 1913 and averaged about 14,560 tons during this period. Styria supplied about 13,460 tons of this average and Lower Austria the remaining 1,100 tons, at a declining rate of production. In 1914 only 424 tons was credited to Lower Austria, as against 10,638 tons to Styria. In 1915 Lower Austria produced 313 metric tons, Upper Austria, 164 tons, and Styria, 14,338 tons. Of the Styrian output, 5,400 tons was consumed within the confines of the present Austrian Republic, 1,400 tons was shipped to Bohemia, 50 or 60 tons to other Provinces of the Austrian monarchy, and 6,600 tons to Hungary and to foreign countries. By adding to the Styrian graphite consumed at home some 500 tons from Lower Austria, perhaps 2,000 tons from Bohemia and Moravia,

FIGURE 3.—Map showing location of graphite deposits in Austria and Czecho-Slovakia.

AUSTRIA.

1. Feistritz-Heiligenblut.
2. Gottsdorf.
3. Hengstberg-Korning.
4. Herzogsdorf.
5. Hohentauern.
6. Kaisersberg.
7. Kallwang.
8. Kaltbach.
9. Kapellen.
10. Klein-Veitsch.
11. Leims.
12. Loja.
13. Mühldorf.
14. Nasting.
15. Oetz.
16. Palbersdorf.
17. Rannach.
18. Rastbach bei Gföhl.
19. St. Kathrein.
20. St. Lorenzen.
21. Wald.
22. Wriesnig.

CZECHO-SLOVAKIA.

1. Bodelsdorf.
2. Černitz.
3. Černy důl in Řimau.
4. Čučice (Czuczitz).
5. Velké Tresné (Gross-Tressny), Rovečin (Rowetschin).
6. Honnetschlag.
7. Kalsching.
8. Chvalovice (Kollowitz).
9. České Krumlov (Krumau).
10. Kunštat (Kunstadt).
11. Staré Mesté (Mährisch-Altstadt).
12. Mugrau.
13. Předmesti bei Swojanow.
14. Přisnitz.
15. Psař.
16. Reith.
17. Rössin.
18. Schlögelsdorf, Weigelsdorf, Koldštyn (Goldenstein).
19. Schweine, Vierhofen.
20. Hůrka (Stuben).
21. Thattern.
22. Thumeritz.
23. Trabenrieth.
24. Tschirm.
25. Untergroschum.
26. Würben.
27. Zettlitz.

and 600 tons imported, chiefly from Bavaria and Ceylon, the yearly pre-war consumption of the lands now constituting the Republic of Austria may be estimated at 8,500 metric tons.

The record of graphite production during the war period is by no means complete. The output of the Styrian mines was 10,638 metric tons in 1914, 14,338 tons in 1915, and 19,832 tons in 1916. This represents about 90 per cent of the production of German-Austria. For all of German-Austria an output of 17,415 metric tons in 1918 is given.

The consumption and the outward shipments of Austrian and Styrian graphite during the war period are shown in the following table, which is based primarily on the official statements of the sales of Styrian graphite so far as these are available:

Austrian and Styrian graphite sold, 1914–1917, in metric tons.

Year.	Total sales of graphite.	Sales in Austria and Styria.	Sales in Bohemia and Moravia.	Sales to Germany.	Sales to other countries.
1914	11,400	[a] 4,700	[a] 700	[a] 5,800	[a] 200
1915	14,500	[a] 7,000	[a] 1,200	[a] 6,000	[a] 300
1916	19,900	8,300	1,300	9,900	400
1917	21,000	7,600	1,100	12,000	300

[a] Estimated.

Before the war the production of flake graphite, obtainable in Lower Austria, was greatly neglected, and imports from Ceylon and Bavaria supplied the demand. The stimulus of necessity caused the development of new deposits at Hengstberg, near Korning, Lower Austria; at Oetz, near Spitz on the Danube; and at Waidhofen; as well as the reopening of formerly active mines of flake graphite, among them the Wilhelmine Nowotny-Hartmann mine at Herzogsdorf, Upper Austria. Nevertheless there was a great shortage of graphite throughout the war.

In 1918, according to an industrial directory,[2] the following firms in Austria and Styria were active in mining graphite:

Firms mining graphite in German Austria, 1918.

Firm.	Location of mines.	Capital (kronen).	Employees.	Horsepower.
LOWER AUSTRIA.				
Barth, Karl, Graphit-Raffinierwerk Feistritz-Heiligenblut.	Heiligenblut, post office Mühldorf bei Spitz.	([a])	4	([a])
Bergbau Grafitwerke Gebrüder Erber, Vienna (V, 1).	Rastbach bei Gföhl	([a])	10–20	5
Lenz und Weber, Vienna (I, Elisabethstrasse 14)	([a])	([a])	([a])	([a])
Mühldorfer Graphitwerke, Vienna (VII, Langegasse 5).	Mühldorf bei Spitz	([a])	12	12
Oesterreichische Mineral-Verwertungs-G. m.b.H., Vienna (I, Helferstorferstrasse 5).	Korning bei Prinzersdorf	180,000	([a])	([a])
STYRIA.				
Aflenzer Grafit und Talksteingewerkschaft, G. m. b. H., Vienna (IX, 3. Sensengasse 10).	Aflenz bei Leoben	75,000	30	48
A. R. von Miller's Graphitwerke, Vienna (XVII).	Hohentauern bei Trieben	([a])	70	50
St. Lorenzer Graphitwerke H. Tafler, Vienna	Trieben	([a])	56	50
Elbogen, Eduard, Vienna (III, 2. Dampfschiffstrasse 10).	Jassinggraben bei Leoben	([a])	([a])	([a])

[a] No data.

[2] Jahrbuch der österreichischen Industrie, 1918, Vienna, 1919.

Graphite crucibles are manufactured at Wiener-Neustadt, Lower Austria, by the firm of Joseph de Centa. Lead pencils are made by the Mühlendorfer Kreide- und Bleistift-Fabrik, A. G., of Vienna (I, Franz. Josefs-Kai 51).

The exports of graphite from the Austrian Republic for the eight months from March to October, 1919, inclusive, were 6,065 metric tons, of which 5,652 tons went to Germany, 247 tons to Czecho-Slovakia, 52 tons to Jugoslavia, 41 tons to Rumania, 31 tons to Switzerland, and 23 tons to the Hungarian Republic. This is equivalent to an average monthly exportation of 758 metric tons. The average monthly exports from Austria and Styria in the years 1910 to 1912 were 517 metric tons. Shipments from March through October, 1919, to countries outside the limits of the former Empire averaged 700 tons a month. This increase in the exports of graphite is probably due to the paralysis of the Austrian metallurgic industries and to decreased consumption within the country rather than to any increase of production.

CZECHO-SLOVAKIA.

The Republic of Czecho-Slovakia, declared October 18, 1918, includes the former Austrian provinces of Bohemia, Moravia, and a part of Silesia, as well as territories formerly under the Hungarian crown.

There are two graphite fields in Czecho-Slovakia. One is in the České Budějovice (Budweis) mining district in Bohemia, and the other in the Brno (Brünn) mining district in Moravia. (See fig. 3.)

Bohemian graphite is of two varieties, crystalline and amorphous. It is suitable for lubricants, crucibles, boiler and foundry purposes, stove and iron polishes, and cheap pencils. Very fine pencils, such as the Koh-I-Noor, are manufactured in Budějovice (Budweis), but Ceylon and Mexican graphite is imported and mixed with the domestic product.

The mines of Moravia produce only amorphous graphite, refined by washing. The mines are worked in the winter; washing is done in the summer. This mode of operation is adapted to the conditions of demand.[3]

The war brought about a keen demand for crucibles for use in steel, brass, and other metallurgic industries. The production of crucible steel in Austria, which averaged 2,550 metric tons from 1911 to 1913, rose to 3,308 tons by 1916 but dropped to 3,045 tons in 1917 and to 1,301 tons in 1918. The greatest part of this steel was produced in Bohemia, where about 60 per cent of the Austrian iron was manufactured before the war.

The Czecho-Slovak provinces of the former dual Empire led in both the production and the consumption of graphite. For the years 1911 to 1913 Bohemia and Moravia produced jointly an average of 30,000 metric tons a year, of which 16,800 tons was exported, chiefly to Germany, and perhaps 2,100 tons went to other provinces of the Empire, leaving 11,100 tons for home consumption. To this must be added 1,400 tons from Austria and Styria and 900 tons imported principally from Bavaria and Ceylon, making the total annual

[3] Geringer, V. A. (U. S. trade commissioner, Prague), unpublished report, Aug. 31, 1920.

consumption in the Czecho-Slovak provinces about 13,400 metric tons.

The production of graphite in the Czecho-Slovak provinces decreased from 32,175 metric tons in 1913 to 20,231 tons in 1915 and rose to 29,073 tons in 1917 and to 27,355 tons in 1918, keeping pace with the demands of war-time industry. In 1919 Czecho-Slovakia produced 31,234 metric tons.

The production and exports of Bohemian and Moravian graphite during the war years are shown in the following table, which is based on official statistics:

Bohemian and Moravian graphite produced and exported, 1914–1917, in metric tons.

Year.	Produced.	Exported.[a]	Year.	Produced.	Exported.[a]
1914	26,973	10,600	1916	26,313	23,500
1915	20,231	16,500	1917	29,073	26,700

[a] Chiefly to Germany.

The following statistics[4] of graphite production in Bohemia by firms were furnished by the České Budějovice (Budweis) Mining Bureau on July 29, 1920.

Graphite produced in Bohemia, 1914–1919, by firms.

No.	1914		1915		1916		1917		1918		1919	
	Production (metric tons).	Workmen.	Production (metric tons).	Workmen.	Production (metric tons).	Workmen.	Production (metric tons).	Workmen.	Production (metric tons).	Workmen.	Production (metric tons).	Workmen.
1	7,570	244	4,633	242	6,332	282	8,782	381	7,439	431	15,695	370
2	3,329	78	3,615	136	3,929	158	6,468	246	4,155	244	1,927	168
3	2,335	115	1,250	125	3,453	148	2,138	130	3,184	167	1,695	204
4		1	794	49	4,370	87	285	26		16		
5			2,800	5	200	11	200	8				
	13,234	438	13,093	557	18,284	686	17,873	791	14,778	858	19,317	742

1. "Schwarzenberské tuhové doly" (Fürst Adolf Joseph zu Schwarzenberg'sche Graphitwerke) at Černá (Schwarzbach).
2. "Jihočeské tuhové doly" (Süd-Böhmische Graphitwerke, G. m. b. H.), at Hůrka (Stuben), P. O. Černá (Schwarzbach).
3. "Krumlovské tuhové závody bratří Poraků" (Krumauer Grafitwerke Brüder Porak), at Český Krumlov (Krumau).
4. "Pasovské tuhové závody akc. spol." (Passauer Graphitwerke A. G., of Obererlau bei Passau, Bavaria), at Chvalovice (Kollowitz).
5. "Česká společnost tuhových a uhelných závodů," at Katovice (Kattowitz).

The Brno (Brünn) Mining Bureau on July 2, 1920, issued the following table:[4]

Statistics of graphite mining in Moravia, 1914–1919.

Year.	Number of concerns.	Number of employees.	Production (metric tons). Raw graphite.	Production (metric tons). Refined graphite.	Year.	Number of concerns.	Number of employees.	Production (metric tons). Raw graphite.	Production (metric tons). Refined graphite.
1914	3	208	13,739	6,210	1917	4	264	11,200	6,746
1915	3	164	7,138	6,207	1918	5	293	12,577	7,383
1916	3	179	8,029	6,202	1919	5	268	11,917	4,237

[4] Transmitted by Trade Commissioner Vladimir A. Geringer, Prague.

The five concerns in operation during 1919 were the Staroměstské tuhové těžařstvo v Sobotíné (Altstädter Alberti Grafitgewerkschaft), at Malé Vrbno (Zöptau); the Společnost tuhových dolů A. M. Buhl ve Starém Městě (Grafitbergbaugesellschaft A. M. Buhl in Mährisch Alstadt) at Koldštyn (Goldenstein); Eduard Elbogen, of Vienna, Austria (Dampfschiffstrasse 10), operating at Cučiče (Czuczitz) near Oslavany; the Moravská montanní společnost, spol. s. v. o., near Brno (Brünn), with one mine located at Kojetice, okr. Třebičský; and the Západomoravské tuhové závody (Mathilde Weypustek, West-Mährische Graphitwerke) at Velké Tresné (Gross-Tressny), P. O. Rovečin (Rowetschin). Since October 28, 1918, no new companies have been formed in Moravia.

The working of the mines at Kunštát (Kunstadt), belonging to the Prague Credit Institute for Trade and Industry, and at Svinov, near Mohelnice, belonging to J. N. Schwarzenberg, was stopped long before the war at the instance of the graphite "cartel," although the Schwarzenberg mine produced a graphite of fine grade. The mines at Malé Vrbno (Zöptau), Tresné (Gross-Tressny), and Koldštýn (Goldenstein) have modern equipment. A Vienna company (the Aflenzer Grafit und Talkstein Gewerkschaft) has 35 claims at Louka, and the Živnostenská banka of Prague 41 claims at Cučice (Czuczitz).

Lead pencils were manufactured in Bohemia and Moravia by the following firms in 1918: [5]

Firms manufacturing lead pencils in Bohemia and Moravia, 1918.

Firm.	Location of plant.	Employees.	Horsepower.
BOHEMIA.			
Hardtmuth, L. & C.	Budweis (Budějovice)	1,500	1,200
Národní Podník obchodní a průmyslový akc. spol. v Praze (Nationale Handels und Industrienunternehmung in Prag A. G.)	Budweis (Budějovice)	120	60
MORAVIA.			
Latzmann, K., Bleistiftfabrik	Ungarisch-Ostra	25	37

Bohemia led the former Austrian Empire in the manufacture of graphite crucibles. This industry under the stress of war necessity was developed to a condition in which it was claimed to be adequate to the requirements of the Empire. It is known, however, that crucibles of quartz glass and of other substitute materials were used in the metallurgic industries, not always with entire success.

In 1918 the following firms in Bohemia were reported [5] as manufacturing graphite crucibles:

Firms manufacturing graphite crucibles in Bohemia, 1918.

Firm.	Location of plant.	Employees.	Horsepower.
Brüder Mráček, Steingutfabrik	Třemoschna bei Pilsen	50	(a)
Krumauer Grafitwerke, Brüder Porak (b)	Krumau	(a)	(a)
Ferdinand Přibyl	Neustadt a. d. Mettau	(a)	(35)

a No data. b Production in 1917, 30 carloads.

[5] Jahrbuch der österreichischen Industrie, 1918.

FRANCE.

The consumption of graphite in France in the four years immediately preceding the World War averaged 4,000 metric tons annually, of which 680 tons was mined in France and 3,320 tons was imported, chiefly from Italy, Great Britain, Ceylon, Germany, and Madagascar. The graphite was used for the most part in foundry work for making crucibles and lubricants, and in painting and electrical work. In 1913 France produced 750 metric tons of graphite crucibles [8] and imported 2,095 tons, of which Great Britain supplied 1,487 tons and Germany 597 tons.

The war created an unprecedented demand for crucible steel. The French production, which stood at 25,055 metric tons in 1913, rallied after the disorganization of 1914 and 1915 to 32,555 tons in 1916, 40,447 tons in 1917, and 40,563 tons in 1918. There was a great demand for both the raw graphite and the manufactured crucibles. The net imports of graphite were 3,006 metric tons in 1913, 3,801 tons in 1914, 1,900 tons in 1915, 8,187 tons in 1916, 13,370 tons in 1917, and 10,636 tons in 1918. Refineries were established at Marseille and Lyon. Domestic production of amorphous graphite at the Col-du-Chardonnet mine, near Briançon, in the Department of Hautes-Alpes, which had stopped at the outbreak of the war, revived with an output of 1,650 metric tons in 1917, and reached 2,132 tons in 1918.

One graphite-crucible factory existed in 1913; four new establishments were built during the war. From a pre-war output of 750 metric tons of crucibles, the capacity of the French factories increased to 14,000 or 15,000 tons at the end of the war. The capital invested in this enterprise in 1919 was stated at 6,000,000 francs. The crucibles produced were claimed to be equal to the imported English ware, except at very high temperatures. Imports of graphite crucibles rose from 2,095 metric tons in 1913 to 4,939 tons in 1916 and 4,975 tons in 1917, but fell to 1,579 tons in 1918 and 1,258 tons in 1919.

Of the 15,000 metric tons of graphite consumed in France in 1917, the crucible industry is credited with 9,000 tons, and lubrication, painting, and electricity with 600 to 700 tons. Foundry work must be considered to have consumed the greatest part of the remainder. The annual post-war requirements of French industry were estimated by the Ministry of Reconstruction early in 1919 to be about 6,000 metric tons.

Both the production and the consumption of graphite in France fell sharply in 1919, with the general demoralization of industry that followed the termination of the war. Only 375 metric tons was mined, and only 3,811 tons was imported in excess of exports. The consumption of graphite in 1919 was 4,186 metric tons, in comparison with the 12,768 tons consumed in 1918

With the purpose of protecting the new crucible industry, a decree of February 3, 1920, raised the import duty on graphite crucibles to 27 francs per 100 kilos, an increase of 200 per cent.

[8] Rapport général sur l'industrie française, p. 174, Paris, Ministère du Commerce, 1919.

GERMANY.

The annual consumption of graphite in Germany amounted to 44,500 metric tons in the two or three years preceding the war. Of this quantity Bavaria produced 12,000 tons; the remainder was imported from Austria-Hungary (19,000 to 20,000 tons), Ceylon (8,000 to 10,000 tons), and other countries.

In normal times the manufacture of lead pencils took about 4 per cent of the country's consumption, the manufacture of crucibles and foundry uses about 35 per cent, and the manufacture of stove polishes and paints about 30 per cent. The remainder was used chiefly in dry lubricants.[9]

The war cut Germany off from all foreign sources of graphite except Austria-Hungary. This ally, which in pre-war days had led the world in production, furnishing 36 per cent of the world's output in 1913, proved incapable of meeting the requirements of wartime industry. While the Austrian production fell below its pre-war level, as the imperfect figures available would indicate, the demand, especially for crucible graphite, increased in higher proportion. For the latter need, Austria-Hungary could offer little assistance.

The output of the Bavarian graphite leaped accordingly from 12,057 metric tons in 1913 to 42,825 tons in 1917 and 64,080 tons in 1918. In 1913 53 mines were active, employing 418 miners; in 1917 there were 45 mines in operation, employing 1,245 miners. In 1918 46 mines were active, employing 1,536 miners. The average value of a metric ton, as shown by production statistics, was 22.06 marks in 1913, 31.33 marks in 1914, 58.04 marks in 1915, 101.40 marks in 1916, 84.79 marks in 1917, and 68.75 marks in 1918.

By arrangement with the Austrian Ministry of War a monthly delivery of Bohemian-Moravian foundry graphite and of Styrian crucible graphite from the Kaisersberg and Trieben mines was procured. The allocation of this material was entrusted at the end of 1916 to the Graphit-Vermittlungsstelle, established by the union of German iron foundries (Verein deutscher Eisengiessereien). The entire distribution and trade in graphite was placed under the control of this agency; mines, refineries, and dealers were forbidden to put any graphite on the market without its permission. The Styrian graphite was allotted to a fixed number of plants that produced fine steel. A special graphite division of the Bavarian Ministry of Foreign Affairs was created.

In May, 1917, a testing laboratory for crucibles was added to the Graphit-Vermittlungsstelle to determine economies in the use of graphite crucibles and to promote the use of substitutes wherever possible. The consumption of graphite crucibles was soon placed under the control of this agency.[10]

Numerous substitutes for graphite, ranging from 39 to 77 per cent in carbon content, were placed on the market and some success was obtained with them in foundry practice. Used crucibles were treated with hydrofluoric acid to extract their graphite; discarded crucibles were required to be turned in to the manufacturers for this purpose.

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[9] Raw materials and substitutes in the German mineral industry: Min. Jour. (London), vol. 123, p. 577, Oct. 5, 1918.

[10] Axelrad, H. E., Ueber die Tätigkeit der von dem Verein eingerichtetem Graphit-Vermittlungsstelle: Stahl und Eisen, vol. 38, No. 48, pp. 1111-1112, Nov. 28, 1918.

Graphite recovered from the kish of the blast furnaces and from the electric furnaces used in the manufacture of ferrosilicon was employed to meet the shortage of production. Some of these substitutes had to be used with caution, as their content of sulphur ran as high as 1.1 per cent.[11]

The use of graphite crucibles was restricted by the Graphit-Vermittlungsstelle to the smelting of pure aluminum, pure zinc, silver, gold, copper and copper alloys, hard solders, and special steels. For all other metals crucibles of low graphitic content or of substitute materials were ordered to be used. The electric smelting process and other processes that did not require the use of crucibles were given every encouragement. Minute directions were given for the handling, use, and repairing of graphite crucibles.

Graphite mining was placed under strict regulation. The Bavarian Ministry of War on March 1, 1917, put the opening of new mines or the reopening of abandoned mines under license. A statute of the Bundesrat, approved June 28, 1917, levied a royalty to the State on the production of graphite and gave the central authorities broad powers to combine the mines and refineries into compulsory associations and syndicates for purposes of joint management, joint consumption of power, and general regulation of the industry.

The end of hostilities in November, 1918, made official regulation no longer necessary, and restrictions on graphite mining were removed in February, 1919. The Bavarian graphite industry was demoralized by the sudden cessation of the war. The overcapitalization and overproduction that had been induced by war demands left excessive stocks of high-priced graphite on hand, and the general depression of all industry gave small promise of a profitable market.[12] At the end of 1919 the graphite industry was almost at a standstill. Cheaper graphite could be imported from Ceylon and Madagascar. The production of Bavarian graphite had fallen so low as to induce the Government in January, 1920, to permit the importation of 200 tons of Madagascar graphite a month to make up the shortage.[13]

The Bavarian graphite operators were reported to be profiting by the depression at the end of 1919 to remodel the industry, introducing new methods and especially developing new applications of graphite, such as the manufacture of electrodes and lubricants, instead of the former one-sided manufacture of crucibles.[14]

ITALY.

Graphite is consumed in Italy primarily in the metallurgic industries and in the manufacture of lubricants. The production of steel, which may be taken as the barometer of the metallurgic industries, increased from 426,775 metric tons in 1913 to its high-water mark of 1,291,158 tons in 1917 and dropped to 992,523 tons in 1918. The production of crucible steel, recorded for the first time in 1915 as 2,000 metric tons, was 710 tons in 1916, 15,149 tons in 1917, and 3,049 tons in 1918.

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11 Raw materials and substitutes in the German mineral industry: Min. Jour. (London), vol. 123, p. 577, Oct. 5, 1918.
12 Min. Jour. (London), vol. 127, p. 721, Nov. 1, 1919.
13 Min. Jour. (London), vol. 128, p. 99, Jan. 31, 1920.
14 Norsk Naeringsliv, Jan. 17, 1920; quoted in Bergverksnyt (Kristiania), Jan. 31, 1920, p. 5.

The general growth of the Italian metallurgic industries under the stimulus of war-time demand was reflected in a decreased consumption of the domestic amorphous graphite and an increased use of imported crystalline graphite, chiefly from Madagascar and secondarily from Ceylon. Imports of graphite, which amounted to 567 metric tons in 1913, reached a maximum of 1,506 tons in 1915 and fell to 1,219 tons in 1919.

Crystalline and amorphous graphite consumed in Italy, 1910–1919, in metric tons.

Year.	Domestic (amorphous).	Austrian (amorphous).	Madagascar (crystalline).	Ceylon (crystalline).	Bavarian (crystalline).	United States.	Other sources.	Total.
1910	5,499	45	14	97	52	....	21	5,728
1911	4,225	24	11	77	68	....	67	4,472
1912	4,606	38	114	133	47	20	51	5,009
1913	1,983	33	269	100	66	12	87	2,550
1914	(a)	20	29	14	35	....	64	150
1915	(b)	....	1,078	49	....	29	350	(c)
1916	2,567	....	710	346	....	15	1	3,639
1917	4,125	(c)	(c)	(c)	(c)	(c)	(c)	5,344
1918	4,342	(c)	(c)	(c)	(c)	(c)	(c)	5,355
1919	5,441	(c)	(c)	(c)	(c)	(c)	(c)	5,336

a Exports exceeded production by 12 tons.
b Exports exceeded production by 983 tons.
c No data.

The foregoing figures, obtained by balancing domestic production with exports of domestic graphite and from import statistics, do not represent the consumption of graphite in Italy for any one year with perfect accuracy, in that they take no account of stocks carried over from one year to another. Nevertheless, an average taken over any series of years will represent with a fair degree of accuracy the consumption of graphite for that period.

The production of amorphous graphite in Italy decreased from 12,117 metric tons in 1917 to 11,653 tons in 1918 and 7,626 tons in 1919. Italy appears to have experienced the same reaction from the overproduction of 1917 as the other graphite-producing countries.

NORWAY.

The deposits of flake graphite at Skaland, on the island of Senjen, off Tromsö, Norway, are being developed by the A/S Skaland Grafitverk, of Bergen, organized with a share capital of 1,800,000 kronor ($482,000). The quality of the deposits is claimed to be sufficiently high to enable competition with Ceylon and Madagascar graphite. A daily output of 100 metric tons of refined graphite was originally planned, but the project was considerably hindered by the burning of the company's mill during the winter of 1919.[15] No statistics of actual production during 1919 have so far (November, 1920) been made public.

15 Letter from Consul George Nicolas Ifft, Bergen, May 6, 1920.

SPAIN.

The production of graphite in Spain during 1919 equaled 1,958 metric tons, valued at 127,800 pesetas, as compared with the 710 tons, valued at 1,775 pesetas, mined in 1918.

SWEDEN.

No graphite was mined in Sweden during 1919.

ASIA.

CEYLON.

The key to the depressed situation in the Ceylon graphite industry lies in the fact that mining is conducted by native owners of small means, who employ on an average not more than 20 native miners each. Any marked fluctuations in the price of their product is sufficient to cause them to open or close their mines, as the occasion may warrant. Consequently the surfeited condition of the world market and the reduced prices of graphite were sufficient to reduce the number of active mines in Ceylon to 263 at the beginning of 1919, with an employed personnel of 6,433, as compared with 1,288 mines, employing 19,912 men, on June 30, 1917, when the industry was at its height.[16]

The trend of production in 1919 may be indicated by the following monthly export statistics:[17]

Graphite exported from Ceylon, 1919.

Month.	Quantity (hundredweight).[a]	Value (rupees).[b]	Month.	Quantity (hundredweight).[a]	Value (rupees).[b]
January	12,961	317,980	August	5,291	60,836
February	21,432	388,490	September	4,173	42,341
March	16,973	176,987	October	9,661	101,281
April	(c)	(c)	November	14,081	185,469
May	(c)	(c)	December	[d] 11,473	(c)
June	1,306	3,920			
July	3,046	30,841		[d] 128,021	(c)

[a] 112 pounds.
[b] Par value, $0.324.
[c] No data.
[d] Report of Ceylon Chamber of Commerce, 1919.

Prices early in 1919 were reported as follows:[18] Lump, $115 to $225 a long ton; chip, $65 to $150; dust, $20 to $100; and flying dust, $13. Late in August[16] lump graphite was quoted at $85 to $175 a long ton, chip at $65 to $105, dust from $25 to $55, and flying dust at $15.

In 1919 the United States bought 58 per cent, by quantity, of the exports of Ceylon graphite, as compared with 55 per cent in 1918, over 80 per cent in 1917, and 75 per cent in 1916. In 1919 the United

[16] Letter from Consul Walter A. Leonard, Colombo, Aug. 27, 1919.
[17] Ceylon Customs Returns (monthly), Colombo, 1919.
[18] Commerce Repts., Mar. 25, 1919, p. 1474.

States also imported, however, 756 long tons of graphite, chiefly of Ceylonese origin, from England, so that this country consumed about 70 per cent of the Ceylonese graphite in 1919. By this mode of calculation the percentages of the previous years would also stand higher.

CHOSEN (KOREA).

Japan continued to be the principal buyer of graphite from Chosen in 1919, though she took 11 per cent less than in 1918. The figures are 11,113 metric tons in 1919 and 12,491 metric tons in 1918. The total exports of graphite from Chosen in 1919 may be estimated at 12,000 metric tons.

The United States imported no graphite directly from Chosen in 1919, but received 112 long tons by way of Japan. The first 50 tons arrived in July, followed by 61 tons in September and 1 ton in December.

Prior to the war the production of amorphous graphite in Chosen greatly exceeded that of crystalline graphite. The output of the amorphous variety decreased greatly in 1914 and has continued to decrease. The demand for flake graphite for crucibles in Europe and in America, as well as in Japan, occasioned by the war, caused a corresponding increase in the production of flake or crystalline graphite in Chosen.[19] The embargo placed by the United States upon the importation of graphite during 1918, however, decreased the output of crystalline graphite, and, although the embargo was lifted early in 1919, the disorganized conditions of transportation and trade, as well as the general depression in the industry, operated to hinder the production of the flake variety throughout the year.

The following statistics were given to Trade Commissioner J. Morgan Clements by the Chosen Bureau of Mines:

Graphite produced in Chosen, 1913–1918, in metric tons.

Year.	Amorphous.	Crystalline.	Total.	Year.	Amorphous.	Crystalline.	Total.
1913	11,731	417	12,148	1916	4,755	3,120	7,875
1914	5,423	312	5,735	1917	3,876	4,976	8,852
1915	4,646	841	5,487	1918 (exports for 11 months).	11,657	1,078	12,735

The foregoing figures may be taken as illustrative of the proportions rather than of the actual quantities of crystalline and amorphous graphite produced. The mining of graphite in Chosen is largely in the hands of small native producers, whose reports to the Chosen Bureau of Mines are often far from complete or accurate. In view of the wide discrepancy between the official statistics of production and the quantities known to be exported, the customs figures of exports are used in this paper as giving a truer index of the actual output.

Crystalline graphite occurs in disseminated flakes and in small masses of scaly crystal aggregates scattered about in gneiss in the

[19] Clements, J. M., trade commissioner, Bureau of Foreign and Domestic Commerce, Mineral production of Chosen (Korea) (unpublished report).

Shinsen (Sinchön)[21] district of the Province of Kokai-do (Hwang-hai-do) and in lenticular and veinlike masses in the pre-Cambrian biotite gneiss, hornfels, and granite of the Shojo (Changsong) and Sakushu (Sakju) district of North Heian-do (North Phyöng-an-do). It occurs in the Yongheung district of South Kankyo-do (South Ham-gyöng-do) in graphite gneiss in the form of beds, lenses, and small masses.[22] (See fig. 4.)

FIGURE 4.—Map showing location of graphite deposits in Chosen.

Amorphous graphite is more widely distributed. It occurs in layers 40 to 120 centimeters thick embedded in the gneiss of Yang-bang, about 4.6 miles west-northwest of Hamchyang, in North Keisho-do (North Kyöng-sang-do).[23] It is found south of Pukwon, in South Heian-do (South Phyöng-an), in disconnected seams and

[21] Mineral resources of Chosen, vol. 3, No. 1, Seoul, 1913.
[22] Mining industry in Japan, p. 52, Tokyo, Imp. Bur. Mines, 1915.
[23] Stutzer, O., Die wichtigsten Lagerstätten der Nicht-Erze, vol. 1, p. 62, 1911.

lenticular masses intercalated in upper and middle Paleozoic strata, which have been metamorphosed by contact with intruded graphite. It is associated here with a chiastolite-graphite slate which distinctly borders on or grades into graphite. Amorphous graphite is mined at Whanggan, in the Chong-san district in North Chusei-do (North Chung-chŏng-do), where three beds of graphite are found in a graphite-sericite gneiss series. Their widths on the swells are respectively 78, 18, and 48 feet. This area extends into the Syang-jyn district, of North Keisho-do (North Kyŏng-sang-do), where one seam has a thickness of 18 feet.[24]

FRENCH INDO-CHINA.

A new source of graphite for the United States was made evident by the importation of 7,600 long tons, valued at $1,000,000, from French Indo-China in September, 1919. This was part of a lot of 15,600 long tons, valued at $2,346,726, invoiced at the United States consulate at Saigon during the year 1919.[25]

The exploitation of the graphite deposits of Quan-Ngai or Kwang-Ngai, in Anam, began in 1917 with an exportation of 8,000 metric tons, which was increased to 15,000 metric tons in 1918. Deposits in the Provinces of Yen-Bay and Lao-Kay, in Tonkin, have also been worked since 1917.[26]

The graphite-bearing region of Quan-Ngai forms a zone extending westward from the coast for a breadth of 12½ to 18 miles into Laos. The graphite occurs in pockets interspersed in mica schists. Numerous outcrops are known.[27]

According to Consul Horace Remillard, of Saigon, the graphiteof Quan-Ngai is of the amorphous variety, suitable for foundry facings. Analyses made at the mines show a carbon content of over 80 per cent, but owing to inexperience in mining and lack of any sorting process the graphite shipped to the United States in 1919 averaged only 44 per cent pure.

Graphite has been known for years to occur in Tonkin in the pre-Cambrian crystalline schistose rocks of the basin of Red River (Song-Koi) and the upper valley of the Song-Cau. (See fig. 5.) It abounds in the gneiss at Yen-Bay, where it completely replaces the mica, giving the rock the aspect of a graphitic gneiss; and in the mica schists of the valley of the Song-Cau, in the Provinces of Thai-Nguyen and Bac-Kan. It occurs in small flaky masses or in small lamellae, without distinct crystalline form or with vaguely hexagonal contours, in great purity. This graphite does not swell after attack by fuming nitric acid.[28]

At Pho-Moi, in the Lao-Kay district, nodules of graphite are found in the black schists. They give on washing 50 to 60 per cent of graphitic carbon.

Graphitic schists of doubtful commercial value occur at Lao-Kay, Yen-Bay, Hagiang, and Dondu. The schists of Dondu contain 23

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[24] Mining industry in Japan, p. 51, Tokyo, Imp. Bur. Mines, 1915.
[25] Annual report of Saigon consulate to State Department, 1919.
[26] L'Exportateur français, December 25, 1919; quoted in La Géographie, vol. 33, No. 2, p. 190, Paris, 1920.
[27] Bulletin de l'Agence générale des colonies, vol. 13, no. 148, pp. 460–461, Melun, April, 1920; quoted from L'Eveil économique de l'Indo-Chine, Oct. 26, 1919.
[28] Dupouy, G., Contribution à l'étude de la minéralogie de l'Indo-Chine; minerais et minéraux du Tonkin, Paris, 1909.

per cent of graphitic carbon, in addition to a large percentage of hydrocarbons.

Small veins of slightly flaky graphite are found in the eruptive rocks of Co-Phuc, Huyen of Tran-Yen, in the Province of Yen-Bay.

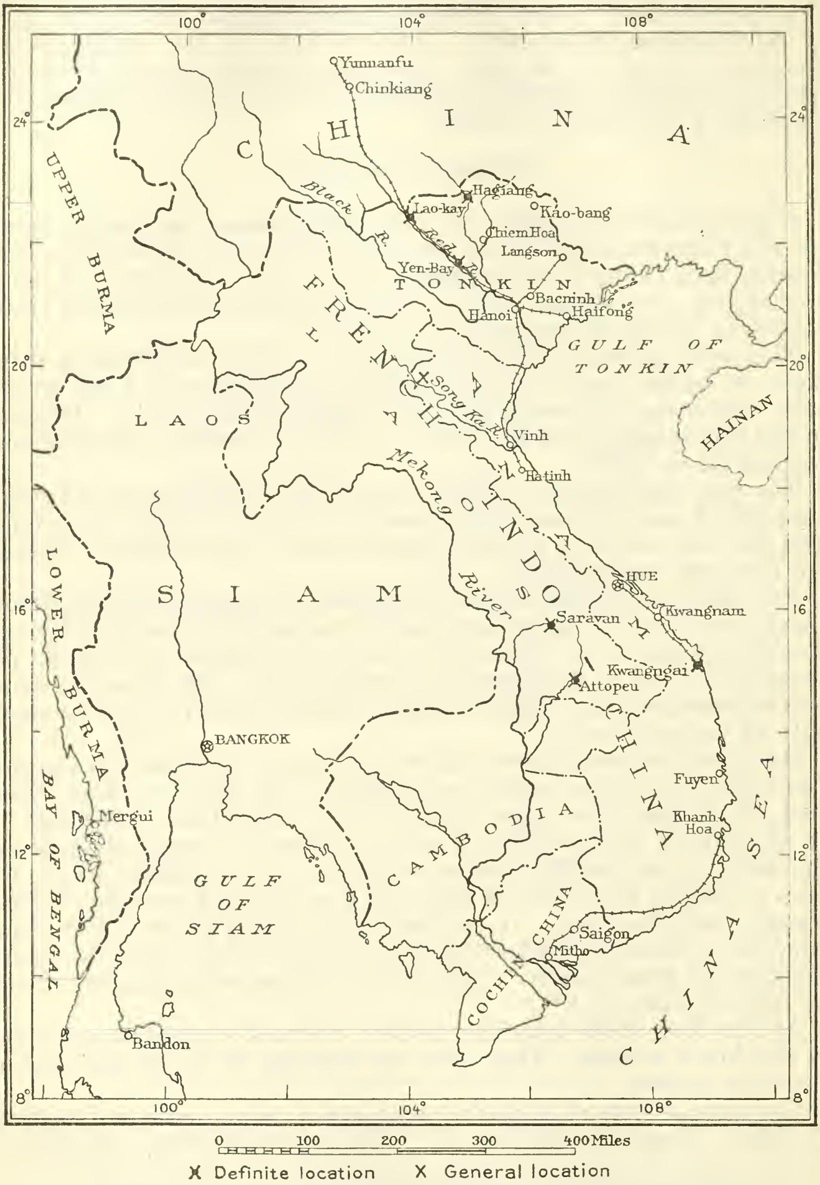

FIGURE 5.—Map showing location of graphite deposits in French Indo-China.

Analysis of a specimen gave a tenor of 84.15 per cent graphitic carbon, 12.55 per cent of silica and alumina, 0.95 per cent of iron peroxide, 2.25 per cent of water, and a trace of lime. An average run-of-mine specimen gave a content of 44.80 per cent graphitic carbon and 52.70 per cent of ash. The silica and alumina of this graphite are easily separated by grinding and washing. The specific gravity of the graphite is 2.15.

In Anam graphite occurs in the crystalline schistose rocks of the Vinh region, along the upper Song-Ka.[29] In upper Laos it is found in the crystalline schists of the valley of the Sekong, in the region of Attopeu, as well as in the neighborhood of Saravan.[30]

JAPAN.

Graphite is found in Japan in both crystalline and amorphous forms. It occurs in bedlike deposits and vein deposits; the former are the more numerous. Of the bedded deposits two forms may be observed—crystalline scales in Archean gneiss and amorphous masses in Paleozoic slate or in Mesozoic shale. An example of the vein deposit is found in liparite at Kataya, in the Province of Kaga.

Bedlike deposits of crystalline graphite are found at Naoi and at Amo, in the Archean gneiss of the Province of Hida.[31] At Sainokami, in the Commune of Sakashitamura, Department of Gifu, Province of Hida, a bed of graphite, ranging between 12 inches and 8.9 feet in thickness and dipping as much as 40°, was discovered in 1894.[32]

In the Province of Etchu crystalline graphite occurs in bedded deposits in Archean gneiss at Senoya, and in segregations of high quality but small quantity in Archean gneiss at Takanuma and Shimizu. At Ashikurazi, in the same province, it occurs as flakes disseminated in limestone.[33]

At Yamamune, in the Province of Rikuzen, a thick stratum of amorphous graphite occurs in Paleozoic slate; and at Torigoye and Koseimura, in the Province of Nagato, a thin layer of amorphous graphite is interbedded with Mesozoic shales intersected by a dike of quartz diorite. This deposit has evidently originated through contact metamorphism from coal, which occurs in thin beds in the Rhaetic (uppermost Triassic) sandstones of the vicinity.

A deposit similar to that at Kosei-mura is found in the Mesozoic shales at Kataura and Yoneyama, on the Peninsula of Noma, in the Province of Satsuma, where an intrusion of andesite occasioned the metamorphism from coal. The graphite of Kataura occurs as spherical or ellipitical inclusions in the porphyrite, 20 feet in maximum diameter; it is massive, not scaly.[34] It is accompanied by limonite, kaolin, and an anthracitelike substance which points to its origin. On the island of Shimo-Koshiki, in the same province, amorphous graphite is embedded in the Cretaceous shale.

At Kataya and Katadani, in the Province of Kaga, amorphous graphite occurs in lenticles in the veins of liparite. Owing to its good quality it has been used for the manufacture of lead pencils.

The crystalline graphite of Kawai, in the Province of Hida, has a carbon content of 60 to 70 per cent; that of Sainokami, in the same province, averages only 28 to 29 per cent.

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[29] Dupouy, G., Études minéralogiques sur l'Indo-Chine française, pp. 7–9, Paris, 1913.
[30] Dammer, B., and Tietze, O., Die nutzbaren Mineralien, vol. 1, p. 70, Stuttgart, 1913.
[31] Mining in Japan, past and present, pp. 134–135, Bur. of Mines, Dept. Agr. and Commerce of Japan, 1909.
[32] Stutzer, O., Die wichtigsten Lagerstätten der Nicht-Erze, pp. 62–63, 1911.
[33] Wada, T., Minerals of Japan, p. 4, Tokyo, 1904.
[34] Stutzer, O., op. cit., p. 62.

The following analyses of amorphous graphite from Kataura are given by C. Iwasaki:

Analyses of graphite from Kataura, Japan.

	Carbon.	Ash.
1	88.50	11.50
2	88.09	11.91
3	89.22	10.78

Analysis 1 by Geerts; analyses 2 and 3 by Gowland.

A specimen from Katadinga, in the Province of Kaga, showed 90 per cent of carbon; but generally the average is below that of the Kawai graphite. The ash was shown by J. Takayama to contain 62.60 per cent of silica, 30.35 per cent of alumina, 1.64 per cent of iron oxide, and small amounts of lime, potash, and manganese oxide.

The production of graphite in 1918 is illustrated by the following table, which includes, however, the output only of mines producing over 3,000 yen ($1,500) worth of graphite. These mines produced crystalline graphite only.

Graphite produced in Japan, 1918.

Mine.	District.	Province.	Quantity (metric tons).	Value.[a]
Yamaguchi	Gifu	Hida	23	$4,053
Motoda	do	do	16	2,699
Ashidani	do	do	12½	2,569
Naoi	do	do	14½	2,411
Kato	do	do	13	2,112
Takashimizu	Toyama	Etchu	853	14,981
Chinodani	do	do	269	8,004
Yamadadani	do	do	398	7,281
No. 258	do	do	212	3,048
			1,811	47,158

[a] Converted at par value, 1 yen=$0.498.

In addition, smaller mines produced about 15 metric tons of crystalline graphite in the Prefecture of Gifu, 48 tons of crystalline graphite in the Prefecture of Okayama, and 11 tons of amorphous graphite in the Prefecture of Miyagi.

The production of amorphous graphite in Japan declined with the importation of the Chosen product. Of a total of 131 metric tons of graphite mined in 1908 by the principal graphite mines in Japan, the amorphous deposits of Yoneyama, in Satsuma, and Yamamune, in Rikuzen, produced 68 tons or 52 per cent. In 1918 the deposits of crystalline graphite in the Provinces of Etchu and Hida supplied 96.8 per cent of the total Japanese output.

AFRICA.

BRITISH EAST AFRICA (KENIA COLONY).

Work on graphite deposits some 12 miles from Machakos, Kenia Colony (formerly British East Africa), was done in 1919 by S. D. Cuthbert, but development had not reached the stage of active production by October. It was stated that the purpose of the exploitation is to aid in the manufacture of lead pencils from local cedar wood.[35] This is the first report of a deposit of graphite of commercial value in the East African Protectorate.

A specimen of graphite gneiss of no commercial worth was obtained from the right bank of Tsavo River, where it was associated with copper carbonate.

In Uganda a dull grayish-black graphitic schist, containing disseminated flakes of graphite, was obtained from Bukunga, in the district of Mugema, on the slopes of Mount Ruwenzori, 4 miles southwest of Entebbe, in Toro Province. It carried 16.7 per cent of carbon. Another specimen of graphitic schist from Ruwenzori was found to contain 32.68 per cent of carbon.

Roughly cylindrical specimens about 6 inches long and 2 inches in diameter were obtained from the hilly country near Kitana's Camp, halfway between Hoima and Butiaba, in Unyora Province. On analysis they gave 31.2 per cent of carbon and 6.4 per cent of volatile matter other than water.[36]

Beds of graphite as much as 3 meters (9.84 feet) in thickness have been reported to occur in the Province of Kisumu.[37]

MADAGASCAR.

The embargo placed on the shipment of graphite from Madagascar to France in 1918 and the cancellation of purchasing contracts to a total of 28,000 metric tons a year by the Graphites Maskar Co., affiliated with the Morgan Crucible Co., of London, left the graphite industry of Madagascar at the end of January, 1919, with a stock of 25,000 tons on hand. Efforts were made to arrange for small shipments to the United States. On the removal of the import restrictions by the United States War Trade Board, January 16, 1919, export to the United States was permitted by the colonial government at the shippers' risk and under license from the authorities. The quantity permitted to be exported to the United States was placed at 15,000 tons for the first six months of the year.[38]

The United States did not fulfill the hopes that were entertained of it as a purchaser. No graphite shipped from Madagascar was purchased until December, and then only 340 metric tons was imported directly from the island. To this quantity should be added, however, 1,024 metric tons imported from France, at a value of $166,662, practically all of Madagascar origin. The total American consumption of Madagascar graphite did not equal one-tenth of the quantity allotted.

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[35] Letter from Consul S. W. Eells, Nairobi, October 11, 1919.
[36] Imp. Inst., London, Bull., vol. 7, p. 166, 1909.
[37] Stutzer, O., Die wichtigsten Lagerstätten der Nicht-Erze, pt. 1, p. 76, 1911.
[38] Commerce Repts., Jan. 6, 1919, p. 51.

Lack of shipping completed the depression produced by the general decrease in demand. Only 28 metric tons was exported in the first six months of 1919. Most of the smaller mines were shut down completely, and the activity of the larger concerns was greatly reduced. The output of the island for the year did not exceed 2,000 tons. Labor conditions were unsatisfactory, and transportation facilities inadequate. One of the larger graphite-mine operators was reported early in the year as arranging for the innovation of carrying his product to the point of shipment by motor truck instead of on men's backs.

The efforts of the producers centered on improving the quality rather than increasing the quantity of their output. The graphite produced in 1916 and 1917 had an average carbon content of 80 to 82 per cent; that analyzed in 1919 showed 87 to 90 per cent; and some mines now ship graphite with an average content of 93 to 95 per cent.

Stocks in July, 1919, still equaled 25,000 tons. Prices on July 20 were 500 francs per metric ton f. o. b. ship at Tamatave, for graphite of 90 per cent carbon content, with increase or reduction of 15 francs for each per cent above or below 90 per cent.

Conditions improved during the third quarter of the year. Enough shipping was obtained to permit a total exportation during the quarter of 2,335 metric tons, most of which was shipped directly to France for transshipment to England or the United States. Direct shipments of graphite to the United States from Tamatave in this quarter amounted to 82 metric tons.

These exports reduced the stocks on hand in the island to about 22,000 metric tons. Mining was absolutely at a standstill. The large stocks on hand and the small demand in France, Great Britain, and the United States made the miners unwilling to resume operations.

In October the last restriction to the free export of graphite was removed by eliminating the required permission of the chiefs of the provinces. Many of these men had formed the habit of referring all applications for such permits to the governor general of the colony, thereby causing considerable delay.

The price of 500 francs per metric ton f. o. b. ship at Tamatave, quoted on July 20, was still asked on December 1, 1919. Several owners were alleged to have sold their stocks at as low as 300 francs a ton in the warehouse at Tamatave, but these sales were said to cover only small quantities.

Graphite exported from Madagascar, 1913–1919.[a]

	Quantity (metric tons).	Value (francs).		Quantity (metric tons).	Value (francs).
1913	6,573	2,892,288	1917	27,838	12,527,140
1914	7,940	3,175,979	1918	15,015	6,755,000
1915	12,189	3,656,572	1919	4,050	1,822,448
1916	26,209	11,793,912			

[a] Commerce Repts.

To protect the foreign purchaser, the colonial government by a decree published October 11, 1919, made arrangements for customs officials at the port of shipment, on the request of the exporter, to take samples for analysis in the official laboratory of the colony and to issue an official certificate of quality on the basis of the analysis.

UNION OF SOUTH AFRICA.

The production of graphite in the Zoutpansberg district of the Transvaal in 1919 showed an increase of one-sixth over the output in 1918. The trend of the industry during 1919 is shown by the following statement of monthly production, based on shipments and sales:

Graphite produced in Transvaal, 1919.[a]

Month.	Quantity (short tons).	Value.	Month.	Quantity (short tons).	Value.
January	9.010	£308	August	3.804	£103
February	6.674	219	September	9.577	238
March	9.809	275	October	2.774	94
April	8.760	267	November	9.085	259
May	8.009	250	December	2.490	153
June	8.234	220			
July	7.285	244		85.511	2,630

[a] South African Jour. Industries (monthly statements).

AUSTRALASIA.

AUSTRALIA.

Amorphous graphite was mined on Mount Bopple, Queensland, from 1905 to 1908, but in recent years the graphite output of Australia has come entirely from New South Wales and Western Australia.

Graphite produced in Australia, 1914–1919, in long tons.

State.	1914	1915	1916	1917	1918	1919
New South Wales	......	70	50	70	200	100
Western Australia	7	......	21	18	5	......
	7	70	71	88	205	100

Amorphous graphite is mined in New South Wales at Bookookoora, in Wilson's Downfall Division. The deposits consist, like those of Mount Bopple, Queensland, of beds of Mesozoic coal graphitized by intrusions of syenite and andesite. A sample from this area showed on analysis 31.76 per cent of fixed carbon, 8.66 per cent of volatile matter, and 59.58 per cent of ash.[39]

A specimen from Fairview, New South Wales, contained 47.12 per cent of carbon, 11.88 per cent of volatile matter, and 46.27 per cent of ash.

In Western Australia 5 long tons of graphite, valued at £75, was mined in 1918. No figures of production for 1919 have yet (November, 1920) been made public. The chief deposits in this State are at Munglinup, between Ravensthorp and Esperance, in the Eucla

[39] Dunstan, B., Graphite: Queensland Govt. Min. Jour., vol. 18, pp. 454–455, 1917.

division, and at Donnelly River, Kendenup, in the Plantagenet district.

On March 13, 1919, the State of South Australia offered a bonus of £1 a ton for marketable graphite produced within the State and sold prior to June 30, 1922. No statistics are yet available to indicate what effect this offer had upon production in 1919. Before 1918 this State had produced no graphite.

Prospecting on one of the deposits of Eyre's Peninsula is stated to to have been so satisfactory that steps have been taken to put up a plant there. Samples of graphite taken from the new shaft of the Port Lincoln Plumbago Syndicate show small amounts of disseminated flake graphite in a decomposed gneissose rock and of fine flake and amorphous graphite in hard limestone. The carbon content in the samples extracted ranges from 0.6 to 1.1 per cent. Samples from the original shaft showed from 0.6 to 2 per cent of carbon. From a shaft in the Hundred of Koppio samples were taken averaging 6 per cent of flake assaying 94.3 per cent of carbon, and 4 per cent of flake assaying 92.3 per cent of carbon.[40]

NEW ZEALAND.

The occurrence of graphite in New Zealand was described in May, 1919,[41] in a monograph by the Director of the New Zealand Geological Survey, from whose paper the following data were obtained:

Graphite is widely distributed throughout New Zealand. (See fig. 6.) It occurs disseminated or in deposits of various sizes in the Paleozoic marbles, gneisses, and schists of western Otago; in the early Mesozoic graywackes and argillites of western Canterbury and the adjoining part of eastern Westland; and in the Paleozoic schists, argillites, and marbles of Nelson and Marlborough. In the North Island graphite is found in the graywackes and argillites of the Rimutaka and Tararua ranges; in the Tertiary volcanic rocks of the Hauraki gold field; in the post-Tertiary eruptive rocks of Mount Egmont; and in the Mesozoic (?) rocks of North Auckland.

Deposits of probable commercial value are not numerous. A sample from Dunstan, on the Clyde, Otago, South Island, showed on analysis 45.4 per cent of carbon, 51.1 per cent of earthy matter, and 3.5 per cent of water. As described by Skey,[42] it "compares very favorably with several of the blackleads used in commerce." An impure graphite from the Orari Gorge, in South Canterbury,[43] was found to contain 20.62 per cent of carbon, 78.79 per cent of earthy matter, and 0.59 per cent of water. A specimen from Mount Potts, in Canterbury, analyzed in 1878, contained 90.17 per cent of carbon, 6.22 per cent of siliceous matter, and 3.61 per cent of water. The ash was reddish. "Although so rich in carbon, it has not that unctuousness which distinguishes the more valuable graphites, but appears indurated, and granular, defects which must depreciate its value considerably."[44]

[40] South Australia Dept. Mines Semiannual Review of Mining Operations, No. 30, June 30, 1919.
[41] Morgan, P. G., Graphite in New Zealand: New Zealand Jour. Sci. and Technology, vol. 2, pp. 198–209, 1919.
[42] Skey, W., Dominion Laboratory Ann. Rept. No. 5, p. 14, 1870.
[43] Idem, No. 15, p. 36, 1878.
[44] Idem, No. 5, p. 14, 1870.

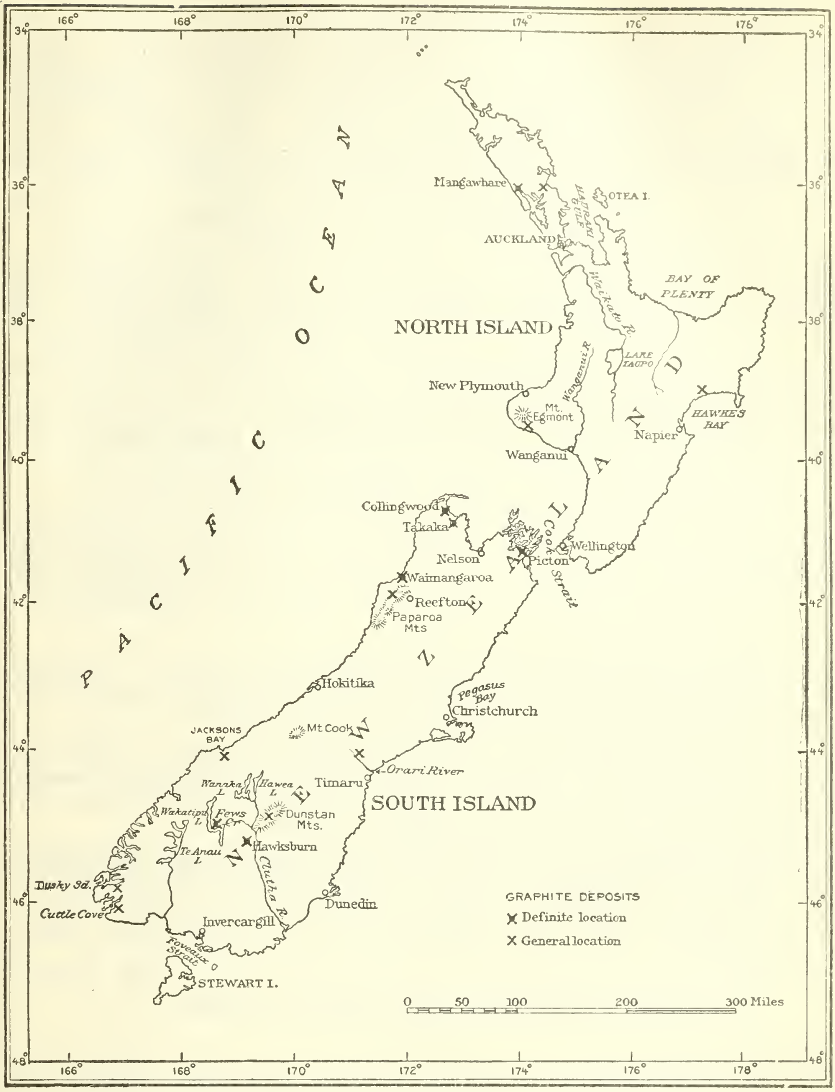

FIGURE 6.—Map showing location of graphite deposits in New Zealand.

Graphitic schists from the Ordovician rocks of the neighborhood of Collingwood gave the following analyses:

Analysis of graphite schist from Collingwood, New Zealand.

Carbon	66.86	33.62	37.38
Water	.85	.60	4.20
Ash	32.29	65.78	54.42
	100	100	100

Graphite was at one time mined in the Pakawau district, near Collingwood. The layer is described [45] as a bed about 7 inches thick, dipping nearly 80° W., contained in brown arenaceous mica schists, which are overlain by hard siliceous sandstones and cherts that form the higher part of Mount Misery. The graphite, which is largely mixed with quartz and other earthy impurities, has the composition shown by the following analyses:

Analyses of graphite from Pakawau, New Zealand.

Carbon	34.40	51.62	31.77	28.27	34.05	39.19	52.12
Water	.59	.40	.02	4.12	1.19	1.17	2.02
Ash	65.01	47.98	68.21	67.61	65.76	59.64	45.86
	100	100	100	100	100	100	100

Graphite shale in the Wakamarama Ranges,[46] in the northwestern part of Nelson, showed on analysis the following proportions:

Analyses of graphite shale from Wakamarama, New Zealand.

Carbon	31.14	22.59
Water	1.12	.66
Earthy matter	67.74	76.75
	100	100

A sample from Avondale, Marlborough, was found to contain 89.49 per cent of carbon and 4.86 per cent of earthy matter; and 5.65 per cent represented water and loss on ignition.[47]

On the North Island the rocks of the Ruahine Range, near Hawkes Bay, contain graphitic shale, of which a sample collected at Keruru showed 12.52 per cent of fixed carbon, traces of hydrocarbon, 5.21 per cent of water, and 82.27 per cent of ash.[48]

Pieces of graphite have been picked up in the stream beds of the slopes of Mount Egmont, of which specimens from Waiokura Creek, near Waimate, Taranaki, yielded on analysis [49] the results shown below. There is little hope, however, of the mineral being found in quantity.

Analyses of graphite from Mount Egmont, New Zealand.

Fixed carbon	86.9	92.5
Volatile matter (including water)	6.6	4.5
Ash	6.5	3.0
	100	100

A sample of impure graphite from Rangiahau, Hokianga County, was found to contain 44.8 per cent of graphite, 1.6 per cent of water, and 53.6 per cent of earthy matter.[50]

Numerous occurrences of minor importance are described or referred to in the monograph cited.

[45] Reports of geological explorations: New Zealand Geol. Survey No. 20, p. 205, 1890.
[46] Dominion Laboratory Ann. Rept. No. 7, p. 19, 1872.
[47] Idem, No. 25, p. 61, 1891.
[48] Idem, No. 26, p. 27, 1892.
[49] Idem, No. 14, pp. 27–28, 1879.
[50] Idem, No. 36, p. 6, 1903.

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PHOSPHATE ROCK.[1]

By R. W. Stone.

PRODUCTION.

PHOSPHATE ROCK SOLD.

The phosphate rock sold in the United States in 1919 amounted to 2,271,983 long tons, valued at $11,591,268. As compared with the production in 1918, this was a decrease in quantity of 9 per cent and an increase in value of approximately 41 per cent. In this report the value of domestic material is the selling price f. o. b. mines. Attention should be called, however, to the fact that some phosphate-mining companies bill their rock to their own fertilizer plants at a price lower than the open market, and a considerable quantity of rock was sold in 1919 on contracts made several years ago at a very low price, and therefore the average value per ton is less than it would be if all material sold were reported on the basis of sales or current market price.

Phosphate rock sold in the United States, 1910–1919.

Year.	Quantity (long tons).	Value.	Year.	Quantity (long tons).	Value.
1910	2,654,988	$10,917,000	1915	1,835,667	$5,413,449
1911	3,053,279	11,900,693	1916	1,982,385	5,896,993
1912	2,973,332	11,675,774	1917	2,584,287	7,771,084
1913	3,111,221	11,796,231	1918	2,490,760	8,214,463
1914	2,734,043	9,608,041	1919	2,271,983	11,591,268

PHOSPHATE ROCK MINED.

The quantity of phosphate rock mined in any year is not the same as that sold, and the quantity in stock at the mines at the end of each year is variable. The total quantity of phosphate rock mined in 1919 was 1,851,549 long tons, a decrease of nearly 19 per cent from the output in 1918, which was 2,284,245 long tons.

Phosphate rock mined in 1918 and 1919, by States, in long tons.

State.	1918	1919	Percentage of increase or decrease.
Florida	1,884,891	1,254,609	−33
South Carolina	33,673	49,032	+46
Tennessee and Kentucky	353,726	530,973	+50
Western States	11,955	16,935	+42
	2,284,245	1,851,549	−19

[1] The statistical tables in this report were prepared by Miss K. W. Cottrell, of the United States Geological Survey, who succeeds Miss L. M. Jones, previously in charge of the work. The tables relating to imports and exports were compiled by J. A. Dorsey from records of the Bureau of Foreign and Domestic Commerce.

There was an increase in the quantity of rock mined in each of the States except Florida, whose decrease of 33 per cent was due to a strike that lasted seven and one-half months.

STOCKS.

Stocks reported on hand at the end of 1919 were about 555,000 long tons, as compared with 1,127,000 tons at the end of 1918, a decrease of about 50 per cent.

The stocks on hand in Florida were reported to be about 521,000 tons, as compared with 1,046,000 tons in 1918. Tennessee likewise reduced stock from 61,000 to 31,000 tons. Each of the Eastern States sold more rock in 1919 than it mined and reduced its stock. In the Western States stocks are not carried and production and sales are therefore the same.

PRODUCTION BY STATES.

OUTPUT AND VALUE.

In 1919 there was an increase in quantity of phosphate rock sold in South Carolina, Tennessee, Idaho, and Utah, and an increase in value in all the producing States except Kentucky. The average value per ton increased in all States, the percentages of increase being 59 in Florida, 14 in South Carolina, 24 in Tennessee, and 17 in the Western States. In the whole country the average value per ton increased from $3.30 in 1918 to $5.10 in 1919, or 55 per cent.

Phosphate rock mined and sold in the United States, 1918–19.

State.	1918			1919		
	Quantity (long tons).	Value.	Average value per ton.	Quantity (long tons).	Value.	Average value per ton.
Florida:						
Hard rock	62,052	$377,075	$6.08	285,467	$2,452,563	$8.59
Soft rock	8,331	147,103	17.66	14,498	196,318	13.54
Land pebble	1,996,847	5,565,928	2.79	1,360,235	5,149,048	3.79
	2,067,230	6,090,106	2.95	1,660,200	7,797,929	4.70
South Carolina:						
Land rock	37,040	164,650	4.45	60,823	308,968	5.08
Tennessee:						
Brown rock	[a]374,535	1,917,546	5.12	[a]475,475	3,123,565	6.57
Blue rock				58,550	290,951	4.97
	[a]374,535	1,917,546	5.12	[a]534,025	3,414,516	6.39
Western States [b]	11,955	42,161	3.53	16,935	69,855	4.12
	2,490,760	8,214,463	3.30	2,271,983	11,591,268	5.10

[a] Includes brown rock from Kentucky.
[b] 1918: Idaho and Utah; 1919: Idaho, Utah, and Wyoming.

FLORIDA.

In 1919 Florida, the leading State in the production of phosphate rock, marketed 1,660,200 long tons, valued at $7,797,929, or 73 per cent of all the phosphate rock sold in the United States. This was a decrease of 20 per cent in quantity from 1918, but an increase in value of 28 per cent.

Hard rock phosphate, less than 20,000 tons of which was sold in 1917, was in demand for export in 1919, and 285,467 tons was marketed. Much of this material was taken from stocks that accumulated in 1917, when production was continued after the sales had fallen off.

Soft rock phosphate was produced by six companies:

Cummer Lumber Co., Newberry, Alachua County.
Franklin Phosphate Co., Newberry, Alachua County.
Florida Soft Phosphate & Lime Co., Ocala, Marion County.
Seminole Phosphate Co., Croom, Hernando County.
Acme Phosphate Co., Morriston, Levy County.
Otis Phosphate Co., Benotis, Taylor County.

The quantity of soft rock marketed in 1919 was 14,498 long tons, valued at $196,318, an increase of 74 per cent in quantity over the production of 1918. The average value per ton was $13.54, as compared with $17.66 in 1918. It is presumed that the high average value of 1918 may have been due in part to one or more of the producers having included cost of freight in their reported value. The selling price in 1919 varied considerably among the six producers, the lowest price being about $7.25 and the highest $16 a ton. Of the total quantity 27 per cent was sold at an average value of more than $15; 24 per cent at about $13.50; 32 per cent at $14; and the remainder at $8 or less.

The quantity of land pebble produced in 1919 was 1,360,235 long tons, a decrease of 32 per cent from the output of 1918. The decrease was caused by a labor strike that lasted seven and one-half months. The average value per ton of land pebble increased from $2.79 to $3.79. According to the reports of Florida producers they sold in 1919 between 1,500 and 2,000 tons of phosphate rock for blast furnaces; in addition between 15,000 and 20,000 tons was ground for direct application to the soil.

Florida phosphate rock sold in 1915–1919.

Year.	Hard rock.			Soft rock.		
	Quantity (long tons).	Value.	Average value per ton.	Quantity (long tons).	Value.	Average value per ton.
1915	50,130	$265,738	$5.30			
1916	a 47,087	a 295,755	5.26	(a)	(a)	$9.76
1917	a 18,608	a 159,366	5.93	(a)	(a)	12.40
1918	62,052	377,075	6.08	8,331	$147,103	17.66
1919	285,467	2,452,563	8.59	14,498	196,318	13.54

Year.	Land pebble.			Total.		
	Quantity. (long tons).	Value.	Average value per ton.	Quantity. (long tons).	Value.	Average value per ton.
1915	1,308,481	$3,496,501	$2.67	1,358,611	$3,762,239	$2.77
1916	1,468,758	3,874,410	2.64	1,515,845	4,170,165	2.75
1917	2,003,991	5,305,127	2.65	2,022,599	5,464,493	2.70
1918	1,996,847	5,565,928	2.79	2,067,230	6,090,106	2.95
1919	1,360,235	5,149,048	3.79	1,660,200	7,797,929	4.70

a Soft rock included with hard rock.

SOUTH CAROLINA.

The phosphate rock mined in South Carolina was land rock only. The quantity sold was 60,823 long tons, an increase of 23,783 tons, or 64 per cent, over that sold in 1918. It was also about 12,000 tons more than was mined. Stocks on hand at the end of the year appear to have decreased from 17,551 tons in 1918 to 5,760 tons in 1919. The average value per ton increased from $4.45 to $5.08, and the total value of the rock sold increased 88 per cent.

South Carolina phosphate rock sold in 1915–1919.

Year.	Quantity (long tons).	Value.	Average value per ton.
1915	83,460	$310,850	$3.72
1916	53,047	211,125	3.98
1917	33,485	138,482	4.14
1918	37,040	164,650	4.45
1919	60,823	308,968	5.08

TENNESSEE AND KENTUCKY.

The quantity of phosphate rock sold in Tennessee and by one operator in Kentucky in 1919 was 534,025 long tons, valued at $3,414,516, an increase of 43 per cent in quantity and 78 per cent in value over 1918. This is very encouraging in contrast with a decrease of nearly 27 per cent in quantity and a slight decrease in value in 1918. About 31,000 tons of Tennessee phosphate was reported by producers as sold in the form of ground rock for direct application to the soil, a slight decrease from the 33,000 tons so reported in 1918. This may not mean a decrease in the use of Tennessee phosphate for this purpose, however, for some rock may be ground by others than the original producers. Tennessee producers report 8,805 tons of phosphate sold to blast furnaces. The average value per ton of Tennessee and Kentucky phosphate rock increased from $5.12 to $6.39. In 1919 the average value per ton of brown rock was $6.57, and of blue rock $4.97, as compared with $5.26 for brown rock and $4.15 for blue rock in 1918.

Tennessee phosphate rock sold in 1915–1919.

Year.	Brown rock.		Blue rock.		Total.	
	Quantity (long tons).	Value.	Quantity (long tons).	Value.	Quantity (long tons).	Value.
1915	[a] 389,759	[a] $1,327,747	([b])	([b])	[a] 389,759	[a] $1,327,747
1916	[c] 364,108	[c] 1,357,888	47,682	$152,465	[c] 411,790	[c] 1,510,353
1917	[c] 447,203	[c] 1,920,533	65,904	205,820	[c] 513,107	[c] 2,126,353
1918	[b] [c] 374,535	[b] [c] 1,917,546	([b])	([b])	[c] 374,535	[c] 1,917,546
1919	[c] 475,475	[c] 3,123,565	58,550	290,951	[c] 534,025	[c] 3,414,516

[a] Includes some blue and some white rock and a very small quantity of rock from Arkansas.
[b] Blue rock is included with brown rock.
[c] Includes a small quantity of brown rock from Kentucky.

WESTERN STATES.

The phosphate-rock industry in the Western States showed an increase of 42 per cent in quantity and 66 per cent in value in 1919, and passed any previous record. Nearly 17,000 tons was sold at an average value of $4.12 a ton.

There were two producers in Bear Lake County, Idaho; one in Rich County, Utah; and one in Lincoln County, Wyo.

It is believed that at least 5,000 tons was shipped directly to Honolulu. More than 7,000 tons was utilized at a chemical plant on San Francisco Bay, and 3,000 tons went to a fertilizer factory near Chicago.

Western States phosphate rock sold in 1915–1919.

Year.	Quantity (long tons).	Value.	Average value per ton.
1915	3,837	$12,613	$3.29
1916	1,703	5,350	3.14
1917	15,096	41,756	2.77
1918	11,955	42,161	3.53
1919	16,935	69,855	4.12

EXPORTS.

The quantity of phosphate rock exported from the United States steadily declined from 1913 to 1918, falling from 1,300,000 long tons to 143,455 tons, or to about one-tenth of its former volume. In 1919, however, European demand for phosphate rock was renewed, as is shown in the following table:

Phosphate rock exported from the United States, 1917–1919.[a]

Kind.	1917		1918		1919	
	Quantity (long tons).	Value.	Quantity (long tons).	Value.	Quantity (long tons).	Value.
Phosphate rock, ground or unground, not acidulated:						
High-grade rock	12,403	$113,392	57,771	$445,419	215,039	$2,261,852
Land pebble	138,010	548,203	64,559	303,758	128,860	904,308
All other	15,945	173,450	21,125	163,308	34,832	401,822
	166,358	835,045	143,455	912,485	378,731	3,567,982

[a] The statistics in this table are compiled from the records of the Bureau of Foreign and Domestic Commerce, Department of Commerce.

Whether our exports of phosphate rock will ever reach their former proportions is uncertain. Europe has been short of phosphatic fertilizers for a number of years, particularly since 1915. It is natural that with the cessation of general hostilities and the resumption of agricultural pursuits there should be a strong demand for phosphate rock. This is indicated partly by the increase in exports from the United States in 1919. These exports, as formerly, went very largely to northern Europe. There can be only a small market in southern Europe for our phosphate rock, because France and Spain have greatly increased their capacity to manufacture sulphuric acid, and with phosphate rock reaching their ports in abundance from Algeria and Tunis they can make superphosphate enough to supply their own needs and in part the needs of their neighbors. Such a condition would result in a smaller demand for Florida phosphate. The rate at which the phosphate rock is produced in Algeria and Tunis appears to be the chief factor in a possible future decline in Florida exports. It will be several years before any considerable quantity can be produced in Morocco, where the deposits are wholly undeveloped and are far from a railroad.

It must be expected that eventually, on account of the abundance of phosphate rock in northern Africa and the short haul and low freight charges to Europe as compared with the long haul and consequently high freight charges from the United States, there will be stronger competition for the phosphate market in northern Europe.

According to the following table showing the destination of our exports of phosphate rock Spain and Switzerland were the only countries in southern Europe to receive them direct in 1919. Denmark, which had not been a market for our phosphate for several years, was the largest buyer, 100,696 long tons having been shipped to that country. Sweden took 61,093 tons, Norway 20,717 tons, Netherlands 41,155 tons, Spain 34,599 tons, England, 27,325 tons, Germany 28,062 tons, and Belgium 21,715 tons. Cuba, Canada, and Costa Rica were the only countries in the Western Hemisphere that took more than a few tons. Canada bought 7,257 tons, Cuba 14,489 tons, and Costa Rica 250 tons of raw rock phosphate.

Phosphate rock, ground or unground, not acidulated, exported from the United States, 1917–1919.

High-grade rock.

Country.	1917		1918		1919	
	Quantity (long tons).	Value.	Quantity (long tons).	Value.	Quantity (long tons).	Value.
Belgium					16,161	$161,610
Canada	111	$1,375	379	$5,823	752	14,195
Cuba	45	615	53	860	1,884	21,216
Denmark					80,753	828,519
England			1,850	9,250		
Germany					28,062	300,782
Mexico	10	108				
Netherlands					10,702	134,147
Norway	8,641	75,336	21,133	145,827	18,517	201,036
Spain					18,527	200,255
Sweden	3,596	35,958	34,356	283,659	37,106	375,048
Switzerland					2,575	25,044
	12,403	113,392	57,771	445,419	215,039	2,261,852

Phosphate rock, ground or unground, not acidulated, exported from the United States, 1917–1919—Continued.

Land pebble.

Country.	1917		1918		1919	
	Quantity (long tons).	Value.	Quantity (long tons).	Value.	Quantity (long tons).	Value.
Belgium	4,769	$16,930				
Canada	5,153	20,036	5,445	$20,991	1,202	$4,807
Cuba	9,876	31,388	12,063	32,134	8,449	32,857
Denmark					17,943	161,776
England	32,140	127,215	19,804	100,936	27,324	177,993
France	8,208	23,124	9,602	48,010		
Ireland	7,500	25,500			11,517	75,889
Italy			1,440	4,320		
Netherlands	4,450	20,025			26,953	185,256
Scotland	5,100	18,337			7,150	82,225
Spain	60,814	265,648	11,848	73,312	16,072	108,540
Sweden			4,357	24,055	12,250	74,965
	138,010	548,203	64,559	303,758	128,860	904,308

All other phosphate rock.

Country.	1917 Quantity (long tons).	1917 Value.	1918 Quantity (long tons).	1918 Value.	1919 Quantity (long tons).	1919 Value.
Barbados					50	$1,375
Belgium					5,554	55,540
Bermuda	298	$2,905				
British Honduras	1	9			1	7
British Oceania [a]	500	6,000				
Canada	5,408	61,205	8,419	$78,888	5,303	70,958
China					1	6
Costa Rica					250	1,450
Cuba	7,555	82,484	4,388	32,337	4,156	74,181
Denmark					2,000	36,960
England			2,525	13,080	1	2
Honduras					1	28
Jamaica					75	1,601
Mexico	1	120			2	70
Netherlands	2,182	20,727			3,500	59,500
Norway			3,975	23,853	2,200	17,607
Other British West Indies					1	10
Sweden			1,818	15,150	11,737	82,527
	15,945	173,450	21,125	163,308	34,832	401,822

[a] Not including Australia and New Zealand. Reported by Bureau of Foreign and Domestic Commerce as "Other British Oceania."

The following table shows the proportion of exports to domestic production in the United States during the last seven years. The exports decreased from 44 per cent of the production in 1913 to 6 per cent in 1917 and 1918 but rose to 17 per cent in 1919.

Phosphate rock marketed in and exported from the United States, 1913–1919.

Year.	Quantity marketed (long tons).	Exports (long tons).	Proportion of exports to domestic production (per cent).
1913	3,111,221	1,366,508	44
1914	2,734,043	964,114	35
1915	1,835,667	253,421	14
1916	1,982,385	243,678	12
1917	2,584,287	166,358	6
1918	2,490,760	143,455	6
1919	2,271,983	378,731	17

WORLD'S PRODUCTION.

World's production of phosphate rock, 1910–1919, in metric tons.

Country.	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919
Algeria	319,069	a 332,897	388,515	377,934	a 355,140	a 225,891	a 389,211	a 234,825	a 198,539	276,040
Angaur Island	45,000	41,000	50,000	90,000	a 60,000	30,000	30,000	....	....	....
Belgium	202,880	196,780	203,110	219,420	105,330	16,350	77,740	138,300	61,700	....
Canada b	1,341	563	149	349	866	197	184	135	127	22
Christmas Island	a 137,700	250,000	300,000	152,405	95,234	24,119	44,209	89,889	....	....
Dutch West Indies:										
Aruba	27,838	88,430	17,215	38,150	86,572	51,000	} 14,700	3,639	....	{ ....
Curacao	3,570	2,000	....	1,850	11,219	32,915				10,058
Egypt	2,397	12,013	70,918	104,450	71,945	82,998	125,008	115,732	31,147	29,364
France	333,506	312,204	330,000	298,859	270,000	145,000	24,700	....	....	....
French Guiana	6,816	7,234	7,014	3,193	....	....	....	....	....	....
Japan, including Rasa Island	1,042	2,271	7,849	25,013	38,264	57,723	114,389	122,000	191,722	....
Makatea Island	39	11,192	38,489	82,056	72,925	71,724	39,285	114,780	....	40,000
New Caledonia, Huon Island	2,558	2,053	3,830	2,100	3,500	8,400	....	....	....	....
New South Wales	....	....	....	2,032	....	....	....	....	305	585
New Zealand	....	....	....	11,176	....	....	....	5,131	5,080	....
Norway b	903	897	1,168	757	750	1,901	2,236	1,832	....	....
Ocean and Nauru Islands	310,625	250,000	298,687	250,000	....	....	70,000	....	....	....
Russia	15,293	10,200	25,000	25,000	15,000	....	....	....	....	....
South Australia	5,283	5,893	6,197	6,045	6,197	4,688	5,093	5,183	8,204	6,045
Spain	2,840	3,520	3,292	3,548	8,312	9,080	14,111	28,148	43,303	25,035
Tunis	1,286,262	1,446,633	2,057,498	2,284,678	1,395,630	1,170,033	1,041,204	576,600	821,145	....
United States	2,697,468	3,102,131	3,020,905	3,161,000	2,777,788	1,865,038	2,014,103	2,625,636	2,530,612	2,308,448
	5,402,430	6,077,911	6,829,836	7,140,015	5,374,672	3,797,057	4,006,173	4,061,830	....	....

a Exports. b Apatite.

FOREIGN PHOSPHATE DEPOSITS.

Because of the great need of European countries for fertilizer material and of the increasing production of phosphate rock in the Eastern Hemisphere, brief descriptions of some deposits in the principal producing countries are given in the following pages. These descriptions of reserves which may eventually reduce greatly the quantity of phosphate rock exported from the United States have recently come to the writer's attention. General statements on foreign deposits of phosphate rock were published in the volume of Mineral Resources for 1918.

EUROPE.

Spain.—The only deposits worked extensively in Spain are in the Province of Caceres, which is in the western part of the country about midway the Portuguese border. Phosphate deposits occur in a zone 120 kilometers long by 60 kilometers wide, extending across the province of Estremadura into Portugal. The deposits form veins in limestone, Cambrian schist, and granite and are genetically related to the granite intrusion. The deposits have been worked since 1865 and formerly yielded as much as 200,000 tons in a year. In 1913 the output was only about 3,500 tons, but it has increased steadily since then and was more than 43,000 tons in 1918. Mining has been done largely by open cuts, some of which are 60 to 70 feet deep. One mine, however, has a nearly vertical shaft 2,000 feet deep. As described by Mr. H. Edwards, mining engineer, of London, in conversation with the writer, the deposits in the vicinity of Caceres are lodes of phosphorite (a concretionary variety of apatite) in limestone and schist. These lodes are of varying widths up to 30 feet, are nearly vertical, and in many places cut across the bedding of the inclosing formation. There are no lodes of ordinary apatite in the limestone. The sedimentary deposits are surrounded by granite carrying quartz apatite lodes. These quartz lodes vary in size, and the apatite, which is the ordinary variety, may occur in any part of the lode but is concentrated more commonly along the footwall. The average thickness of the apatite segregations is only 6 to 8 inches. The principal apatite deposits are in the district of Alegon, and the principal mining town is Zarza la Mayor. There are several types of phosphorite, and the tricalcium phosphate content ranges from 66 to 87 per cent.

Other European countries.—Belgium and France have long been the largest producers of phosphate rock in Europe. The high-grade deposits in these countries are now exhausted, and the principal product consists of phosphatic chalk and nodules averaging 25 to 35 per cent of tricalcium phosphate. Russia has large deposits, but there is no probability of their early development. Phosphatic nodules have been mined in England in a small way in recent years, less than 50 long tons of phosphate of lime being produced from 1904 to 1917; but in 1918 the production was 3,372 long tons (3,426 metric tons) and in 1919 there was no production.

AFRICA.

ALGERIA.

The deposits of phosphate rock in Algeria are sedimentary beds of Eocene age. The two chief mining districts are near the towns of Setif and Tebessa, in the Department of Constantine, eastern Algeria. The production was more than 300,000 tons a year before the war, and the rock exported carried 58 to 68 per cent of tricalcium phosphate. Exports decreased to about 200,000 tons in 1918 and rose to 242,000 tons in 1919. The boundary between Algeria and Tunis crosses the phosphatic region, and at present Tunis produces more than Algeria. The Algerian deposits are on the high plateaus, from Setif to the chain of the Aures. The principal mining centers are in the region between Setif and Bordj bou Areridj and in the Tebessa region. Phosphate has been exploited also in the Department of Oram.

The largest producer is the Compagnie des phosphates de Constantine; other producers are the Compagnie des phosphates du M'Zaita, the Compagnie algérienne des phosphates de Tocqueville, and the Compagnie centrale des phosphates de Bordj Redir.

Of one of these companies United States Consul Arthur C. Frost, Algiers, makes the following statement:[1a]

> La Société des phosphates du M'Zaita, which was organized in 1910 and was producing at the time the war broke out 400 metric tons a day, expects a large increase in production as soon as labor and other conditions become satisfactory. Its concession covers 2,000 hectares (4,942 acres), of which 40 per cent is on the public domain and 60 per cent on private property. It controls four deposits, one of which is about 1 meter thick, and is said to run 58 per cent. Another, of an average thickness of from 1½ to 2 meters, has already produced 15,000 tons, yielding 65 per cent to 68 per cent. Still another deposit, containing gray-black phosphate, has a minimum of 60 per cent. The total deposits aggregate some 60,000,000 tons.
>
> The phosphate is brought from the mine by cable, 3 kilometers (1.86 miles) in length, to the factory for sorting and crushing, where it is broken into pieces of from 12 to 15 centimeters (from about 5 to 6 inches). The plant has a capacity of 200,000 tons, which can be easily doubled. The phosphate is then loaded automatically on railway cars. A normal-gage railway of 13 kilometers (8.08 miles) connects the mine with the Est Algérien system, by which it is transported to the port of shipment, Bougie. The distance from the mine to the port is 190 kilometers (118.06 miles), and the freight charges before the war were 3 centimes per kilometer-ton. The present freight per ton is 35 centimes on the branch line and 10 francs 85 centimes on the Est Algérien.

The Compagnie des phosphates de Constantine, operating at El-Bey, near Tebessa, built a new plant in 1919, which handles 100 tons of phosphate an hour.[2] The phosphate rock is sorted, crushed, pulverized, dried, and put in storage or loaded on railway cars entirely by mechanical means. The plant has storage facilities for 55,000 tons.

[1a] Commerce Repts. May 1920, pp. 782–783.
[2] Commerce Repts., Feb. 9, 1920, pp. 788–789, and May 7, 1920.

Algerian phosphate rock produced and shipped in 1919, in metric tons.

Company.	First quarter.		Second quarter.		Third quarter.		Fourth quarter.	
	Production.	Shipments.	Production.	Shipments.	Production.	Shipments.	Production.	Shipments.
Compagnie algérienne des phosphates de Tocqueville	1,856	....	2,207	2,800	596	4,518	1,935	2,540
Compagnie centrale des phosphates de Bordj-Redir	3,075	....	1,620	339	2,566	8,690	124	....
Compagnie des phosphates du M'Zaïta	4,901	11,670	4,427	6,580	2,746	8,470	7,559	2,040
Compagnie des phosphates de Constantine	42,706	26,540	61,648	43,778	72,665	60,175	65,409	59,300
	52,538	38,210	69,902	53,497	78,573	81,853	75,027	63,880

According to the figures supplied by the Bureau of Mines of Algeria, the production was 276,040 metric tons and shipments were 237,440 metric tons for the year 1919.

TUNIS.

The principal deposits of phosphate rock in Tunis are in the Gafsa fields, in the southern half of the country. The phosphate occurs in beds several feet thick, and only those carrying more than 58 per cent of phosphate are exploited. The deposits are of Eocene age, can be traced for several hundred miles, and constitute a reserve of hundreds of millions of tons. Tunis now produces more phosphate than any other foreign country, its annual output being between 1,500,000 and 2,000,000 tons, most of which goes to southern Europe.

The production of phosphate rock in Tunis fell from 2,284,000 tons in 1913, the year before the war, to 576,000 tons in 1917. There was a slight recovery in 1918, to 821,000 tons, and it is believed that the output of 1919 was much larger, though figures are not yet available. The exports during the war were decreased by the shortage of transportation facilities particularly, but also by the shortage of labor, the cutting off of German and Austrian markets, the use of sulphuric acid in making ammunition rather than fertilizer, and the burning of the superphosphate plant of the Compagnie tunisienne des produits chimiques.

Only those deposits are worked that are near the railroad and that carry at least 58 per cent of tricalcium phosphate, and many of the known deposits of this quality have not been touched because they have not ready transportation facilities to the coast. There are large deposits of high-grade material which will not be worked for many years for this reason, and when these are exhausted there will remain still larger quantities of phosphate rock running from 50 to 58 per cent of tricalcium phosphate.

The great phosphate mine at Gafsa contains four principal beds. By mixing the material from two beds 10 feet and 6 feet thick the product has an average of 60 per cent of tricalcium phosphate. The concessions of the Gafsa Co. are extensive. The known reserves are estimated at 40,000,000 tons near Metlaoui, 30,000,000 tons at Redeyef, and 70,000,000 tons at Mrata and Moulares. The lowest percentages of phosphate at these three localities are, respectively, 60, 64, and 63 per cent.

MOROCCO.

The following is an extract from a special press bulletin prepared by James C. Martin, of the United States Geological Survey, on the phosphate deposits in Morocco:[3]

The recent rumors of large newly discovered deposits of phosphate in Morocco assign them to the district of El Boroudj and the Oued Zem, in the central part of the northwest coastal region. This district is about 80 miles south-southeast of Casablanca, a seaport having a population of about 45,000, and has an areal extent variously estimated at 30 to 1,000 square miles.

The existing military railway from the Oum-er-R'bia to Casablanca does not meet the demands of the industry, and plans in mind contemplate the construction of a railroad from Marrakech to Casablanca and a side line from El Boroudj to Settat.

Morocco is, on the whole, a rugged country. It contains two distinct mountain masses, one extending along the shore of the Mediterranean and the other forming the interior massif—the Atlas Mountains, which reach an altitude of over 13,000 feet. Between these two chains is the Taza Pass, which affords communication between the western part of Morocco and Algeria. The central part of the country, between Casablanca and Khenifra, 115 miles east-southeast, is composed of three distinct topographic and geologic units—(1) the Atlas Mountains, a high and almost totally unexplored region; (2) a region of strongly folded and faulted Carboniferous and Jurassic (?) formations, a kind of Moroccan Jura or pre-Atlas zone; (3) a region of Tertiary and Quaternary table-lands, nearly 100 miles broad, bordering the Atlantic Ocean. It is within these table-lands that the phosphates are found.

In the zone along the coast there are four plateaus or terraces, which belong to different geologic periods—one to the Quaternary, two to the Tertiary, and one to the Cretaceous—and which extend like arms of the sea up into the interior between ridges composed of folded beds of Paleozoic rock.

The upper or Cretaceous terrace, the plateau of Settat, which contains the phosphates found at El Boroudj, is limited on the west by a long line of steep seaward-facing cliffs, which run parallel to the coast and were greatly modified by Tertiary marine erosion. Above this terrace, as above the lower and later terraces, rise isolated ridges of folded Carboniferous strata. The formations composing this terrace are mostly of undetermined age, are uniform in character, and lie practically horizontal. The general succession of strata in descending order, as shown in the gulches, is hard, yellow limestone; fossiliferous yellow limestone of Cenomanian or Turonian age; white, chalky, marly limestone containing Cenomanian fossils; sandstone; yellow shale; and Triassic red shale and conglomerate.

The formations of the Cretaceous plateau in the vicinity of El Boroudj and the Oued Zem have been raised in a gentle anticline, the eroded summit of which now forms the broad basin of Boujad. The axis of this anticline strikes in general northeast. The beds of phosphatic rock that crop out near El Boroudj are in the southeastward-facing cliff on the north limb of the anticline, overlooking the plain of Oum-er-R'bia, and are 50 to 65 feet thick. A description of the stratigraphic section on this side of the anticlinal axis has not been published. but the sequence of the beds on its south limb is shown below:

Vertical section in the El Boroudj phosphate district, Oum-er-R'bia, Morocco.

Quarternary	Alluvium.
Tertiary:	
Oligocene-Miocene	Red beds with conglomerate.
Lutecian or Ypresian	*Turritella* limestones.
Lower Eocene (Suessonian)	Cherty phosphatic sand and limestone carrying shark teeth.
Cretaceous:	
Senonian	Soft yellowish limestone.
Turonian	Yellow sand.
Cenomanian	Hard limestone, with *Exogyra delettrei* and *Plicatula auressensis*.

[3] U. S. Geol. Survey press bulletin, September, 1920.

The gray limestones of the Lutecian, which overlie the phosphate beds, contain numerous molds and casts of bivalves and gastropods, many of them scarcely recognizable.

The lower Eocene cherty phosphate beds are found in all the ravines of the region. They contain abundant shark teeth but are especially rich in the vertebræ of sharks, the following species of which have been found: *Odontaspis cuspidata* var, *hopei, Otodus obliquus,* and *Myliobatis* sp. A bed at this horizon appears at the bottom of the Kaikat ravine and is overlain by beds that contain *Turritella,* and these beds disappear beneath Oligocene-Miocene red beds and conglomerates and the Quaternary gravels of Kasba Tadla. The phosphatic sands are in the upper part of the lower Eocene and alternate with beds of flint and of the limestone that carries the fish remains. Below these comes a stratum of dense flint, which dips slightly to the southeast and over which for a distance of 3 miles runs the roadway from Boujad to Kasba Tadla. Below this stratum, forming the base of the lower Eocene, is a bed of very fine white sandstone. The phosphatic formation is considerably thicker here than at the north side of the Oum-er-R'bia. It attains a thickness of about 200 feet and forms a long band 3 to 4 miles broad. The upper phosphate bed contains 66.7 per cent of tricalcium phosphate, the middle bed 30 per cent, and the lower beds 53 per cent, and the commercial average for the group is 58.6 per cent. In the Oued Zem area some beds contain 72 to 75 per cent, and the material is so friable as to need little if any crushing.

The deposits of El Boroudj and Oued Zem are in the lower Eocene, formerly the only Tertiary horizon at which phosphate was found in Morocco or in Algeria and Tunis. Explorations made by the French geologists during the last few years, however, have shown that the upper Tertiary also includes phosphatic beds. Such beds have been recently observed at a point about 10 miles southeast of Rabat, and are referred to the Pliocene or Miocene. They crop out in the Oued ben Regrag, and can be followed eastward toward Dar bel Hamri. The geologic sections show (1) lower Eocene (Suessonian) at the base, consisting, from below upward, of clays, cherty limestone, and crystalline limestone carrying *Scutellina nummularia;* (2) Miocene blue clays containing *Ostrea crassissima* and overlain by white marls; (3) above an unconformity, a 5-foot bed of Pliocene basal conglomerate with *Pecten jacobeus;* (4) 16 feet of phosphatic sandy clay containing a very rich but friable fauna, from which were collected *Ostrea lamellosa, Venus plicata, V. multilamella, Dentalium sexangulum,* and *Amussium cristatum;* (5) hard sandstone, passing to a red or yellow sand and containing *Pecten benedictus, P. pixidatus,* and *Ostrea cucullata,* together with numerous molds of pelecypods. A sample across the entire thickness of the phosphatic formation (No. 4) yielded 46.8 per cent of tricalcium phosphate; it is said that work on the deposit has already been undertaken. It is suggested, but not definitely proved, that the upper Tertiary deposit consists of reworked lower Tertiary (Suessonian, or lower Eocene) deposits, which are abundant in French northern Africa.

PACIFIC ISLANDS.

NAURU ISLAND.

An agreement between the governments of Great Britain, Australia, and New Zealand provides that 42 per cent of the phosphate output of Nauru Island, a British mandate, shall be allotted to Great Britain, 42 per cent to Australia, and 16 per cent to New Zealand. This agreement was passed by the Commonwealth Parliament at the end of 1919. In view of the present interest in the phosphate on Nauru, the following description of the island and its phosphate industry is condensed from Stewart's Handbook of the Pacific Islands, 1920 edition.

Nauru (or Pleasant) Island lies less than 30 miles south of the Equator and about 160 miles west of Ocean Island. It is in about the same longitude as Dunedin, New Zealand, and was formerly a German possession. It is a circular atoll about 3½ miles in diameter.

The shore is bordered by a belt of flat country several hundred yards wide, above which the center of the island rises precipitously to an elevation of 100 to 250 feet. The commercial value of the island lies mainly in the vast deposits of phosphate extending over some 4,500 acres on the high land. These are worked by the Pacific Phosphate Co. Yanger, the only white settlement, is on the western side of the island and comprises the housing accommodations for the company's staff, stores, power house, phosphate bins, drying plant, and workshops. There are about 1,300 natives on the island. A few of these are employed by the Pacific Phosphate Co., but the main source of labor consists of several hundred recruits from the Caroline and Marshall islands and Chinese mechanics and coolies numbering about 300. There are 75 white inhabitants, including the missionaries. There is a wireless station of 60-kilowatt power controlled by the naval authorities.

Only surface mining is necessary. The bulk of the phosphate is alluvial. The surface is harrowed, and the phosphate is hoed into heaps and shoveled into baskets, which are borne by coolies to the nearest truck on the light railways that closely follow the workings. The coral pinnacles here and there protruding as the surface is removed are so heavily phosphatized that when convenient they also are shipped after blasting. Small steam locomotives draw the trucks of phosphate to the nearest gravity incline, whence it is lowered to the marginal flat and shipped directly. If no ship is at the moorings the trucks are run to one of the three large bins (holding in the aggregate 25,000 tons and built against a hill), and the phosphate is tipped out and left for storage. When the phosphate is wet the trucks are run from the field to hoppers which feed the wet phosphate into driers. These driers are large steel cylinders with fixed internal vanes, which slowly revolve while the flue gases from powerful furnaces traverse them from end to end. After the drying mechanical conveyers feed the phosphate into the bins. The storage bins have concrete floors under which the empty trucks are run and filled. Small electric locomotives on a light railway convey the phosphate to the end of two wharves about half a mile apart. At the end of the wharf, each side, the phosphate is dumped by a chute into the four baskets carried in each of the flat-bottomed heavy surfboats that ply between wharf and ship. Each boat carries 2 tons per trip, and 10 to 16 boats are employed at a time. The surfboats are towed by launches. The ship lies several hundred yards from shore and is made fast to a large buoy shackled to moorings that are said to be the deepest in the world. As ships lie at moorings in the open roadstead, it follows that loading is frequently interrupted by heavy weather.

The phosphate deposits on Nauru Island are of very high grade, ranging, according to reports, from 78 to 88 per cent of tricalcium phosphate. It has been estimated that 40,000,000 to 100,000,000 tons is available.

MAKATEA ISLAND.

Nearly 115,000 tons of high-grade phosphate is reported as produced in Makatea Island in 1917. The output in 1919 was only 40,000 tons, but the occurrence and production are significant. Makatea is one of the Society Islands, about 120 miles north of Tahiti. It has an area of only about 1,200 acres. The Compagnie française des phosphates, a French corporation with main office in Paris, has the exclusive mineral rights of the island and has been mining phosphate there since 1910. According to H. F. Withey,[4] United States consul at Tahiti, the phosphate, which is virtually the soil itself, is dug with pick and shovel and loaded on cars on a light railway. At the plant it is crushed, dried, and stored in bins awaiting shipment. Vessels are moored offshore, and the phosphate is loaded on lighters by means of two piers about 300 meters in length, a part of which, however, is on shore.

Before the war the phosphate was shipped mostly to France, Honolulu, and San Francisco, but now nearly all of it goes to New Zealand.

The phosphate is irregularly distributed between reefs and pinnacles of dolomite. Some of the rock carries 85 per cent of tricalcium phosphate. The quantity available is estimated at 10,000,000 tons.

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[4] Commerce Repts., July 13, 1920.

MAGNESITE.

By Charles G. Yale and Ralph W. Stone.

PRODUCTION.

A preliminary estimate published by the United States Geological Survey in April, 1920, gave 162,000 short tons as the quantity of crude magnesite mined and sold or treated in the United States in 1919. The delay of many months in publishing this final report, based on replies from producers, was caused by cooperation of the Geological Survey and the Bureau of the Census in the canvass of the mining industry.

The total sales of crude domestic magnesite in 1919 appear to have been 156,226 short tons, valued at $1,248,415, or a decrease of about 32 per cent in quantity from 1918. Production and sales are not identical, for some magnesite is mined but because of poor quality or low price is not sold. This quantity, however, is small and stocks are small, so that sales reflect production closely. The magnesite reported in the following tables entered the market during the calendar year.

Crude magnesite produced and sold or treated in the United States in 1918–19.

State and county.	1918		1919	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.
California:				
Fresno, Riverside, San Benito			2,876	$28,986
Fresno, Riverside	3,865	$32,884		
San Benito, San Bernardino	5,440	48,755		
Napa	28,462	281,120	10,112	86,752
Santa Clara	11,522	101,198	10,912	128,924
Sonoma	4,045	39,798		
Stanislaus	4,166	33,328	4,057	40,730
Tulare	26,577	224,728	22,063	219,581
	84,077	761,811	50,020	504,973
Washington:				
Stevens	147,528	1,050,790	106,206	743,442
	231,605	1,812,601	156,226	1,248,415

Crude magnesite produced and sold or treated in the United States, 1914–19.

Year.	Quantity (short tons).	Value.	Year.	Quantity (short tons).	Value.
1914	11,293	$124,223	1917	316,838	$2,899,818
1915	30,499	274,491	1918	231,605	1,812,601
1916	154,974	1,393,693	1919	156,226	1,248,415

The figures are somewhat indefinite because reports made by producers to the Bureau of the Census do not agree in all particulars with reports made by the same producers to the California State Mining Bureau or to the United States Geological Survey. It is for this reason that the Geological Survey figures for sales in California, based on reports to the Census, show about 6,000 tons more than the figures published by the State Mining Bureau. Likewise, the value of the country's crude magnesite output is uncertain, although expressed in the tables in precise figures. Magnesite mined in Washington was not sold crude on the open market, most of it being converted by the producing company into calcined or dead-burned magnesite and marketed as such. A few thousand tons was sold crude but not in a competitive market. The value of $7 a ton for the crude magnesite produced in Washington therefore is an assumed value, and does not represent the total value of the magnesite as marketed in that State.

IMPORTS.

The following statistics of imports were obtained from the Bureau of Foreign and Domestic Commerce, Department of Commerce. This table shows that the imports from Canada greatly decreased in 1919 compared with those in 1918—from 20,000 to 8,000 tons; that central Europe and Mexico again made shipments; and that the total imports decreased about 24 per cent.

Magnesite calcined, not purified, imported into the United States, in 1918 and 1919.

[General imports.]

Country.	1918		1919	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.
Austria-Hungary			2,650	$64,933
Germany			34	2,023
Italy			2,416	62,753
England	2	$507	29	4,849
Scotland	867	94,689	94	9,369
Canada	20,003	789,169	8,066	216,605
Mexico			2,563	13,500
	20,872	884,365	15,852	374,032

The following table showing imports by months sets forth the steady shipments from Canada, aggregating more than half the receipts, and the entry of European material principally after the middle of the year:

Magnesite calcined, not purified, imported into the United States in 1919.

[General imports.]

Month.	Austria-Hungary.		Canada.		Other countries.	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
January			938	$23,531		
February			802	22,311	43	$3,661
March	27	$298	176	4,171		
April	27	366	405	9,235	9	711
May			881	22,393		
June			570	16,677		
July			848	19,320	6	596
August	363	8,493	613	17,119	5	1,946
September	1,105	24,144	1,028	32,395	985	7,710
October	576	15,867	812	23,619	2,437	65,257
November	513	15,122	546	13,786	706	5,423
December	39	643	447	12,048	945	7,190
	2,650	64,933	8,066	216,605	5,136	92,494

Magnesium compounds imported for consumption in the United States in 1918 and 1919.

Material.	1918		1919	
	Quantity (pounds).	Value.	Quantity (pounds).	Value.
Magnesia:				
Calcined, medicinal	523	$312	22,637	$11,358
Carbonate of, medicinal			5,094	1,101
Sulphate of (epsom salts)	2,045	196	17,647	1,473
Magnesite:				
Calcined, not purified	38,098,815	824,022	18,941,440	270,721
Crude	10,864,000	103,233	12,761,280	103,311

Magnesite imported for consumption in the United States, 1914–1919.

Year.	Crude.		Calcined, not purified.	
	Quantity (pounds).	Value.	Quantity (pounds).	Value.
1914	26,708,381	$54,677	243,633,205	$1,323,194
1915	99,527,772	255,140	53,148,739	232,071
1916	150,689,445	634,447	18,539,704	204,183
1917	60,554,420	232,105	7,931,159	232,601
1918	10,864,000	103,233	38,098,815	824,022
1919	12,761,280	103,311	18,941,440	270,721

CONDITION OF THE MAGNESITE INDUSTRY.

In the early part of 1919 the magnesite industry was much depressed. In California many of the plants were idle, and in Washington only one company continued in operation. This condition was due largely to the falling off in demand from the steel industry, which was buying no more magnesite than was absolutely necessary, on the assumption that the European material would soon be available and at a much lower price than that commanded by the domestic product. Even as late as June, 1919, this assumption was still held, but imports did not come, and by midsummer buying of California and Washington magnesite had been resumed.

A hearing before the Committee on Ways and Means, House of Representatives, was held June 16 and 17, 1919, in Washington, D. C., for the presentation of arguments on the so-called magnesite bill. The bill is as follows:

A bill to provide revenue for the Government and to establish and maintain the production of magnesite and manufactures thereof in the United States.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That on and after the day following the passage of this act, there shall be levied, collected, and paid upon the articles named herein, when imported from any foreign country into the United States or into any of its possessions, the rates of duties which are herein prescribed, namely:

1. Magnesite, commercial ore, either crushed or ground, three-fourths of a cent per pound.
2. Magnesite, calcined, dead burned, and grain, 1¼ cents per pound.
3. Magnesite brick, 25 per centum ad valorem.

SEC. 2. That paragraph 539 of the tariff act of October 3, 1913, is hereby expressly repealed; and that so much of paragraph 71 of said tariff act and of any heretofore existing law or parts of law as may be inconsistent with this act are hereby repealed.

Representatives of companies producing magnesite in Washington appeared in favor of the proposed tariff, and representatives of companies manufacturing refractory products from magnesite opposed the bill.

On January 13, 1920, a hearing on this same bill was held before the Committee on Finance, United States Senate. Practically all the witnesses, representing manufacturers of composition floors and other users of imported magnesite, opposed the bill. In January, 1921, no further hearings had been held and the proposed bill had not been enacted into law.

CALIFORNIA.

GENERAL FEATURES.

The magnesite industry in California continues to be in a depressed condition as compared with the activity prevailing during the war period. Increased costs and lack of demand have restricted production and caused the closing down of several properties of some magnitude. It may be stated, however, that since the end of 1919 the market for plastic magnesite has been more active, and that there are signs of a greatly increased demand for that product.

The principal producers of magnesite in California in 1919 were the White Rock mine, in Napa County; Western Magnesite Development Co., in Santa Clara County; and Tulare Mining Co., Porterville Magnesite Co., and Oakland Magnesite Co., in Tulare County. The following table shows the output of crude magnesite in California from 1913 to 1919, inclusive:

Crude magnesite produced and sold or treated in California, 1913–1919.

Year.	Producing mines.	Quantity (short tons).	Value.
1913	1	9,632	$77,056
1914	6	11,293	124,223
1915	16	30,499	274,491
1916	45	154,259	1,388,331
1917	65	211,663	2,116,630
1918	30	84,077	761,811
1919	18	50,020	504,973

The table shows that there were 12 fewer producing magnesite mines in California in 1919 than in 1918. The decrease in quantity of ore sold or treated in 1919, as compared with 1918, was 34,057 tons, and the decrease in total value was $256,838. Prices for crude ore ranged from $7 to $14 a ton, but the general average price for all ore produced was $10.10 a ton.

REVIEW BY COUNTIES.

Alameda County.—No magnesite was produced in Alameda County in 1919, the Cedar Mountain mine having been idle since 1917.

Fresno County.—Sinclair Bros & Ferguson, at Piedra, had their calcining furnace in operation part of the year, principally on ore from the Ward mine, near by, which was worked under lease by G. S. Lane and Henry Nolte. The furnace is of the vertical cupola type, with a capacity of 25 tons a day. They report that by careful regulation of the temperature, using an electric pyrometer, they obtain caustic magnesite at 800° to 900°, with not to exceed 4 per cent of CO_2 remaining, yielding "a more active MgO."

Kern County.—The sedimentary deposits at Bissell were not worked in 1919.

Napa County.—The White Rock mine in Pope Valley continued in 1919 to be the principal magnesite producer in Napa County. This mine, which is operated by Frank R. Sweasey, of San Francisco, is one of only two thus far developed in California which has yielded any considerable quantity of natural ferromagnesite. The ore from this mine is sufficiently high in iron to yield a dead-burned product satisfactory for use in metallurgic furnaces. Much of the output has been consumed by the steel industry on the Pacific coast.

Some magnesite also was shipped crude in 1919 by the Soda Creek mine in Chiles Valley.

Riverside County.—The magnesite mine near Hemet and Winchester sent out some shipments, all in the calcined state, in the early part of the year, but the property was closed May 10. The machinery, including belt and screw conveyors, rotary calciner, and grinders, is reported to have been removed, and the buildings were razed for the lumber in them. This deposit was a stockwork or mass of small curly veins, mostly less than 1 inch thick but in places forming lumps 4 or 5 inches in diameter. It was worked by open cut and by tunnel and glory hole. It required the handling of many tons of waste rock to obtain 1 ton of ore. In comparison with several other magnesite deposits in California, where veins are several feet thick, there seems little justification for the efforts that have been made to produce magnesite at this locality.

San Benito County.—Although the magnesite deposit on Sampson Peak, near New Idria, is large, it is about 40 miles from a railroad and was idle most of 1919. A small tonnage was shipped, calcined, during the last four months of the year.

San Bernardino County.—The production of magnesite near Cima, on the Los Angeles & Salt Lake Railroad, by the Cima Copper Syndicate was reported in the fall of 1919, but the report has not been confirmed.

Late in 1919 the Cliffside Magnesite Co. began the construction of a tramway and ore bins near Afton for handling magnesite from the sedimentary deposit in that vicinity. Afton is on the Los Angeles & Salt Lake Railroad, in the central part of the county.

Santa Clara County.—The Western Magnesite Development Co. worked the mine on Red Mountain and made the principal output of magnesite in Santa Clara County in 1919. This mine is about 30 miles from the railroad at Livermore, which is the shipping point. The calcining plant, consisting of four vertical kilns, is connected with the mine by an aerial tram half a mile long. In December, 1919, the mine and plant were operated with a crew of about 40 men. Two kilns were in use and produced about 15 tons of calcined magnesite daily. Low-grade distillate is used for fuel. Besides the bodies of solid ore 10 to 15 feet wide developed in the mine, there are several outcrops of other veins in the immediate vicinity which indicate the possibility of developing a fairly large output. Litigation which had retarded work on this property for 11 years was settled in 1919, and the property was operated by the company under the general management of Charles H. Spinks and C. S. Maltby.

The Madrone Magnesite Co., near Coyote and Madrone, made some shipments of crude magnesite during 1919. Magnesite mined here in recent years has been used in part at Oakland for producing carbon dioxide.

San Diego County.—The plant of the International Magnesite Co., at Chula Vista, near San Diego, treating ore from Lower California, was in operation the latter part of the year.

Sonoma County.—The California Magnesia Co.'s plant at Guerneville was idle, as was that of the Sonoma Magnesite Co. near Cazadero. The Refractory Magnesite Co., at Preston, ceased operations on the death of its president, F. R. Turton, and resumption of mining by this company is doubtful.

Stanislaus County.—The mine of the Gustine Magnesite Co. and the adjoining mines 16 miles west of Gustine and Ingomar were operated by the Plastic Magnesite Co., H. H. Harlan, manager. About 15 men were employed at the end of the year. The ore has been shipped crude.

The bulk of the magnesite from Stanislaus County in 1919 was shipped by the Red Mountain Magnesite Co. from the east side of Red Mountain, in the Arroyo del Porto district, near Patterson.

Tulare County.—The Porterville Magnesite Co. of California operated its mine and plant near Porterville, employing about 75 men at the end of the year. The workings are on a number of small veins, at most only 3 or 4 feet wide, and the quantity of ore in sight is not large. All mining is underground. The smaller of two rotary kilns was sold and removed in the summer of 1919, and the remaining kiln, 125 feet long and 7 feet in diameter, has a capacity of 60 tons in 24 hours, or more than the mines were producing. Therefore the kiln was idle at times while ore was accumulating. The company purchased ore also from the Dinuba Magnesite Co., whose property was operated in 1919 by Cone & Kemble.

The Tulare Mining Co. has a large property about 9 miles east of Porterville, which is a consolidation of the Adams (or Lindsay), Hawley, and Tulare mines. The large acreage includes narrow veins, lenses several feet wide, and a vein reported to have a maximum width at one place of 60 feet. The mine has two vertical kilns, having a combined capacity of 18 tons of calcined magnesite in 24 hours.

At the end of 1919 36 men were getting out ore and 43 men were employed around the plant. Special attention was being given to the preparation of exceptionally white material for plastic uses. The Tulare Mining Co. regained, in 1919, the lead as the largest producer of magnesite in California, a position which it had held for a number of years prior to the World War.

The custom calcining plant of the American Magnesite Co., at Porterville, was idle during a considerable part of 1919. It was purchased by C. W. Hill, of Los Angeles, who has an interest in the International Magnesite Co. at San Diego, and was put into operation just before the end of the year, calcining ore from several small properties in the vicinity of Porterville, Lindsay, and Exeter. This plant has two rotary kilns, 50 feet and 75 feet in length.

WASHINGTON.

Three companies operating in Washington in 1919 produced 106,206 short tons of magnesite, valued at $743,442. This value was obtained by assuming an average value of $7 a ton and is only approximate, because one company calcined all its product and sold it in that form; another sold all its rock crude to a third company, which mixed it with its own crude rock to make dead-burned ferro-magnesite. Dead-burning reduces the weight more than one-half, and the burned material sold to other industries was practically 50,000 tons, valued at about $1,438,000. Less than 100 tons was shipped crude, about 2 per cent was calcined, and the remainder was dead-burned.

The American Mineral Production Co., at Valley, did not operate its mine from January 1 to August 15, except for a few days in April and May. The number of employees increased from 2 in July to 24 in August and 92 in December. The railroad was extended from the Allen quarry to the Finch quarry of the Northwest Magnesite Co., and all the output was sold crude to that company, which delivered it over its 5-mile aerial tram to the plant at Chewelah. The company was preparing in 1919 to calcine magnesite for plastic uses.

The Northwest Magnesite Co., Chewelah, was the largest producer in the United States and made some shipments in each month in the year. Shipments were smallest in May and June, but increased rather steadily to the end of 1919, and the output continued strong in 1920. This company had its plant in operation 314 days during 1919 and employed as many as 280 persons. The whole output was from the Finch quarry, the Keystone deposit not being developed. Crude magnesite was bought also from the neighboring quarries of the American Mineral Production Co. Practically all this company's output was dead-burned in rotary kilns fired with pulverized coal.

The Western Materials Co. operated the Double Eagle quarry, formerly operated by the Valley Magnesite Co., at Valley. Work continued 120 days, from September to December, 1919. The crude magnesite was calcined in vertical stack kilns fired with wood, and the material was shipped to the Eastern States for refractory use. Experimental work was done toward adapting the material to plastic uses, and it is reported that 1,800 yards of wainscoting was made and applied to a State building.

Washington magnesite in calcined or dead-burned form was shipped almost exclusively to points east of the Mississippi River. Of the 50,000 tons sold only about 500 tons remained in the West; 300 tons was consigned to Washington plants and 200 tons was distributed between Montana, Texas, California, and Alaska. About 21,000 tons was shipped direct to steel mills and the remainder—approximately 28,000 tons—was shipped to makers of refractory products and either resold by them as received or used in the manufacture of brick and other products.

Sales and shipments are not the same in any year because a considerable quantity of material sold near the end of a year may not be shipped until the beginning of the next year. Shipments of magnesite in all forms from Chewelah and Valley in 1919 were about 60,000 tons, of which about 10,000 tons was billed from Valley.

NEW MEXICO.

A deposit of magnesite that crops out on a steep hillside west of Ash Creek 2 miles above its junction with Gila River, about 30 miles north of Lordsburg, N. Mex., was examined by R. W. Stone, in May, 1920. The general alignment of the outcrops might indicate that it is a continuous body, 1,000 to 1,500 feet long and 30 feet thick, in limestone, but close examination shows that the limestone occurs as a number of detached blocks, none of them more than a few rods long, inclosed in granite and cut by dikes and sills of diabase older than the granite.

The magnesite has replaced certain beds of limestone. At one place where the deposit has been prospected and has since caved there appears to be a total thickness of 20 to 30 feet of magnesite and limestone. The best exposure shows only 7 feet of magnesite in a limestone block 5 or 6 rods long, in which the beds stand vertical. Not all the limestone blocks contain magnesite. The small quantity of magnesite available and the distance of the deposits from a railroad render them of little present commercial interest.

The magnesite is hard, amorphous, and pure white, resembling the variety common in California. It is believed to have been derived from the diabase.

USES.

Practically all the magnesite produced in Washington in 1919 was made into synthetic ferromagnesite and went to steel plants and to manufacturers of refractory products. In the dead-burned form, either granular or made into brick, it is used as a refractory lining for open-hearth furnaces and converters in the steel industry, in copper converters, reverberatories, settlers, and electric and other melting and welding furnaces. Magnesite brick are used also for lining rotary kilns in the manufacture of Portland cement.

The magnesite produced in California in 1919 was used largely in the caustic calcined form for the manufacture of oxychloride or Sorel cement. This cement consists of finely ground calcined magnesite mixed with a solution of magnesium chloride. This mixture is generally modified by the addition of filler materials, such as sawdust, cork, talc, asbestos, clay, marble dust, and sand, besides coloring matter. The cement thus produced is sold under various trade names, commonly referred to as sanitary flooring. The use of magnesite cement in floors and as stucco and interior and exterior wall plaster is growing in this country. Magnesite from California mines is used also for making carbon dioxide, pipe and furnace coverings, and other products which consume only a minor part of the output. The output of the White Rock mine, Napa County, is used by Pacific coast steel plants as a refractory lining in their basic, open-hearth, and electric furnaces.

PRODUCERS OF MAGNESITE IN 1919.

CALIFORNIA.

Edward Duryee, Los Angeles.
G. W. Elder, 799 Oak Street, San Francisco.
H. L. Haehl, Humboldt Bank Building, San Francisco.
J. D. Hoff Asbestos Co., Monadnock Building, San Francisco.
Alvah Joyner, Exeter.
G. S. Lane and Henry Nolte, Piedra, by way of Fresno.
Madrone Magnesite Co., Madrone.
Magnesco Refractory Products Co., Winchester.
Oakland Magnesite Co., Realty Syndicate Building, Oakland.
Plastic Magnesite Co., Gustine.
Porterville Magnesite Co. of California, Porterville.
Red Mountain Magnesite Co., Russ Building, San Francisco.
E. F. Schrei, Lindsay.
Sinclair & Ferguson, Fresno.
Sonoma Magnesite Co., Humboldt Bank Building, San Francisco.
Frank R. Sweasy, Humboldt Bank Building, San Francisco.
Tulare Mining Co., 310 Sansome Street, San Francisco.
Western Magnesite Development Co., Clunie Building, San Francisco.

WASHINGTON.

American Mineral Production Co., Valley.
Northwest Magnesite Co., Chewelah.
Western Materials Co., Valley.

SAND-LIME BRICK.[1]

By Jefferson Middleton.

The production of sand-lime brick in 1919, after the large decrease in 1918, rallied and increased considerably in quantity and nearly doubled in value. The increase in quantity was 48,548,000 brick, or more than 49 per cent. The value increased $821,234, or 93 per cent. The relatively larger increase in value is due, of course, to increased cost of production and increased demand. Increase in building operations, which were light during the early months of the year, but heavier in the summer and fall, is the cause assigned for this gain. The production in 1919 was less than that of 1917 by 40,599,000 brick and was less than the maximum production of 227,344,000 brick, which occurred in 1916, by 80,397,000 brick. The value of the sand-lime brick marketed reached its maximum in 1919 and was greater by $284,833 than that of 1917 and greater by $231,090 than in 1916, the year of maximum value prior to 1919.

The number of operators (35) reporting marketed product in 1919 was the smallest since 1903. The average value of sales per active operator in 1919 was $48,719, compared with $21,046 in 1918, $30.220 in 1917, and $27,813 in 1916. The average output per active operator was 4,198,000 brick in 1919, 2,343,000 in 1918, 3,990,000 in 1917, and 4,290,000 in 1916.

Sixteen States reported the production of sand-lime brick in 1919, a decrease of two—California and Washington. The 11 States that increased in quantity and value of output were Florida, Georgia, Idaho, Indiana, Michigan, Minnesota, New York, Ohio, South Dakota, Texas, and Wisconsin. The output of Massachusetts also increased in value but decreased in quantity. In 1919, as for many years, Michigan was the leading State in marketing sand-lime brick and reported 29 per cent of the quantity and 30 per cent of the value for the year. This was an increase of 86 per cent in quantity and of 155 per cent in value, compared with 1918. Minnesota ranked second in both quantity and value, reporting 16 per cent of the quantity and 14 per cent of the value. Wisconsin was third, rising from eighth in quantity and sixth in value in 1918. Florida was fourth in quantity and fifth in value, and Indiana was fifth in quantity and sixth in value. The first five States, rated by production, reported 73 per cent of the quantity and 69 per cent of the value.

About 99 per cent of the output, in both quantity and value, was marketed as common brick, in which there was an increase of 50

[1] The statistical data in this report were prepared by Miss Katrine W. Cottrell, of the United States Geological Survey.

per cent in quantity and 94 per cent in value, compared with 1918. The output of face brick was 1,670,000 brick, valued at $22,197, an increase of 6 per cent in quantity and of $4,247, or 24 per cent, in value.

The average price per thousand for common brick in 1919 was $11.58, compared with $8.94 in 1918 and $7.54 in 1917. For face brick the average price was $13.29, compared with $11.35 in 1918 and $9.36 in 1917.

Sand-lime brick marketed in the United States, 1910–1919.

Year.	Number of operators reporting sales.	Quantity (thousands).	Value.	Year.	Number of operators reporting sales.	Quantity (thousands).	Value.
1910	76	172,507	$1,169,153	1915	56	179,643	$1,135,104
1911	66	142,963	897,664	1916	53	227,344	1,474,073
1912	71	178,541	1,200,223	1917	47	187,546	1,420,330
1913	68	189,659	1,238,325	1918	42	98,399	883,929
1914	62	172,629	1,058,512	1919	35	146,947	1,705,163

Sand-lime brick marketed in the United States in 1918 and 1919.

State.	1918			1919		
	Number of operators reporting sales.	Common brick.[a]		Number of operators reporting sales.	Common brick.[b]	
		Quantity (thousands).	Value.		Quantity (thousands).	Value.
Indiana	3	7,903	$62,633	3	11,738	$108,089
Massachusetts	3	6,851	55,440	2	(c)	(c)
Michigan	9	22,564	198,633	8	42,063	507,010
Minnesota	3	12,255	90,212	3	23,391	239,676
New York	4	6,776	79,515	4	10,958	159,399
South Dakota	3	1,249	13,617	2	(c)	(c)
Texas	3	2,560	27,384	2	(c)	(c)
Other States[d]	14	38,241	356,495	11	58,797	690,989
	42	98,399	883,929	35	146,947	1,705,163

[a] Common brick, except 1,581,000 face brick, valued at $17,950, made in Florida, Idaho, Indiana, Massachusetts, Michigan, and Wisconsin.

[b] Common brick, except 1,670,000 face brick, valued at $22,197, made in Florida, Indiana, Michigan, and Wisconsin.

[c] Included under "Other States."

[d] 1918: California, District of Columbia, Florida, Georgia, Idaho, Louisiana, North Dakota, Ohio, Pennsylvania, Washington, and Wisconsin. 1919: District of Columbia, Florida, Georgia, Idaho, Louisiana, Massachusetts, North Dakota, Ohio, Pennsylvania, South Dakota, Texas, and Wisconsin.

SALT, BROMINE, AND CALCIUM CHLORIDE.[1]

By Herbert Insley.

SALT.

PRODUCTION AND TRADE CONDITIONS.

The salt produced and sold in the United States in 1919 amounted to 6,882.902 short tons, valued at $27,074,694, a decrease of 4.9 per cent in quantity compared with 1918, but an increase of 0.5 per cent in value.

Salt produced and marketed in the United States, 1913–1919.

Year.	Quantity.				Total value.	Average selling price per ton.
	Manufactured (evaporated) (short tons).	In brine (short tons).	Rock salt (short tons).	Total (short tons).		
1913	2,131,229	1,622,382	1,062,291	4,815,902	$10,123,139	$2.10
1914	2,159,094	1,652,758	1,060,804	4,872,656	10,197,417	2.09
1915	2,335,823	1,851,199	1,165,387	5,352,409	11,747,686	2.19
1916	2,454,836	2,539,717	1,368,353	6,362,906	13,645,947	2.14
1917	2,482,564	2,890,588	1,605,025	6,978,177	19,940,442	2.86
1918	2,724,203	2,830,600	1,683,941	7,238,744	26,940,361	3.72
1919	2,390,206	2,850,639	1,642,057	6,882,902	27,074,694	3.93

The average selling price of all salt was $3.93 a ton—an increase of 21 cents over the price in 1918. The increase may be attributed to the increase in costs of labor, fuel, and other supplies and to the inefficiency of the labor that was obtainable.

This is the first year since 1908 that there has been a decrease in the quantity of salt produced compared with the preceding year. This decrease was probably due to the unusual trade conditions brought about by the war. The average annual rate of increase in the quantity of salt produced from 1903 up to and including 1914 was about 4 per cent. The increased demand for salt in the chemical and metallurgic industries during the war caused the annual rate of increase to rise to 9.8 per cent in 1915, 18.9 per cent in 1916, and 9.7 per cent in 1917. If the normal annual rate of increase had persisted through the war the production in 1919 would have been considerably less than it actually was. A decrease in the quantity pro-

[1] The statistical tables of this report were prepared by Miss E. A. Menaugh, with the exception of those on imports and exports, which were compiled from records of the Bureau of Foreign and Domestic Commerce by J. A. Dorsey, both of the United States Geological Survey.

duced was therefore to have been expected after the unusual demand had ceased. A part of the decrease in 1919 may be ascribed to the lack of freight cars in which to move the product. Many manufacturers reported production in excess of actual sales in 1919, and the reason assigned for this condition by almost everyone was the shortage of freight cars.

Producers in Michigan complained of shortage of cars and increased cost of labor, material, and fuel. Many producers reported a decreased demand after the end of the war. The Marine City Salt Co., Marine City, Mich., was succeeded by the Michigan Salt Works.

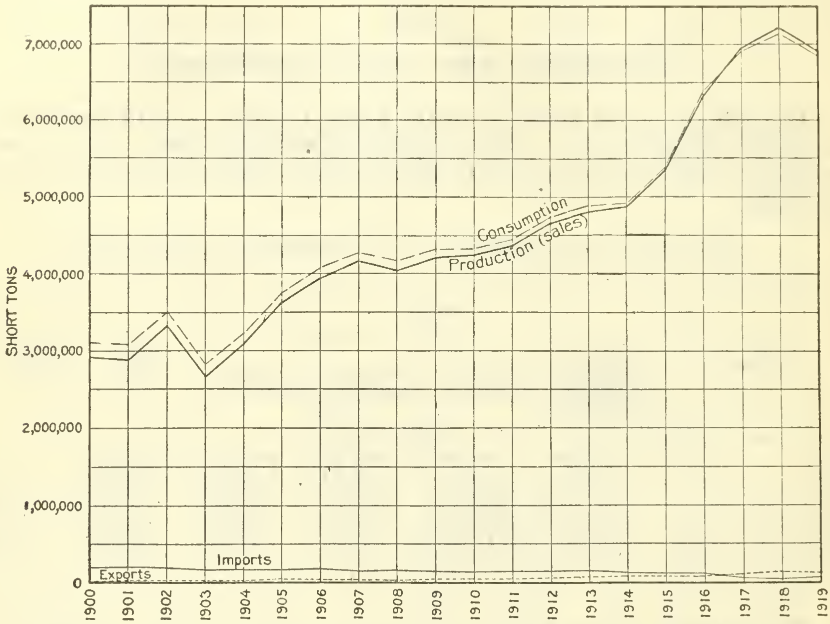

FIGURE 7.—Diagram showing production (sales), consumption, imports, and exports of salt, 1900–1919, in short tons.

In New York State many producers found that increased importation of foreign salt had decreased the demand for their salt. Because of a general shortage of freight cars and a scarcity of men to load the cars available the sales were considerably less than the production. Two producers reported their plants shut down, owing to unfavorable business conditions.

One plant in Ohio reported production in excess of sales because of the coal strike and consequent inability to move its product and because buyers were overstocked. Other operators found business conditions about the same as in the rest of the United States. In general, the increase in costs was not compensated by the increase in price.

Two plants in Louisiana produced salt in 1919. The plant of the Myles Salt Co., Weeks Island, was destroyed by fire in May, 1919. The plant of the Benners Salt Co. (Inc.), Lafayette, was not completed. The Jefferson Island Salt Co. expected to begin production about July 1, 1920.

The Pittsburgh Salt & Chemical Co., Pittsburgh, Pa., stopped operations and dismantled its plant owing to dilution of the natural brines.

MANUFACTURE OF POISON GASES.

A very considerable part of the increase in production of salt during the war was undoubtedly due to the use of chlorine in poison gases. Chlorine is made commercially by the electrolytic process. A current of electricity is passed through a solution of common salt (sodium chloride). The salt is broken down by electrolysis and chlorine gas is given off. Chlorine gas, as such, was used early in the war. Later phosgene and mustard gas, both deadly gases, were produced in this country and were used in large quantities. Phosgene is formed by the combination of two gases, chlorine and carbon monoxide, in the presence of a catalyzer. Mustard gas (dichlorethyl sulphide) is made by blowing gaseous ethylene into liquid sulphur monochloride under controlled temperature conditions. Sulphur monochloride is made by passing chlorine gas over heated sulphur.

PRODUCTION BY STATES.

Fifteen States and Territories produced salt in 1919, and those leading in the quantity produced were Michigan, New York, Ohio, Kansas, California, Louisiana, and Virginia. California had 22 operating salt plants, Kansas 10, Louisiana 2, Michigan 23, New York 16, and Ohio 7. There were 102 operating plants in the whole United States, the same number as in 1918.

Salt produced and marketed in the United States, 1916–1919, by States.

State.	1916		1917		1918		1919	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
Michigan	2,088,559	$4,612,567	2,250,939	$6,877,202	2,403,125	$9,048,650	2,492,378	$9,456,138
New York	1,972,285	3,698,798	2,164,069	5,371,713	2,130,530	7,336,867	1,947,829	7,159,547
Ohio	938,867	2,038,749	1,026,803	2,839,575	1,089,887	3,273,390	991,730	2,362,941
Kansas	639,071	1,302,359	746,976	2,027,466	819,504	3,598,289	773,576	4,497,247
California	157,393	656,975	215,154	933,429	204,957	1,167,777	200,115	1,555,596
Texas	75,762	427,119	85,181	564,029	79,657	762,006	(a)	(a)
Utah	60,653	289,457	79,195	352,145	94,204	580,375	77,336	432,130
West Virginia	33,389	122,669	24,844	191,044	26,077	251,668	18,599	167,529
Idaho	44	511	16	216	(a)	(a)	39	530
Nevada	(a)	(a)	(a)	(a)	970	4,175	(a)	(a)
Undistributed[b]	396,883	496,743	385,000	783,623	389,833	917,164	381,300	1,443,036
	6,362,906	13,645,947	6,978,177	19,940,442	7,238,744	26,940,361	6,882,902	27,074,694

[a] Included in "Undistributed."

[b] 1916: Hawaii, Louisiana, Nevada, New Mexico, Oklahoma, Porto Rico, and Virginia; 1917: Hawaii, Louisiana, Nevada, New Mexico, Oklahoma, Pennsylvania, Porto Rico, and Virginia; 1918: Hawaii, Idaho, Louisiana, New Mexico, Oklahoma, Porto Rico, and Virginia; 1919: Hawaii, Louisiana, Nevada, New Mexico, Porto Rico, Texas, and Virginia.

ROCK SALT.

Rock salt is mined in Kansas, Louisiana, Michigan, and New York, from deposits lying at some distance below the surface. In the arid districts of California, New Mexico, and Utah rock salt is taken from deposits at or near the surface. New York and Kansas together produce more than three times as much as all the other States, but New York produces almost twice as much as Kansas.

Rock salt produced and marketed in the United States, 1914–1919.

Year.	Quantity (short tons).	Value.	Average selling price per ton.
1914	1,060,804	$2,024,898	$1.91
1915	1,165,387	2,299,894	1.97
1916	1,368,353	2,665,270	1.95
1917	1,605,025	3,897,595	2.43
1918	1,683,941	5,684,661	3.38
1919	1,642,057	6,240,450	3.80

The production of rock salt increased from 1914 to 1918, but in 1919 it decreased 41,884 tons, or 2.5 per cent, in quantity, compared with 1918, whereas the value increased 9.8 per cent.

In 1919 rock salt was mined in California, Kansas, Louisiana, Michigan, New Mexico, New York, and Utah. Production of rock salt was reported by 21 operators. In 1918 there were 19 operators. In some of the Western States there are a few small mines that are worked only intermittently. These may be operated one year and shut down the next.

BRINE SALT.

Brine salt produced and sold or used in the United States, 1914–1918.

Year.	Evaporated.		In brine.		Total.	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
1914	2,159,094	$7,583,000	1,652,758	$589,519	3,811,852	$8,172,519
1915	2,335,823	8,845,827	1,851,199	601,965	4,187,022	9,447,792
1916	2,454,836	10,148,836	2,539,717	831,841	4,994,553	10,980,677
1917	2,482,564	14,959,261	2,890,588	1,083,586	5,373,152	16,042,847
1918	2,724,203	20,010,435	2,830,600	1,245,265	5,554,803	21,255,700
1919	2,390,206	19,410,820	2,850,639	1,423,424	5,240,845	20,834,244

Salt in brine.—In 1919 the only kind of salt that showed an increase in quantity was salt in brine. This increased about 20,039 tons, or 0.7 per cent, over the production of 1918. In 1918 this was the only kind of salt that showed a decrease. As salt in brine is usually sold to chemical works or is produced by them and used in their own plants, the increase or decrease in production of salt in brine might be to some extent an index to the condition of the chemical industries. Salt in brine is used in the manufacture of salt cake (sodium sulphate), soda ash (sodium carbonate), caustic soda, sodium acetate, sodium chlorate, sodium phosphate, sodium silicate, sal soda, Glauber salt, calcium chloride, chlorine, and hydrochloric acid.

Evaporated salt.—Salt manufactured by evaporating natural and artificial brine, not including salt in brine, made up 35 per cent of the total quantity of salt produced in 1919. Evaporated salt is put on the market under different names according to use, size of grain, or method of preparation. The usual subdivisions are table and dairy, common fine, common coarse, coarse solar, and pressed blocks. In 1919 evaporated salt showed a decrease of 12.3 per cent in quantity.

Evaporated salt produced and marketed in the United States in 1918 and 1919, by States.

State.	1918		1919	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.
California	202,607	$1,154,852	158,651	$1,310,062
Kansas	347,255	2,665,330	338,183	3,215,343
Michigan	1,059,872	7,926,745	993,195	8,020,757
Nevada	545	2,900	(a)	(a)
New York	521,568	3,871,887	436,209	3,785,279
Ohio	389,887	2,773,390	301,730	1,923,656
Texas	79,657	762,006	(a)	(a)
Utah	88,067	558,838	73,313	416,347
West Virginia	26,077	251,668	18,599	167,529
Undistributed[b]	8,668	42,819	70,326	571,847
	2,724,203	20,010,435	2,390,206	19,410,820
Percentage of decrease in 1919			12.3	3.0

[a] Included in "Undistributed."
[b] 1918: Hawaii, Idaho, New Mexico, Oklahoma, and Porto Rico: 1919: Hawaii, Idaho, Nevada, New Mexico, Porto Rico, and Texas.

Michigan produced the greatest quantity of evaporated salt in 1919; New York was second, Kansas third, Ohio fourth, and California fifth.

AVERAGE SELLING PRICE.

The average selling price per ton of all salt increased from $3.72 in 1918 to $3.93 in 1919. Evaporated salt, as usual, had a much higher average value than rock salt or brine salt. Evaporated salt is commonly used for the finer grades of table and dairy salt. In 1919 its average price was $8.12 a ton; in 1918, $7.35 a ton.

The average price for rock salt was $3.80 a ton, an increase of 42 cents over the price for 1918. As usual, salt in brine brought a very low price—about 50 cents a ton. Salt in brine requires little or no refining. It is usually produced by chemical plants and is used in their own processes, and therefore many producers give the cost of production as the value.

Average selling price per ton of domestic salt, 1915–1919, by States.

State.	Rock salt.					Brine salt.[a]				
	1915	1916	1917	1918	1919	1915	1916	1917	1918	1919
California	$3.98	$2.99	$4.21	$5.50	$5.92	$4.73	$4.20	$4.34	$5.69	$8.26
Hawaii						8.00	7.00	15.00	18.00	9.99
Idaho		10.00	10.00	10.00		10.00	15.00	15.60	18.00	13.59
Kansas	1.34	1.35	1.66	2.53	2.94	2.55	2.61	3.63	5.91	9.51
Louisiana	2.52	2.28	3.37	3.67	5.05					
Michigan	2.02	2.60	2.92	3.63	3.86	2.43	2.18	3.06	3.78	3.79
Nevada			3.00	3.00		4.07	4.35	3.18	5.32	6.00
New Mexico					1.50	2.76	2.00	2.41	10.00	2.34
New York	1.95	1.98	2.41	3.59	3.88	1.86	1.81	2.52	3.33	3.37
Ohio						1.78	2.17	2.77	3.00	2.38
Oklahoma						6.91	6.22	6.61	4.74	
Pennsylvania								3.00		
Porto Rico						2.57	2.62	4.24	4.00	4.90
Texas						5.55	5.46	6.62	9.56	8.74
Utah	2.29	2.24	2.54	3.50	3.92	5.04	4.99	4.60	6.35	5.68
West Virginia						3.54	3.67	7.69	9.65	9.00
Average for the United States	1.97	1.95	2.43	3.38	3.80	2.26	2.62	2.99	3.83	3.98

[a] Includes evaporated salt and salt in brine.

From the table it is apparent that the price of brine salt is much more variable in different States than the price for rock salt. This is due to the fact that in some States a relatively large quantity of salt in brine, which has a very low value, is produced, whereas in other States where a large quantity of evaporated salt is produced there may be little or no salt in brine. To a certain extent the price seems to be governed by the proximity to a market. The average price in salt-producing States that are remote from the larger centers of population seems to be higher than in the other States, although this rule does not always hold.

DOMESTIC CONSUMPTION.

In 1919 the population of the United States, including territories and possessions, was about 118,000,000. As the total consumption of salt was 6,823,000 short tons the per capita consumption was 116 pounds.

Supply of salt for domestic consumption, 1910–1919, in short tons.

Source.	1910	1915	1916	1917	1918	1919
Domestic production	4,242,792	5,352,409	6,362,906	6,978,177	7,238,744	6,882,902
Imports	137,103	122,326	122,079	64,922	40,290	59,514
Total	4,379,895	5,474,735	6,484,985	7,043,099	7,279,034	6,942,416
Exports	49,013	80,474	84,065	113,993	136,783	119,416
Domestic consumption	4,330,882	5,394,261	6,400,920	6,929,106	7,142,251	6,823,000
Comparison with preceding year	+6,444	+473,096	+1,006,659	+528,186	+213,145	−319,251
Percentage of imports to total consumption	3.2	2.3	1.9	0.9	0.6	0.9

IMPORTS.

According to figures obtained from the Bureau of Foreign and Domestic Commerce, Department of Commerce, and after conversion from pounds as reported by that bureau to short tons, the salt imported and entered for consumption in the United States in the last six years is as follows:

Salt imported and entered for consumption in the United States, 1914–1919.

Year.	In bags, barrels, and other packages.		In bulk.		Total.	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
1914	32,807	$212,349	97,997	$168,454	130,804	$380,803
1915	28,724	196,593	93,602	169,859	122,326	366,452
1916	24,402	200,290	97,677	142,298	122,079	342,588
1917	13,472	139,339	51,450	140,796	64,922	280,135
1918	10,259	148,128	30,031	133,340	40,290	281,468
1919	9,676	137,627	49,838	105,077	59,514	242,704

The source of the imported salt is shown in the following table:

Salt imported into the United States, 1917–1919, by countries.

[General imports.]

Country.	1917		1918		1919	
	Quantity (pounds).	Value.	Quantity (pounds).	Value.	Quantity (pounds).	Value.
France					56,000	$601
Germany					6,613,800	81,698
Portugal	3,724,600	$7,651	112,000	$216	22,100	242
Spain	7,342,000	5,209	10,180,000	6,750	55,722,100	37,952
England	34,960,600	164,624	34,102,700	219,007	18,401,200	139,408
Canada	5,718,000	18,734	589,200	6,663	299,700	3,050
Panama						1
Mexico	956,800	823	76,500	614	79,700	637
British West Indies	65,859,900	72,621	25,779,400	35,815	41,930,900	55,423
Cuba			103,800	134		
Dutch West Indies	13,102,900	10,459	4,731,400	8,779	2,139,300	4,633
French West Indies			200,000	425		
Virgin Islands of United States					374,600	725
Dominican Republic			3,858,000	4,824		
China	15,200	14				
Japan			200	5	1,500	12
Hongkong					200	5
Portuguese Africa			896,000	800		
Australia					1,100	15
	131,680,000	280,135	80,629,200	284,032	125,642,200	324,402

The difference in the total of imports as given in the table by countries and the total in the table of salt imported and entered for consumption is due to the fact that some of the salt shown in the table of general imports was in warehouse at the end of the year. Perhaps an additional small quantity was reexported and had not been entered for consumption.

In relation to the total quantity of salt consumed in the United States the quantity imported is very small, only 0.9 per cent. From 1913 to 1918 the importation of salt into the United States continually decreased, while exports increased. Before 1913 annual imports had been variable, but had averaged approximately 150,000 short tons.

After the World War began foreign countries found that they had enough to do to supply their own demands, and warring nations cut down their production. The principal reason for the decrease in imports, however, was the lack of shipping facilities. Our imports of salt came principally from Spain and the West Indies. Vessels that usually plied between these countries and the United States were diverted to routes from the United States to the Allied countries, and the United States found it necessary to substitute domestic salt for that usually imported. Now, however, the quantity of salt imported is increasing, and trade seems to be coming back to its pre-war condition.

Imports of salt from Spain in 1919 were more than five times as much as they were in 1918, and imports from the West Indies increased about 28 per cent. Germany, for the first time since 1915, exported salt to the United States.

Notwithstanding the increase in imports in 1919 over 1918, the quantity of salt imported in 1919 was only about half that imported in 1914.

A large part of the imported salt is coarse solar salt made by evaporating sea water and comes from the West Indies and Spain. This cheap material enters the United States at a low freight rate and is used largely for curing fish and meats. Salt is imported from England largely to supply packers who think they can not get satisfactory results without Liverpool salt.

EXPORTS.

Salt exported from the United States, 1914–1919.

Year.	Quantity.		Value.
	Pounds.	Equivalent in short tons.	
1914	164,589,012	82,295	$586,055
1915	160,948,077	80,474	613,847
1916	168,129,201	84,065	567,441
1917	227,985,222	113,993	1,000,773
1918	273,565,496	136,783	1,677,577
1919	238,831,706	119,416	1,396,625

Salt exported from the United States, 1917–1919, by countries.

Country.	1917		1918		1919	
	Quantity (pounds).	Value.	Quantity (pounds).	Value.	Quantity (pounds).	Value.
Europe:						
Azores, and Madeira Islands					1,471	$25
France	14,181	$187	10,000	$150		
Germany					820	17
Iceland and Faroe Islands	9,245	119	51,284	2,031	12,570	439
Italy	600	4	4,400	67	2,520	48
Netherlands					1,000	20
Norway	950	18	2,160	84	7,500	222
Russia in Europe	179,648	1,360	27,714	241	5,308	174
Serbia and Montenegro, etc					200	3
Turkey in Europe					8,536	526
Switzerland			26,000	390		
United Kingdom—England	7,572	160	56,694	406		
North America:						
Bermuda	367,582	3,733	295,650	2,909	34,840	622
British Honduras	699,601	2,861	611,722	4,598	320,166	3,228
Canada	141,977,910	474,810	160,360,923	617,907	157,596,910	654,657
Central American States:						
Costa Rica	358,070	3,148	240,819	4,200	649,177	6,233
Guatemala	136,640	1,222	173,521	1,876	132,199	1,883
Honduras	1,774,138	9,810	2,159,241	16,892	1,842,919	17,730
Nicaragua	853,841	7,473	557,894	6,883	700,306	8,932
Panama	4,126,157	29,267	5,881,821	49,707	3,945,329	37,980
Salvador	504	10	5,735	194	5,632	336
Mexico	11,157,848	76,038	6,958,031	78,554	7,931,184	89,534
Miquelon, Langley, etc	5,450	45	1,346	23	1,656	63
Newfoundland and Labrador	4,081,348	29,014	5,827,019	48,115	4,891,549	31,211
West Indies:						
Barbados	5,633	112	1,952	48	15,557	219
Jamaica	764,245	2,844	43,749	295	28,511	334
Trinidad and Tobago	3,200	39	3,105	88	4,890	66
Other British	19,446	322	15,262	428	19,327	646
Cuba	52,171,794	262,265	58,498,163	530,669	47,291,884	388,956
Dominican Republic	134,563	2,424	572,821	5,320	361,246	4,630
Dutch West Indies	498	11	487	10	190	12
French West Indies	29,787	578	20,158	572	24,281	705

Salt exported from the United States, 1917–1919, by countries—Continued.

Country.	1917		1918		1919	
	Quantity (pounds).	Value.	Quantity (pounds).	Value.	Quantity (pounds).	Value.
North America—Continued.						
West Indies—Continued.						
Haiti	12,301	$216	12,989	$430	7,530	$304
Virgin Islands of the United States [a]	155,152	876	3,957	100	16,714	466
South America:						
Argentina	91,093	626	26,140	1,015	521,600	4,110
Bolivia			320	9	1,400	8
Brazil	18,455	283	7,946	127	3,799	118
Chile	32,356	435	27,044	452	5,160	132
Colombia	287,655	2,959	189,362	2,698	445,096	4,283
Ecuador	50	2			244	12
Guiana:						
British	366,124	5,741	18,453	334	710	19
Dutch	16,632	173	6,010	132	21,910	370
French	5,650	48	17,000	198	5,000	75
Paraguay			14,000	175		
Peru	68,123	657			148	4
Uruguay	162	4				
Venezuela	6,724	116			1,320	40
Asia:						
China	8,227	302	28,175	1,710	36,651	1,882
Kwantung, leased territory					36	3
Japanese China			74	6		
Chosen	11,475	185	5,819	225	11,297	386
East Indies:						
British:						
British India	7,319	126	42,269	2,975	18,619	1,201
Straits Settlements	2,850	132	7,345	439	18,728	742
Other British	1,484	28	11,882	755	5,506	299
Dutch	47,220	1,786	498,712	17,783	95,222	3,626
French			6,979	283	4,192	230
Hongkong	20,267	831	7,077	467	29,360	2,257
Japan	1,835,454	12,291	2,418,230	13,369	7,138,600	38,974
Russia in Asia	40	2	70	2	249,600	2,287
Siam	2,640	106	7,586	233	595	57
Turkey in Asia					12	1
Oceania:						
British:						
Australia	2,604,029	35,637	3,992,560	50,988	2,209,634	44,457
New Zealand	3,017,167	20,369	22,931,065	192,988	1,553,914	26,484
Other British	6,516	143	34,748	494	21,069	552
French Oceania	198,613	2,208	537,074	7,109	174,384	2,865
German Oceania	31,886	435	53,914	869	44,836	866
Philippines	231,239	5,735	222,679	7,760	192,976	7,760
Africa:						
Belgian Kongo	723	12	7,876	143	6,605	343
British Africa:						
West	4,001	166	17,522	567	61,110	1,034
South	6,600	128	124	2		
East	5,200	118	1,200	40	595	19
French Africa	112	4	100	3	89,648	901
German Africa					74	3
Liberia	1,160	16	520	19	56	1
Portuguese Africa	72	3	1,004	21	78	3
	227,985,222	1,000,773	273,565,496	1,677,577	238,831,706	1,396,625

[a] Danish West Indies prior to March 31, 1917.

The quantity of salt exported from the United States in 1919 was 119,416 short tons, a decrease of 13 per cent compared with the quantity exported in 1918. Exports from the United States had increased every year since 1911, except in 1915, when there was a slight decrease. In 1919, however, there was a marked decrease, due probably to a return to normal conditions. Since the war many countries have endeavored to begin the production of salt or to increase their present production in order to be independent.

The quantity of salt exported from the United States in 1919 represented only about 1.7 per cent of the total quantity produced.

Canada, Cuba, Mexico, and Japan receive most of the salt exported from the United States. The quantity of salt exported to Japan was almost three times as much in 1919 as it was in 1918. In 1916 our exports of salt to Japan amounted to only 25 tons. The quantity sent to Canada decreased slightly in 1919, owing probably to the development of new salt deposits in that country.

Australia developed some new salt resources, and this may account for the marked decrease in exports to Australia and New Zealand.

DOMESTIC DEPOSITS.

The salt deposits in the United States are fully described in United States Geological Survey Bulletin 669, "The salt resources of the United States," by W. C. Phalen. This illustrated bulletin of 285 pages was issued in May, 1919, and may be obtained free of charge on application to the Director, United States Geological Survey, Washington, D. C. It contains descriptions of the deposits, arranged by States, a discussion of the origin and formation of saline deposits, many analyses of rock salt, brines, and bitterns, and statistics of the production of salt since the beginning of the industry.

FOREIGN DEPOSITS.

A summary of the distribution of salt throughout the world was published in Mineral Resources for 1918, Part II, pages 126–131. The chapter containing this summary may be had free of charge on application to the Director, United States Geological Survey. The following additional statements on foreign deposits have been taken from Commerce Reports:

Spain.—Although the production of salt in Spain for 1919 was normal (about 302,000 short tons) there was a very large stock of salt on hand, owing to the scarcity of shipping facilities and the extremely high freight rates prevailing during the war. This stock represented a total of not much less than the combined harvests of 1917, 1918, and 1919.

The salt known as Cadiz salt is considered of very high quality, especially for the curing of fish. Cadiz salt is obtained from the solar evaporation of sea water in the San Fernando district, contiguous to the Bay of Cadiz and the Atlantic Ocean.

Portugal.—Portugal exports from 150,000 to 200,000 tons of salt annually. The principal salt-producing districts are Aveiro, Setubal, and the district along the Tagus. Before the war Portugal exported salt to the Netherlands, France, Newfoundland, Norway, Sweden, and Ireland, but now the Netherlands, Sweden, and Norway buy salt from Germany, and France buys from England. The Portuguese salt crops harvested in 1917 and 1918 are still unsold.

Holland.—Hitherto Holland has been entirely dependent upon foreign sources for its salt, but in 1919 the Royal Netherlands salt industry struck rock salt with the drill in the Provinces of Gelderland and Overyssel. Toward the end of 1919 the mines were delivering five carloads a day, and it is expected that the production may increase until Holland will become independent in respect to salt.

Poland.—Poland has rich salt deposits in the Provinces of Galicia and Posen and in what was formerly Russian Poland. The mine at Wieliczka, in Galicia, is one of the largest and best known in the world. The total production just before the war of the territories now included in Poland was 225,491 tons, of which 63 per cent came from Galicia.

Siberia.—Salt is found in Siberia in saline springs, in salt lakes, and as rock salt. Salt lakes occur in the Tobolsk and Tomsk Governments. Brine springs are found in the Yenisei and Irkutsk Governments and in the Yakutsk Province. Although extensive deposits of salt are available in Siberia, very little is produced, and salt is imported into western Siberia from European Russia and Germany to the extent of 9,000 tons annually. The salt that is produced in Siberia is generally obtained by the crudest methods and without proper cleaning.

BROMINE.

PRODUCTION.

The bromine produced in the United States in 1919 amounted to 1,854,971 pounds, valued at $1,234,969. This is an increase of 7.4 per cent in quantity and 27.3 per cent in value over the production in 1918. The quantity produced in 1918 was an increase of 92.9 per cent over that for 1917. Although the enormous war demand for bromine no longer exists, there is still sufficient demand for it to keep the production up.

Bromine produced and marketed in the United States, 1910–1919.

Year.	Quantity (pounds).	Value.	Average selling price per pound.
1910	245,437	$31,684	$0.13
1911	651,541	110,902	.17
1912	647,200	145,805	.22
1913	572,400	115,436	.20
1914	576,991	203,094	.35
1915	855,857	856,307	1.00
1916	728,520	951,932	1.31
1917	895,499	492,703	.55
1918	1,727,156	970,099	.56
1919	1,854,971	1,234,969	.67

The figures in the third column are derived from the total quantity and value as reported to the Geological Survey by the producers and represent average prices for the year f. o. b. at the plants.

The output in 1919, which was by far the largest in the history of the industry, was made as usual from bittern left after extracting salt from the brine pumped from deep wells at Midland and Saginaw, Mich.; at Pomeroy, Ohio; and at Mason, Hartford, and Malden, W. Va. About 94 per cent of the total quantity came from Michigan, and the rest from Ohio and West Virginia.

A large part of the output is not actually marketed as bromine, but as potassium and sodium bromide and other bromine salts. The figures given include the bromine content of these salts.

Bromine has not been imported into the United States for several years, and exports of bromine are not separately reported by the Bureau of Foreign and Domestic Commerce.

QUOTED PRICE.

The average quoted price per pound for bromine in 1919 was 67 cents. In 1918 it was 56 cents. The price remained fairly steady throughout 1919, although in June and July it dropped to 40 cents a pound.

Wholesale quoted price per pound of bulk bromine in New York City, 1915–1919.

	1915	1916	1917	1918	1919
January	$0.40–$0.50	$5.00–$6.50	$1.40–$1.50	$0.75–$0.85	$0.75
February	.40– .50	5.00– 6.50	1.40– 1.50	.75– .85	.65
March	.40– .50	5.00– 6.50	1.30– 1.40	.75– .85	.65
April	.40– .50	(a)	1.30– 1.40	.75– .85	.55–$0.60
May	.40– .50	4.75– 5.25	.80– 1.00	.75– .85	.55 .60
June	.85– .87	3.50	.85– 1.00	.75– .85	.40 .50
July	.85– .87	3.50	.55– .60	.75– .85	.40 .50
August	.85– .87	2.40– 2.50	.55– .60	.75–	.65– .75
September	1.00– 1.25	1.30– 1.40	.55– .60	.75–	.65– .75
October	1.25– 1.60	1.20– 1.30	.55– .60	.75–	.65– .75
November	1.50– 1.75	1.40– 1.50	.55– .60	.75–	.75– .85
December	1.50– 1.75	1.40– 1.50	.60– .65	.50–	.75– .85

a Not quoted.

NATURE AND OCCURRENCE.

Bromine at ordinary temperatures is a deep-red liquid. It boils at 59° C., forming a deep-red vapor which is extremely irritating to the eyes and respiratory organs.

Bromine was first isolated by A. J. Balard in 1826 from the salts in the waters of the Mediterranean. Bromine does not occur as such in nature, but in combination with metals. Bromyrite (AgBr) and embolite (Ag(Cl,Br)) are bromine minerals found sparingly in nature.

The commercial source of bromine is magnesium bromide, which is associated with common salt and other chlorides in the deposits at Stassfurt, Germany, and in the brines of Michigan, Ohio, and West Virginia.

METHODS OF MANUFACTURE.

The following condensed description of the three principal methods used in the manufacture of bromine has been abstracted from Bulletin 146 of the Bureau of Mines.[2]

Periodic or intermittent process.—The periodic or intermittent process of making bromine is in use along Ohio River in Ohio and West Virginia, at Malden, W. Va., and at Bay City, St. Charles, and Saginaw, Mich. After the removal of the bulk of the salt in the main grainers, the bittern in the last grainer is further concentrated to 39° or 41° Baumé, the strength desired for entry to the bromine still.

[2] Phalen, W. C., Technology of salt making in the United States: Bur. Mines Bull. 146, pp. 85–94, 1917.

The stills are made of sandstone and are of various designs. Some consist of cubical or rectangular blocks hollowed out and placed together edge to edge, so that the hollow parts form a single interior chamber, and some are built up of sandstone rings, 6 inches or more thick, clamped together and cemented with acid-resisting and bromine-resisting material. The top and bottom slabs are usually the thickest. Holes in the top slab admit the brine and the chemicals. The working capacity of the stills ranges from 400 to 1,200 gallons of liquid.

Sodium chlorate and sulphuric acid of 66° Baumé are used in liberating the bromine from the bittern. After the bittern enters the still and the requisite sodium chlorate and sulphuric acid are added, a jet of steam is discharged into the solution. As the temperature rises, a reaction approximately represented by the following equation takes place:

$$3MgBr_2+3H_2SO_4+NaClO_3=6Br+NaCl+3MgSO_4+3H_2O.$$

The bromine set free passes from the still as a gas, but some chlorine also is liberated and goes out with the bromine. The bromine is freed from the chlorine by passing it through washers filled with milk of lime, which forms with the chlorine calcium chloride and calcium hypochlorite. The bromine distilled goes to a condenser and is collected in glass bottles in series. Any bromine that passes the last bottle is caught in towers 6 to 8 feet high and 2 or 2½ feet in diameter, made of sewer pipe and filled with coke. Bromine water that collects in them runs out at their base.

Continuous process.—Certain disadvantages connected with the intermittent process have led to the use of what is usually known as the continuous process. In this process chlorine gas is the agent used to liberate the bromine from its combinations. The chlorine gas is passed through the bromine-bearing brine, and the bromine is liberated according to the simple reaction $MBr_2+Cl_2=MCl_2+Br_2$, in which M stands for metal. The bromine is left mechanically held in the solution. The bromine is recovered from the solution by air currents brought into contact with it. The bromine-laden air is then brought into contact with such substances as will readily form a chemical combination with it. Iron may be used, a solution of ferric bromide being formed. If a solid is desired, ferrous bromide may be made from the ferric salt by suitable means.

Electrolytic process.—The electrolytic process for making bromine depends on the principle that bromides decompose at a lower voltage than chlorides and hence are first decomposed by the electric current. A weak current is used—not more than 4 or 5 volts.

One method of carrying on the process is as follows: The brine is run into long wide wooden vats in which carbon electrodes are introduced and in which the electrolysis takes place. The solution containing the bromine trickles continuously over a latticework down a tall wooden tower, upward through which passes a strong current of air. The bromine vapor is then passed through water and an aqueous solution is formed. The aqueous solution then trickles downward through another tower built of bromine-resisting material such as sewer pipe. In this tower are coils of thin iron ribbon or wire. The iron combines with the bromine, forming bromide of iron. This

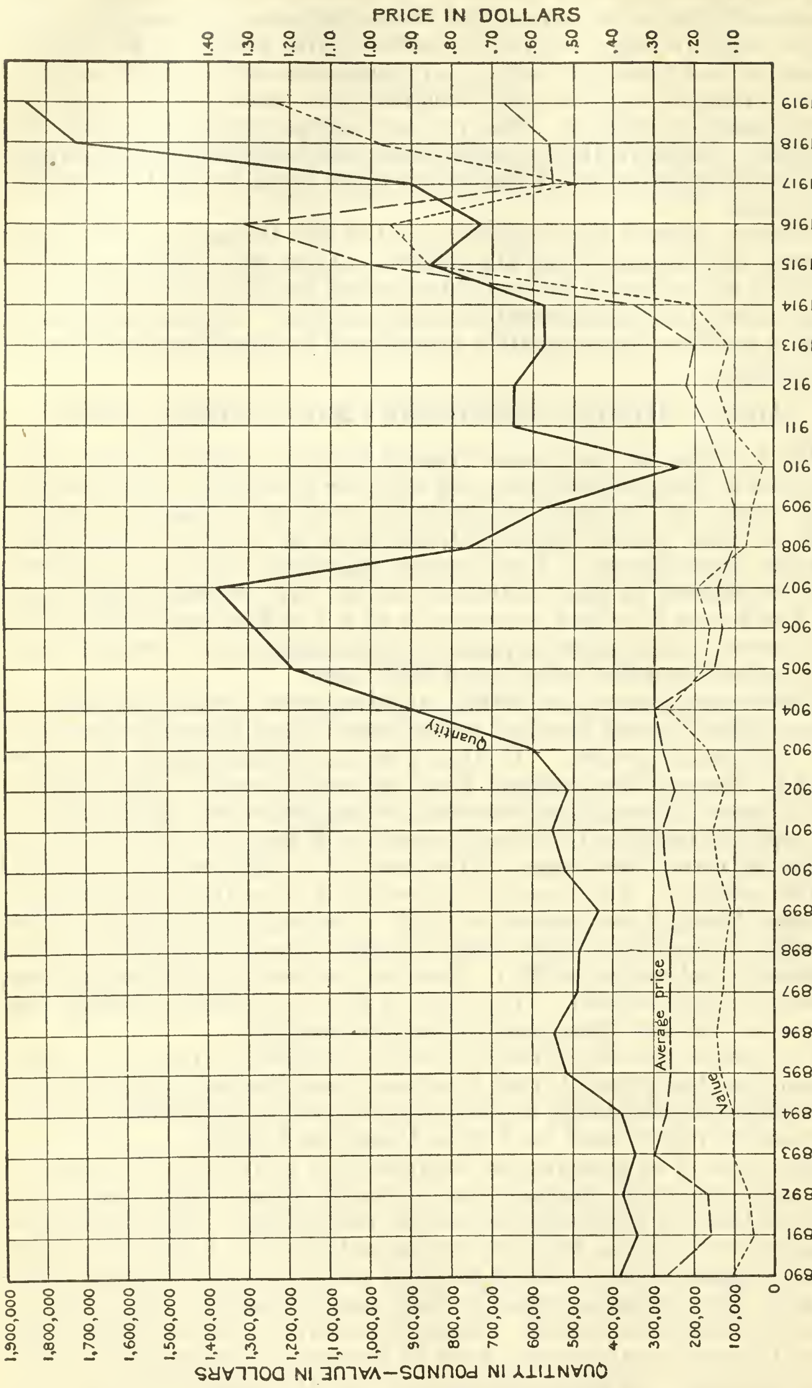

FIGURE 8.—Diagram showing quantity, value, and average price per pound of bromine produced annually in the United States, 1890–1919.

compound is next treated with sodium, potassium, or ammonium hydroxide according to the bromide desired. The mixture is boiled down in cylindrical iron tanks, and after the reaction is completed the precipitated ferric hydroxide is filtered off and the clear solution further concentrated until the bromides crystallize out.

USES.

Bromine is used in the manufacture of certain coal-tar dyes such as eosin and Hofmann's blue and in the manufacture of bromides. The organic bromides and potassium bromide are used principally in medicine and are very effective as depressants in nervous diseases. Silver bromide is used in photography. In peace times the uses in medicine and photography probably consume most of the bromine produced.

Bromine is used considerably in analytical chemistry and is an effective oxidizing agent. It has been used in the extraction of gold from the ore.

"Bromum solidification" is a disinfectant composed of diatomaceous earth pressed into sticks with some bond such as molasses, burned until coherent, and then soaked in liquid bromine.

Since bromine has so irritating an effect on the eyes and nose it was used in the war as the base for practically all the tear gases. Brombenzyl cyanide was one of the most effective of these gases and was the one that the United States had begun to manufacture when the armistice was declared.

DEVELOPMENT OF THE BROMINE INDUSTRY.

The curve of production of bromine from 1890 to the present time (fig. 8) exhibits an irregularity that is unusual, even in a chemical industry, where the demand is always somewhat variable. The curve is also an illustration of the futility of trying to control prices and sales by trade combinations for any long period of years and the inability of anyone to regulate the law of supply and demand.

In studying the bromine industry it must be remembered that bromine is usually manufactured as a by-product of the salt industry and that the manufacture of bromine probably would not pay if it was the only product of the brine. Consequently, whether the demand for bromine is great or small, the quantity manufactured depends to a great extent on the condition of the salt industry. There may be peaks in the curve of the production of bromine which are not connected with any increased demand. This relation was not so close through the war years, for then the price of bromine was so high that in many plants it ceased to be a by-product from the brine and became the only product that was used or sold.

The commercial production of bromine was begun in 1849 by Dr. David Alter, on a very small scale, at the salt works at Freeport, Pa. In 1865 the manufacture of bromine from the bromides in the carnallite at Stassfurt, Germany, was begun. This induced the salt manufacturers of West Virginia to produce bromine, and later those of the Pomeroy and Tuscarawas districts in Ohio. In 1865 the price ranged from $8 to $16 a pound, but so much bromine was thrown on the market that the price fell rapidly. In 1880 it was only 28 cents a pound.

In 1885 the Midland district, Mich., began producing bromine, its production for that year being 40,000 pounds.

Early in 1885 a combination was effected among nearly all the producers of bromine in the United States and the product was pooled and sold through the National Bromine Co. Owing to this combination the price rose from 29 cents in 1885 to 33 cents in 1886, and the quantity produced increased to 428,334 pounds in 1886. This price was sufficiently high to cause some consumers to seek foreign supplies, and a small quantity was imported during the fiscal year 1886.

The accumulation of stocks and the dullness of trade caused many of the bromine manufacturers to cease operations for a part of 1887, and the production decreased to 199,087 pounds, although the price remained nearly the same as in 1886. In 1888 and 1889 the production increased and the price averaged about 31 cents. The use of bromine as a disinfectant increased, 6,800 pounds being used at Johnstown, Pa., after the Johnstown flood, May 31, 1889. In 1890 the production decreased about 8 per cent and the price averaged about 27 cents a pound. In March, 1891, the National Bromine Co., which had acted as sales agent for the American producers, expired. The individual producers shipped their product abroad in an effort to market it, though an agreement had previously existed with the Leopoldshall-Stassfurt Bromine Convention that each country should limit sales to its own territory. German producers then shipped bromine from Germany to the United States, and the price dropped from 25 to 17½ cents a pound at New York. Better understanding between American producers prevailed in 1893, and the price was brought back to normal (25 cents). From 1893 to 1904 the price ranged from about 26 to 30 cents. Production also fluctuated from 348,000 pounds in 1893 to 897,000 pounds in 1904 and to about 1,193,000 pounds in 1905.

Since the beginning of the industry in Michigan the output of that State, particularly of the Midland district, had increased rapidly until by 1904 Michigan was far ahead of any other State.

From 1904 to 1907, inclusive, the output of the whole United States increased rapidly. The price, on the other hand, declined rapidly—from about 30 cents in 1904 to about 20 cents in 1907, the result of overproduction and increased imports from Germany. There was a natural reaction to this overproduction, and the quantity produced in 1910 was less than in any year since 1887. In 1910 imports from Germany ceased, and in 1911 price and quantity began to return to normal. The beginning of the war cut off most of the imports of photographic and other chemicals from Germany, so that the demand for American bromides increased, and at the same time the price went up at an astonishing rate. In 1916 the average price was $1.31 a pound—the highest it has been since 1865. Part of this advance was probably artificial, stimulated by the great increase in price of other chemicals. In 1917 the new brombenzyl cyanide, a tear gas for use in the trenches, was invented. From that time on the demand was as great as the supply. The new brine wells drilled in the Midland district in 1918 helped to increase the production. The price receded from its high point of 1916, although in 1917 and 1918 it was still twice as high as the normal price before the war. The production increased after the war, probably as a result of the continued demand for bromides in the photographic trade, especially for moving-picture films and in the treatment of nervous diseases.

CALCIUM CHLORIDE.

PRODUCTION.

Large quantities of calcium chloride are produced in connection with the ammonia soda process at Solvay, N. Y., Wyandotte, Mich., Barberton and Fairport Harbor, Ohio, Hutchinson, Kans., and Saltville, Va.; but this material derives its calcium from limestone and its chlorine from common salt and is not an original constituent of the brine pumped at these places. For this reason the calcium chloride so produced is not considered by the Geological Survey in its statistics. Only that calcium chloride which is an original constituent of natural brine and which is produced in connection with the manufacture of salt and bromine from such brine is here recorded. This material is interchangeable for most uses with the waste product of the ammonia soda process but contains a notable percentage of magnesium. Analyses of calcium chloride obtained from natural brines show from 2 to 6 per cent of magnesium as an impurity. Calcium chloride containing magnesium was made in 1919 at Midland and Saginaw, Mich.; Pomeroy, Ohio; Mason and Malden, W. Va.; and Saltus, San Bernardino County, Calif.

Calcium-magnesium chloride produced and marketed in the United States, 1910–1919.

Year.	Quantity (short tons).	Value.	Average selling price per ton.
1910	10,971	$74,713	$6.81
1911	14,606	91,215	6.25
1912	18,550	117,272	6.32
1913	19,611	130,030	6.63
1914	19,403	121,766	6.28
1915	20,535	130,830	6.37
1916	27,709	224,997	8.12
1917	30,503	451,480	14.80
1918	26,624	503,452	18.91
1919	26,123	321,596	12.31

The production of calcium-magnesium chloride in 1919 showed a decrease of 1.9 per cent in quantity and of 36.1 per cent in value, compared with that of 1918. The average selling price declined from the abnormally high mark of $18.91 a ton in 1918 to $12.31 a ton in 1919.

USES.

Calcium chloride is used for the prevention of dust on roads and playgrounds, in brine for refrigerating plants, for protection against fire, for the prevention of freezing, as a drying agent, and for some other purposes. Because of its strong affinity for water, sprinkling with calcium chloride will keep a road moist and therefore dustless for several weeks. A calcium-chloride solution has some advantage over salt brine in refrigerating machinery for ice factories, meat-packing houses, and cold-storage warehouses. A solution of calcium chloride in fire buckets has an advantage over water in that it does not corrode metal, has a lower freezing point, and because of its affinity for water tends to keep the buckets full by extracting moisture from the air. For this same reason it is used to dry gases, fruits, and vegetables.

FULLER'S EARTH.[1]

By Jefferson Middleton.

GENERAL CONDITIONS.

The activity in the fuller's earth industry continued during 1919 with increased vigor and is reflected in the large output for the year. The prospects for increased output seem good; many inquiries have been received at the Geological Survey for information on the subject, and many new developments will probably take place in the near future. This appears to be especially true of the Pacific coast, where deposits of large size and excellent quality have been found. The deposit in Ash Meadows, Nye County, Nev., near Death Valley, Calif., was developed experimentally in 1919 and, with other deposits that have been discovered in the same region, promises to be of great value. As fuller's earth is used largely in the refining of petroleum, the quantity of fuller's earth mined is naturally affected by the quantity of petroleum produced; hence in consequence of the large production of petroleum in 1919, fuller's earth reached its maximum output in that year. It also reached its highest value and its greatest increase in average price per ton. The output in 1919 was 106.145 short tons, valued at $1,998,829, an increase of 21,677 tons, or 26 per cent, in quantity and of $852,475, or nearly 75 per cent, in value. The larger proportionate gain in value is, of course, due to the higher prices received. The increase in average price per ton was $5.26, or 39 per cent, compared with 1918. Imports also increased, though not in the same proportion as production, the increase in quantity being 10 per cent and in value 15 per cent. Exports of fuller's earth are not separately classified by the Bureau of Foreign and Domestic Commerce, but partial returns from producers indicate that in 1919 they amounted to about 1,400 short tons. On this basis the domestic earth used was about 89 per cent of the total consumption in 1919, compared with about 87 per cent in 1918 and about 81 per cent in 1917.

OCCURRENCE.

Fuller's earth has been reported in Alabama, Arizona, Arkansas, California, Colorado, Florida, Georgia, Massachusetts, Minnesota, Mississippi, Missouri, Nebraska, Nevada, New York, Pennsylvania, South Carolina, South Dakota, Texas, Utah, Virginia, and Washington; but it was produced in 1919 only in Alabama, Florida, Georgia, Massachusetts, and Texas. These five States and in addition Arkansas, California, and Nevada were producers in 1918 also.

[1] The statistical data of this report were prepared by Miss Katrine W. Cottrell, of the United States Geological Survey.

USES.

Fuller's earth obtains its name from its original use in fulling cloth, but only a small quantity, mainly domestic, is now used in this country for that purpose. It is used principally in bleaching and in clarifying or filtering fats, greases, and oils. It is also used in the manufacture of pigments for printing wall papers, in detecting certain coloring matters in some food products, as a substitute for talcum powder, and, in medicine, as a poultice and as an antidote for alkaloid poisons.

PRODUCTION.

The growth of the industry in the last 10 years and the production in 1918 and 1919 by groups of States are shown in the following tables. The output in 1919 was more than three times as great and the value was nearly seven times as great as in 1910. The output in 1919 was fifteen times as great and the value was forty-eight times as great as in 1895, the first year of commercial production in the United States. The lowest average selling price per ton ($5.72) was in 1904, the highest ($18.83) in 1919:

Fuller's earth produced and marketed in the United States, 1910–1919.

Year.	Operators reporting sales.	Quantity (short tons).	Value.	Average selling price per ton.
1910	17	32,822	$293,709	$8.95
1911	13	40,697	383,124	9.41
1912	13	32,715	305,522	9.34
1913	10	38,594	369,750	9.58
1914	14	40,981	403,646	9.85
1915	12	47,901	489,219	10.21
1916	10	67,822	706,951	10.42
1917	11	72,567	772,087	10.64
1918	14	84,468	1,146,354	13.57
1919	10	106,145	1,998,829	18.83

Fuller's earth produced and marketed in the United States in 1918 and 1919.

State.	1918			1919		
	Number of operators reporting sales.	Quantity (short tons).	Value.	Number of operators reporting sales.	Quantity (short tons).	Value.
Alabama, Florida, and Texas	6	76,844	$1,057,204	6	102,972	$1,944,792
Georgia and Massachusetts	3	6,251	73,820	4	3,173	54,037
Arkansas, California, and Nevada	5	1,373	15,330			
	14	84,468	1,146,354	10	106,145	1,998,829

The small number of producers makes it impossible to publish totals for some States without disclosing the output of individual operators; consequently the distribution of output is grouped as above. In 1919 Texas was the only State west of the Mississippi reporting sales of fuller's earth. Practically the entire output of the country in 1919 came from the Southern States, only one other State, Massachusetts, reporting an output of this material. Named in order of rank in quantity and value the producing States were Florida, Texas, Georgia, Alabama, and Massachusetts. Florida, which has been the leading State in the quantity and value of fuller's earth sold since the beginning of the industry in this country, reported about seven-eighths of the total quantity and value in 1919.

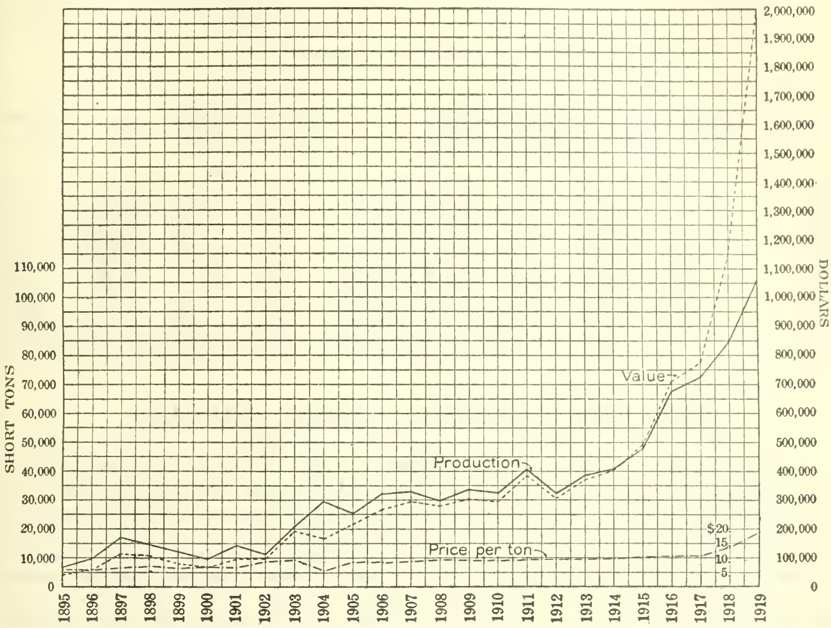

FIGURE 9.—Diagram showing production, total value, and average selling price per ton of fuller's earth, 1895–1919.

IMPORTS.

The imports of fuller's earth entered for consumption in 1919 amounted to 13,873 short tons, valued at $189,711. Imports on the whole have been declining since 1914, but rallied in 1919 and increased 1,266 tons in quantity and $24,176 in value, compared with 1918. The increase was in the wrought or manufactured earth, the unwrought earth decreasing largely in both quantity and value. The average price per ton at the principal markets of the countries from which the material was exported, as taken from the records of the Bureau of Foreign and Domestic Commerce, showed but little change from 1918; the general average increased 54 cents. The wrought earth increased 49 cents and the unwrought earth decreased 14 cents a ton. In 1919 97 per cent of the imported earth was wrought or manufactured; the remainder was unwrought or unmanufactured. Although the imports increased in 1919, compared with 1918, the quantity imported was the smallest recorded in 10 years, 1918 excepted. In 1914 the imports of fuller's earth reached their maximum quantity and value, and those of 1919 were 44 per cent less than the maximum in quantity but only 3 per cent less in value. The rates of duty on imported fuller's earth under the act of October 3, 1913, are, on unwrought and unmanufactured earth, 75 cents a long ton; on wrought or manufactured earth, $1.50 a long ton.

Fuller's earth imported and entered for consumption in the United States, 1910–1919.

Year.	Unwrought or unmanufactured.			Wrought or manufactured.			Total.		
	Quantity (short tons).	Value.	Average price per ton.	Quantity (short tons).	Value.	Average price per ton.	Quantity (short tons).	Value.	Average price per ton.
1910	2,160	$14,399	$6.67	14,427	$118,146	$8.19	16,587	$132,545	$7.99
1911	1,881	10,877	5.78	16,343	132,717	8.12	18,224	143,594	7.88
1912	1,970	11,619	5.90	17,139	133,718	7.80	19,109	145,337	7.61
1913	1,916	12,344	6.44	16,712	133,657	8.00	18,628	146,001	7.84
1914	1,468	9,283	6.32	23,509	185,800	7.90	24,977	195,083	7.81
1915	850	5,176	6.09	18,591	147,317	7.92	19,441	152,493	7.84
1916	1,132	7,742	6.84	15,669	131,922	8.42	16,801	139,664	8.31
1917	1,441	11,718	8.13	15,553	164,699	10.58	16,994	176,417	10.38
1918	900	10,502	11.67	11,707	155,033	13.24	12,607	165,535	13.13
1919	373	4,301	11.53	13,500	185,410	13.73	13,873	189,711	13.67

FULLER'S EARTH IN GREAT BRITAIN.

Owing to the interest in the fuller's earth deposits of Great Britain, which was the chief if not the sole source of supply for the United States prior to 1895, the following extract [2] is reproduced:

Fuller's earth has been worked in Great Britain in a number of places, but at the present time the largest works is situated near Reigate, Surrey, where the large quarry owned by the Fuller's Earth Union (Ltd.) employs upward of 45 men. The quarry of the Surrey Fuller's Earth Co. (Ltd.) at Nutfield, in the same district, is next in importance, and there are three mines in active operation at the present time in the same neighborhood.

The earth is found in strata of Cretaceous age, a section of which, according to Dr. A. H. Cox, shows the following sequence:

	Feet.
Clayey glauconitic sands	20
Mottled bluish calcareous sandstones weathering grey, with interbedded seams of fuller's earth	20–25
Fuller's earth	10

The whole series dips down the hill at an angle of 3° to 5°.

The fuller's earth bed sometimes reaches a thickness of 12 feet, and as a rule the upper portion is oxidized to a brownish color by the action of percolating water, the lower portion being blue.

In Somerset fuller's earth has been worked at a number of places in the vicinity of Bath. It is found overlying the Inferior Oolite and is covered by the Great Oolite. The limestones of the Inferior Oolite contain fuller's earth in the cavities.

The sequence of beds is as follows:

	Feet.
Blue and yellow clay with nodules of industrial marl	30–40
Bad fuller's earth	3–5
Good fuller's earth	2½–3
Clay containing beds of bad fuller's earth and layers of nodulized limestone and indurated marl	100

The two mines now worked are Coombe Hay and Midford. The bureau is informed on good authority that for use as a clarifier the blue Somerset earth

[2] The mineral industry of the British Empire and foreign countries; war period; fuller's earth (1913–1919), pp. 5–8, London, Imperial Mineral Resources Bureau, 1920.

is as good as the Nutfield earth. The Somerset blue earth contains a considerable percentage of calcium carbonate (see analysis below).

Other notable deposits of fuller's earth include those of Woburn Sands, in Bedfordshire. The evidence of borings and sinkings indicates that these are coextensive with the Oxford clay. A superior quality of fuller's earth is procured from the Lower Greensand at Espley Heath, Bedfordshire. The water thrown out by this formation is very soft and pure, and blocks of the earth have on this account been used for the purpose of purifying water in wells.

The following analyses showing the composition of various English fuller's earths are taken from the Geological Survey Memoir on the Jurassic rocks of Great Britain (Memoirs of the Geological Survey, 1894, vol. 4, p. 491).

	1 Nutfield earth.	2 Midford blue earth.	3 Midford yellow earth.	4 Woburn blue earth.	5 Woburn yellow earth.
Silica	58.66	54.0	59.3	60.0	56.9
Alumina	17.33	18.6	20.8	15.2	15.7
Ferric oxide	7.21	3.9	4.2	7.8	9.5
Ferrous oxide	....	.8	....	1.7	.1
Lime	3.17	7.0	2.5	2.7	2.1
Magnesia	3.26	2.3	1.9	3.3	2.7
Soda	} 1.63	.7	.6	.2	.3
Potash		1.8	1.7	.6	.7
Carbonic acid	....	3.4	.3	....	....
Loss on ignition (not including carbonic acid)	8.74	7.2	8.6	8.4	11.9
	100.00	99.7	99.9	99.9	99.9

Analysis 1 is of purified fuller's earth and was made by B. Dyer, July, 1885. Analyses 2, 3, 4, and 5 were made by J. H. Player for the Geological Survey in 1890.

A bed of clay described as fuller's earth occurs at Rhiwlas, Frongoch, near Bala, North Wales. The beds are about 60 feet thick, and samples analyzed by P. G. Sandford show very much the same composition as the earths at Nutfield, referred to above. Their appearance, however, is different. The Surrey earth is greasy to the touch and has a comparatively hard, smooth surface. The Frongoch earth is comparatively soft and friable, dark gray in color, and dissolves in water to the extent of about 4 per cent of its weight. Sandford states that this earth appears to be even better than the Nutfield samples as regards the grease-absorbing properties.

The following are analyses of two samples by Sandford of the Frongoch earth.[3]

	1	2
Insoluble residue	78.27	78.53
Al_2O_3	12.95	2.84
Fe_2O_3	.42	8.50
MnO	Trace.	Trace.
CaO	.82	.90
MgO	1.65	2.30
SO_3	.31	.05
Alkalies	2.02	2.12
Combined H_2O	3.56	4.76
	100.00	100.00
Insoluble residue equals:		
SiO_2	63.25	57.01
Fe_2O_3	8.72	Trace.
Al_2O_3	6.30	21.52
	78.27	78.53

[3] Geol. Mag., 1893, p. 160.

Production of fuller's earth in the United Kingdom,[a] in short tons.

County.	1913	1914	1915	1916	1917	1918	1919
Bedford (from mines)	716	706	661				
Gloucester (from mines)							554
Somerset (from mines)	3,986	4,767	4,956	6,246	4,602	4,237	3,885
Surrey (from quarries)	30,699	36,933	27,197	26,352	26,664	21,848	23,320
	35,401	42,406	32,814	32,598	31,266	26,085	27,759

[a] Figures supplied to the bureau by the chief inspector of mines, Home Office.

Value of imports of fuller's earth to the United Kingdom, 1913–1918.[4]

	£		£
1913	Nil.	1916	4,808
1914	Nil.	1917	2,577
1915	11,649	1918	4,038

Value of exports of fuller's earth from the United Kingdom, 1913–1918.[4]

	£		£
1913	48,882	1916	44,427
1914	56,451	1917	49,949
1915	47,203	1918	53,789

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TALC AND SOAPSTONE.

By J. S. Diller.

TALC.

PRODUCTION.

The depression of the talc business during the early months of 1919 consequent upon the end of the war was followed by its recovery a few months later.

In 1919 the total sales of domestic talc amounted to 168,339 short tons, valued at $1,822,512, a decrease as compared with 1918 of approximately 13 per cent in both quantity and value.

There were 33 producers (3 less than in 1918), of whom 6 were in Vermont, 4 in New York, 5 in North Carolina, 8 in California, 2 each in Georgia, Maryland, Pennsylvania, and Virginia, and 1 each in Massachusetts and Washington. No production was reported in New Jersey.

Vermont ranked first in the quantity of talc sold but second in value. Although the output of talc in Vermont was 16,166 short tons greater than that in New York, its total value was about $85,000 less. The average value per ton of New York talc in 1919 was $12.01; that of Vermont talc was $8.46.

The States showing increased sales in 1919 were North Carolina, 57 per cent; Massachusetts, 13 per cent; Pennsylvania, 7 per cent; and Georgia, 15 per cent. The production decreased 17 per cent in California, 67 per cent in Maryland, 12 per cent in New York, 13 per cent in Vermont, and 65 per cent in Virginia.

Talc mined and sold in the United States in 1918 and 1919, by States.

State.	1918			1919		
	Quantity (short tons).	Value.	Average value per ton.	Quantity (short tons).	Value.	Average value per ton.
California[a]	11,864	$185,775	$15.66	9,837	$147,470	$14.99
New York	71,167	902,100	12.68	62,495	750,765	12.01
North Carolina	1,661	72,348	43.56	2,602	76,158	29.27
Vermont	90,537	775,012	8.56	78,661	665,652	8.46
Virginia	3,265	24,723	7.57	14,744	182,467	12.38
Georgia, Maryland Massachusetts, New Jersey, Pennsylvania, and Washington	14,483	145,002	10.01			
	192,977	2,104,960	10.91	168,339	1,822,512	10.83

[a] Figures for 1918 revised because some material reported from California as soapstone was found on examination of specimens to be talc.

MODE OF OCCURRENCE.

Talc is found in this country in commercial quantities only in areas of regional metamorphic rocks and generally results from the alteration of such magnesian minerals as amphibole and pyroxene. Most of the domestic talc comes from such areas in the mountains of the Atlantic States, but considerable is produced in California and Washington. In New York sheets of tremolite schist inclosed in limestone have been altered to fibrous talc. The deposits of talc that lie in western North Carolina and Georgia are considered to be of the same origin. The talc that occurs in numerous bodies in the Green Mountains of Vermont [1] is regarded as an altered intrusive rock near the composition of enstatite. Of essentially the same origin is the talc of Pennsylvania, Maryland, and Virginia.

Pyrophyllite is a mineral similar to talc and used for the same purposes. It is mined and sold near Glendon, Moore County, N. C.

CONDITION IN WHICH TALC IS MARKETED.

The quality of the talc and the demand for different purposes determines the form in which it shall be prepared for market. About 9 per cent is sold rough (crude) as it comes from the mine; less than 1 per cent is cut into pencils and crayons; and by far the greater portion, nearly 91 per cent, is ground to talc flour. The following table shows the quantity sold during the last two years in each condition.

Talc mined and sold in the United States in 1918 and 1919, by classes.

Condition in which marketed.	1918			1919		
	Quantity (short tons).	Value.	Average value per ton.	Quantity (short tons).	Value.	Average value per ton.
Rough (crude) [a]	14,763	$121,228	$8.21	15,625	$73,437	$4.70
Manufactured into pencils and blanks [b]	945	114,002	120.64	921	147,339	159.98
Ground [c]	177,269	1,869,730	10.55	151,793	1,601,736	10.55
	192,977	2,104,960	10.91	168,339	1,822,512	10.83

[a] Includes some sawed talc in 1918.

[b] Includes slate pencils and metal workers' crayons and blanks used in making acetylene burners and other objects. In 1919 includes also sawed talc.

[c] For foundry facings, filler for paper, paint, and rubber goods, toilet powder, foot ease, lubricators, for dressing skins and leather, etc.

USES.

Talc is one of the most widely used of all nonmetallic minerals. Its uses have recently been noted in detail in a publication of the United States Bureau of Mines.[2]

Talc is employed principally in the manufacture of paper, but largely also for toilet powder, for lubricators, and as a filler for paint. The domestic supply of ground talc is large. Its chemical stability makes it very durable under a wide range of conditions, and new uses are being found for it.

Compact talc of the highest grade is cut into gas tips, pencils, and insulators. The demand for it exceeds the domestic supply, and a considerable quantity is imported. Its chemical composition is given in the following table: [3]

[1] Jacobs, E. C., Vermont State Geologist Rept., 1915–16, p. 273.

[2] Ladoo, R. B., Uses of talc and soapstone: Bur. Mines Monthly Reports of Investigations, May, 1920. See also Chem. and Met. Eng., vol. 23, p. 235, Aug. 11, 1920.

[3] Diller, J. S., Fairchild, J. G., and Larsen, E. S., High-grade talc for gas burners: Econ. Geology, vol. 15, pp. 665–673, December, 1920.

Chemical analyses of talc used for gas burners.

	German.	Indian.	Italian.	French.	North Carolina.	Maryland.	Theoretical composition of $H_2Mg_3Si_4O_{12}$.
SiO_2	61.37	61.00	61.52	61.44	61.35	58.68	63.5
Al_2O_3	1.96	2.12	.84	1.52	4.42	3.75	
Fe_2O_3	None.	None.	None.	None.		(a)	
FeO	1.47	1.74	1.27	.97	1.68	5.52	
MgO	30.23	29.83	31.38	31.55	26.03	26.80	31.7
CaO	None.	None.	None.	None.	.82	None.	
(Na_2O)					.62		
H_2O-, H_2O+	5.36	5.56	5.42	5.19	5.10	5.33	4.8
	100.40	100.25	100.43	100.67	100.02	100.08	100.0

a Indeterminate; chemical analysis gives negative result for Fe_2O_3.

The talc of New York and Vermont is ground and used largely for paper, although some of it goes into paints. During the World War Vermont furnished much ground talc for the army as "footease." In Georgia and western North Carolina much of the talc is cut into crayons for metal workers, and the residue is ground for foundry facing, paint, and paper. Essentially the same uses are made of the talc mined in Pennsylvania and Virginia. In California some of the talc is used as paper filler, and a portion of that produced in southern California is used in the manufacture of pottery.

IMPORTS.

The total imports of talc for consumption in 1919 amounted to 14,602 short tons, an increase of 433 tons, or about 3 per cent, as compared with the imports in 1918, but the value declined. Of the general imports, amounting to 12,973 short tons, about 91 per cent came from Canada. The quantity imported from Canada in 1919 was 333 tons less than in 1918. The imports from Italy and France increased notably in 1919, although the average value of their talc per ton is considerably greater than that of Canada. Brief statements of the occurrence of talc in various foreign countries are given in the report on talc for 1918.

Talc imported for consumption[a] in the United States in 1918 and 1919.[b]

Kind.	1918			1919		
	Quantity (short tons).	Value.	Average value per ton.	Quantity (short tons).	Value.	Average value. per ton.
Crude and unground steatite and French chalk c	1,434	$9,253	$6.45	1,641	$10,105	$6.16
Ground talc, or steatite, cut, powdered, washed, or pulverized d	12,735	251,323	19.73	12,961	248,899	19.20
	14,169	260,576	18.39	14,602	259,004	17.74

a General imports and imports for consumption for any period will differ to the extent that the value of entries for warehouse for the period differs from the value of withdrawals from warehouse for consumption. The term "entry for consumption" is the technical name of the import entry made at the customhouse and implies that the goods have been delivered into the custody of the importer and that the duties have been paid on the dutiable portion. Some of them may be afterwards exported.
b Statistics compiled from records of the Bureau of Foreign and Domestic Commerce, Department of Commerce.
c Duty free.
d Duty of 15 per cent ad valorem

General imports of talc, ground or manufactured, into the United States, 1918 and 1919.[a]

Country.	1918			1919		
	Quantity (short tons).	Value.	Average value per ton.	Quantity (short tons).	Value.	Average value per ton.
Canada	12,185	$214,036	$17.57	11,852	$202,447	$17.08
England						
France	22	491	22.32	163	7,236	44.39
French Africa						
Italy	490	36,575	74.64	958	40,565	42.34
	12,697	251,102	19.78	12,973	250,248	19.29

[a] Statistics compiled from records of the Bureau of Foreign and Domestic Commerce, Department of Commerce.

SOAPSTONE.

Soapstone is a massive rock composed chiefly of impure talc with other minerals and can be readily sawed into slabs for manufacturing table tops, laundry tubs, and other objects. Talc is a soft, weak mineral, and soapstone is therefore so easily broken that a large percentage is lost in its manufacture and transportation. The principal impurities in soapstone are residual pyroxene and amphibole, which have not yet completely altered to talc. Chlorite is also a very common constituent. Where residual pyroxene is abundant it renders the soapstone susceptible of polish and more difficult to saw. However, when polished the rock is much more attractive.

The term soapstone is frequently but less properly applied to high-grade massive talc such as is generally sawed into slabs or cut into pencils or crayons. It should be remembered, however, that fine-grained compact soapstone is occasionally cut for pencils or ground for roofing or other special purposes.

Years ago commercial soapstone was mined in the United States chiefly at Athens and Perkinsville, Vt. Now, however, these old quarries are practically closed, and Virginia is the only soapstone-producing State in the country.

Two producers in California reported the production of soapstone in 1919, but upon examination of specimens it was classified as talc, and is included in the talc production for that State.

There are two producers of soapstone in Virginia—the Virginia Alberene Corporation, at Schuyler, and the Oliver Bros. (Inc.), operating the Phoenix quarries near Arrington, both in Nelson County. The soapstone of Virginia is a more or less altered form of the basic igneous rock peridotite. It appears as irregular discontinuous bodies in Nelson, Albemarle, and Orange counties, which can afford an abundant future supply.

The total sales of soapstone in the United States in 1919 amounted to 16,504 short tons, valued at $530,163, as compared with 15,330 short tons, valued at $576,059, in 1918, an increase of nearly 8 per cent in quantity but a decrease of 8 per cent in value.

MICA.

By Herbert Insley.[1]

PRODUCTION.

The mica produced and sold in the United States in 1919 amounted to 4,031 short tons, valued at $541,651. Of this quantity 1,545,709 pounds, valued at $483,567, was sheet mica; the rest was scrap mica. The quantity of sheet mica produced was a decrease of 6 per cent and the value a decrease of 34 per cent in 1919, compared with 1918. The quantity of scrap mica produced in 1919 was an increase of 42 per cent over that in 1918, but was less than in most recent years. The marked decrease in value of the sheet mica produced in 1919 was probably due not to a decrease in price of the mica but to a relatively larger production of the smaller and less valuable sizes of sheet mica.

Mica produced and sold in the United States, 1910–1919.

Year.	Sheet mica.		Scrap mica.		Total quantity (short tons).	Total value.
	Quantity (pounds).	Value.	Quantity (short tons).	Value.		
1910	2,476,190	$283,832	4,065	$53,265	5,303	$337,097
1911	1,887,201	310,254	3,512	45,550	4,456	355,804
1912	845,483	282,823	3,226	49,073	3,649	331,896
1913	1,700,677	353,517	5,322	82,543	6,172	436,060
1914	556,933	278,540	3,730	51,416	4,008	329,956
1915	553,821	378,259	3,959	50,510	4,236	428,769
1916	865,863	524,485	4,433	69,906	4,866	594,391
1917	1,276,533	753,874	3,429	52,908	4,067	806,782
1918	1,644,200	731,810	2,292	33,130	3,114	764,940
1919	1,545,709	[a] 483,567	3,258	58,084	4,031	[a] 541,651

[a] The figures for value of sheet mica in 1919 are not strictly comparable with those for previous years, as they show the values at the mine's mouth to a greater extent than heretofore.

The table has been compiled from reports made by the producers to the Geological Survey. The figures for sheet mica include cut sheet, uncut sheet, punch, and splittings.

The mica sold in 1919 came from the following States, arranged in order of the quantity of sheet mica sold: North Carolina, New Hampshire, Virginia, Georgia, New Mexico, and Alabama. No sales of sheet mica were reported from South Dakota or Colorado, but they sold small quantities of scrap.

[1] The statistical tables on domestic mica in this report were prepared by Miss B. H. Stoddard, of the United States Geological Survey.

Mica produced and sold by chief producing States, 1914–1919.

Year.	Sheet mica.			Scrap mica.		Total quantity.	Total value.
	Quantity.		Value.	Quantity.	Value.		
North Carolina:	*Pounds.*	*Short tons.*		*Short tons.*		*Short tons.*	
1914	274,121	137	$171,370	1,789	$23,900	1,926	$195,270
1915	281,074	141	266,650	2,840	33,943	2,981	300,593
1916	546,553	273	380,700	2,755	41,880	3,028	422,580
1917	643,476	322	543,207	2,180	34,134	2,502	577,341
1918	941,200	471	460,450	1,046	12,930	1,517	473,380
1919	1,021,306	511	331,498	1,639	32,338	2,150	363,836
New Hampshire:							
1914	133,556	67	39,588	600	8,249	667	47,837
1915	96,685	48	59,414	516	7,557	564	66,971
1916	125,502	63	64,386	724	10,853	787	75,239
1917	472,519	236	159,822	680	9,229	916	169,051
1918	376,900	188	106,200	530	7,040	718	113,240
1919	235,724	118	90,915	738	13,356	856	104,271
Georgia:							
1914	(a)	(a)	(a)	(a)	(a)	(a)	(a)
1915	4,949	2	635			2	635
1916	16,037	8	2,094			8	2,094
1917	30,534	15	12,141	26	1,400	41	13,541
1918	208,200	104	77,300	40	2,750	144	80,050
1919	47,018	24	19,682	51	778	75	20,460
Virginia:							
1914	27,672	14	22,358	153	2,295	167	24,653
1915	10,808	5	9,590	63	828	68	10,418
1916	39,978	20	18,251	182	2,703	202	20,954
1917	68,558	34	22,831	253	2,709	287	25,540
1918	78,500	39	46,200	404	4,280	443	50,480
1919	(a)	(a)	(a)	578	7,811	(a)	(a)
South Dakota:							
1914	27,323	14	1,366	515	6,138	529	7,504
1915	25,992	13	8,230	179	2,684	192	10,914
1916	115,392	58	49,298	527	10,472	585	59,770
1917	37,523	19	5,975	272	5,033	291	11,008
1918	(a)	(a)	(a)	(a)	(a)	(a)	(a)
1919				(a)	(a)	(a)	(a)
Alabama:							
1914	32,900	16	3,964			16	3,964
1915	8,400	4	5,545	23	395	27	5,940
1916	14,132	7	4,955	65	660	72	5,615
1917	18,476	9	3,528	12	280	21	3,808
1918	11,800	6	3,150			6	3,150
1919	(a)	(a)	(a)			(a)	(a)

[a] The figures may not be given, as there were less than three operators.

North Carolina and Virginia were the only States that increased their sales of sheet mica in 1919. North Carolina's quantity was the greatest for that State in the last eight years. The sales of sheet mica in New Hampshire were less in 1919 than in either 1917 or 1918 but more than in 1916. Georgia's sales of sheet mica decreased 77 per cent compared with 1918, but they were greater than in 1916. On the other hand Virginia sold more than twice as much as in 1918. The production of sheet mica has steadily increased in Virginia since 1912, except in 1915, when there was a decrease compared with the preceding year.

Sheet mica produced and sold in the United States in 1918 and 1919.

	1918		1919	
	Quantity (pounds).	Value.	Quantity (pounds).	Value.
Cut	123,900	$382,210	68,255	$144,138
Uncut	333,600	253,840	349,146	240,959
Punch	1,175,500	90,270	1,093,308	84,720
Splittings [a]	11,200	5,490	35,000	13,750
	1,644,200	731,810	1,545,709	483,567

[a] Refers to splittings actually produced in the mining or sheeting of the mica. A small portion of the uncut sheet is manufactured into splittings. These are not given here.

PRICES.

Value of domestic mica sold in the United States, 1910–1919.

Year.	Total value.	Average value per short ton of all mica mined.	Average value per pound of sheet mica.
1910	$337,097	$64	$0.11
1911	355,804	80	.16
1912	331,896	91	.33
1913	436,060	71	.21
1914	329,956	82	.50
1915	428,769	101	.68
1916	594,391	122	.61
1917	806,782	198	.59
1918	764,940	246	.45
1919	541,651	134	.31

This table indicates that the average value per ton of all mica as well as the average value per pound of sheet mica in 1919 decreased, as compared with the corresponding values in 1918. These values are obtained by dividing the value of the mica sold by the quantity. The table below, which is based in part on price quotations submitted by producers, indicates that actual values for different sizes of sheet mica did not decrease but increased slightly. The apparent decrease in value shown by the table above is due to the relatively greater sale of scrap mica and of uncut mica, particularly of the smaller sizes. With the increase in the use of mica in electrical work and the decrease in the use of mica for glazing, there has been a lessened demand for the large sheets and a greater demand for smaller sheets of the first quality.

Average prices per pound paid in the South for rough-trimmed sheet mica of good quality split and sorted to cut the sizes indicated, 1913–1919.

Size (in inches).	1913	1914	1915	1916	1917	1918	1919
Punch	$0.035	$0.03	$0.04	$0.05	$0.055	$0.07	$0.08
1½ by 2	.12	.10	.20	.30	.40	.55	.55
2 by 2	.30	.25	.40	.55	.70	.90	.95
2 by 3	.70	.65	.70	.90	1.10	1.30	1.35
3 by 3	1.15	1.00	1.00	1.35	1.55	1.75	1.85
3 by 4	1.35	1.20	1.25	1.70	1.85	2.05	2.15
3 by 5	1.70	1.50	1.50	1.95	2.15	2.45	2.55
4 by 6	2.25	2.00	2.10	2.85	3.10	3.45	3.50
6 by 6	3.00	2.70	2.80	3.50	3.80	3.90	(a)
6 by 8	4.00	3.60	3.50	5.00	4.70	6.00	(a)
8 by 10	6.00	5.40	5.20	7.50	7.50	8.00	(a)

a Prices exceedingly variable.

This table probably reflects more truly the prices of the second half of 1919 than those of the first half. Prices for corresponding sizes of imported mica, especially for Indian mica, were generally much higher than those quoted above. Indian mica is usually more in demand for high-voltage electrical work, and as a rule more care is given to the grading of Indian mica than of domestic mica.

IMPORTS.[1]

The imports of sheet mica in 1919, including cut mica, uncut mica, and splittings, were valued at $1,488,769. This was slightly less than the value of the imports for 1918 but more than for the previous year. Imports of mica were received from nine countries.

Mica imported for consumption in the United States, 1910–1919.

Year.	Sheet.				Ground.		Total.	
	Unmanufactured.[a]		Cut and splittings.[b]					
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Pounds.		*Pounds.*		*Pounds.*		*Pounds.*	
1910	1,424,618	$460,694	536,905	$263,831	(c)	$1,298	(c)	$725,823
1911	1,087,644	346,477	241,124	155,686	(c)	3,389	(c)	505,552
1912	1,900,500	649,236	88,632	99,737	d 343,824	6,611	(c)	755,584
1913	2,047,571	751,092	(c)	191,926	290,757	4,765	(c)	947,783
1914	360,888	168,591	(c)	456,805	404,848	4,088	(c)	629,484
1915	433,822	240,449	(c)	447,962	344,040	3,858	(c)	692,269
1916	703,832	421,856	(c)	646,080	362,000	3,420	(c)	1,071,356
1917	656,391	414,823	(c)	1,014,181	92,963	1,044	(c)	1,430,048
1918	741,429	658,576	(c)	880,906	11,587	1,647	(c)	1,541,129
1919	723,713	726,532	(c)	762,228	62	9	(c)	1,488,769

a Essentially trimmed sheets.
b Includes the Madras square-shaped uncut sheets.
c Quantity not reported.
d Figures for quantity cover only last six months of 1912.

The import duty on mica as quoted from the tariff act of October 3, 1913, is as follows:

Mica, unmanufactured, valued at not above 15 cents per pound, 4 cents per pound; valued above 15 cents per pound, 25 per centum ad valorem; cut mica, mica splittings, built-up mica, disks, plates, and all manufactures of mica, or of which mica is the component material of chief value, 30 per centum ad valorem; ground mica, 15 per centum ad valorem.

The figures in the following table refer to mica brought to port of entry and not necessarily entered for consumption in the same year. These figures, therefore, are not comparable to those given in the table of mica imported for consumption.

Sources of imported mica, 1915–1919.

Country.	1915	1916	1917	1918	1919
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
India, direct and through England	32	47	53	54	40
Canada	65	50	38	26	14
Brazil	1	3	6	15	26
Argentina	....	(a)	3	4	15
Miscellaneous	2	(a)	(a)	1	5
	100	100	100	100	100

a Less than 1 per cent.

This table shows some very marked changes in the relative rank of the exporting countries. Imports from Argentina and Brazil have been increasing rapidly, and in 1919 larger percentages of the total

[1] The statistical information on imports and exports given in this report has been compiled, as in earlier reports, by J. A. Dorsey, of the United States Geological Survey, from records of the Bureau of Foreign and Domestic Commerce, United States Department of Commerce.

imports came from both Argentina and Brazil than from Canada. Canada's share of the total annual imports of mica into the United States has been steadily decreasing. Apparently the combined imports from Argentina and Brazil may more than equal the imports from all the other countries in a few years. Imports of mica were also received from Mexico, Guatemala, China, and South Africa.

EXPORTS.

The total value of the mica exported in 1919 was much greater than for any previous year. Mica was exported to 46 countries, but more than 75 per cent of it went to Canada, England, Mexico, Norway, Brazil, France, and Australia in the order named.

Mica exported from the United States, 1910–1919.

Year.	Unmanufactured.		Manufactured.	Total value.
	Quantity (pounds).	Value.	Value.	
1910	(a)	(a)	(a)	$20,543
1911	415,862	$15,649	$20,267	35,916
1912	356,601	14,936	25,876	40,812
1913	298,711	14,175	48,009	62,184
1914	467,451	23,145	27,751	50,896
1915	54,183	5,118	33,915	39,033
1916	63,168	4,544	74,127	78,671
1917	[b] 11,771	3,073	71,412	74,485
1918	(a)	(a)	(a)	74,529
1919	(a)	(a)	(a)	109,348

[a] Not reported. [b] For six months, January to June.

NATURE AND OCCURRENCE.

Although there are many varieties of mica, only three have been widely used in the industries—muscovite, phlogopite, and lepidolite. Lepidolite is valuable not because of its physical properties but because lithia salts can be extracted from it. Muscovite and phlogopite are valuable because of their unusual combination of physical properties—cleavage, flexibility, elasticity, transparency in thin sheets, nonconductivity of heat and electricity, brilliancy of cleavage flakes, and softness. Other micas—roscoelite, biotite, and mariposite—have been mined in the United States. Roscoelite is a source of vanadium. Ground and roasted biotite has been used as a decorative material. Mariposite, a fine-grained greenish mica, is also used for decorative purposes and as a pigment in paint. Clinochlore, although a member of the chlorite group and not a true mica, is used when ground for the same purposes as ground muscovite mica.

Muscovite is a silicate of aluminum and potassium; phlogopite is a silicate of magnesium, aluminum, and potassium. In thin sheets both are transparent when free from impurities, but muscovite is light in color, whereas phlogopite is generally much darker. In sheets one-sixteenth of an inch or more in thickness muscovite may be colorless, gray, yellow, inclining to amber, red, brown, or green. In sheets less than one-sixteenth of an inch in thickness phlogopite may be yellow or brown and much of it has a coppery appearance.

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Except the phlogopite from Canada, nearly all the mica produced in the world is muscovite. Although muscovite is found in several varieties of igneous rocks, in many metamorphic schists and gneisses, and also in sandstones and shales, it occurs in sheets large enough to be of commercial value only in pegmatite dikes. Pegmatite is a rock similar to granite in chemical and mineral composition, but it has a more variable and a coarser texture. It may occur in large irregular masses, although usually it has a lenticular or sheetlike form. Single minerals are commonly much larger in pegmatite than in granite, even occurring in masses weighing many pounds. It is this occurrence in large masses that makes the muscovite found in pegmatite particularly valuable. Usually the masses of mica are scattered irregularly throughout the pegmatite, although in some deposits they are grouped along one or both walls of the pegmatite or form a band connected by small stringers or leads.

DISTRIBUTION.

Deposits of mica of economic value may be found in small quantities in many parts of the world, but India, the United States, and Canada now produce 95 per cent of the world's mica. Brazil, Argentina, the British East Africa Protectorate, and Australia are rapidly becoming important producers of mica. Guatemala, the Union of South Africa, Madagascar, Nyasaland, China, and Ceylon have deposits which will undoubtedly be exploited in the near future. Short descriptions of the foreign occurrences of mica are given in the chapter on mica by Waldemar T. Schaller in Mineral Resources of the United States, 1918, Part II, pages 670–693.

In the United States North Carolina and New Hampshire are the principal mica producers.

Pegmatite dikes in which mica of commercial importance may be found occur in the eastern Appalachian region from Alabama to New York and New England; in northern Wisconsin, Michigan, and Minnesota, and in the region including corners of Minnesota and Iowa and part of South Dakota; in the Rocky Mountain region from Texas to Montana; and in many smaller and more or less isolated areas in nearly all the States west of the Rocky Mountains. The following States contain mica deposits which are now being worked or which have been worked in recent years: North Carolina, Georgia, Virginia, South Carolina, Alabama, New Hampshire, Maine, South Dakota, Idaho, New Mexico, Colorado, and Texas.

The Appalachian region has usually produced the best quality of sheet mica, although good deposits of sheet mica are known in South Dakota and Idaho. In general, however, a greater percentage of scrap mica is taken from the western deposits than from the eastern. It is the relatively large quantity of good sheet mica in the eastern deposits that has made the mining of mica more profitable there than in the West. Most mica mines must yield good sheet mica to make the mining profitable; it has rarely been found possible to work a mica deposit for scrap alone. Mica, to be of value as sheet, must yield a rectangle at least 1½ by 2 inches, which must split readily and be free from cracks, rulings, corrugations, and wavy structure and must be reasonably free from stains and inclusions. It is safe to say that mica mining should be attempted only where first quality mica yielding rectangles larger than 1½ by 2 inches can be obtained.

PHYSICAL PROPERTIES.

The properties which make muscovite and phlogopite practically indispensable for certain industries are perfect cleavage, flexibility, elasticity, transparency, and nonconductivity of heat and electricity.

Lack of perfect cleavage is a common defect in large mica sheets and one that makes the sheet useless for most purposes. Imperfection of cleavage is due to many causes—cleavage pieces may interlock or run together; planes of weakness parallel to certain prominent crystallographic directions may develop in the mica crystal; gliding planes may be formed; the sheet of mica may be wavy, corrugated, or buckled. Mica sheets with such structural defects are called tangle-sheet, ribbon, wedge, "A," reaved, fishbone, horsetail, ruled, wavy, corrugated, or buckled mica.

Specks and stains may seriously impair the value of sheet mica for certain purposes. Specks are usually some form of iron oxide and are often arranged in lines parallel to a prominent crystallographic direction. Such specks when present in large numbers lower the mica's resistance to puncture by the electric current and thus make it useless for electric insulation. "Clay-stained" mica contains films of clay or dirt which lie between the sheets. These stains can often be removed by splitting off the thin layer of mica that carries the stain. According to the quantity of stains and specks present mica is classified as clear, slightly specked or stained, heavily specked or stained, and stained.

Color is of importance in sheet mica that is to be used for glazing or in optical instruments, but color that is not due to the presence of mineral impurities does not noticeably affect the value of sheet mica for electrical work. Color has been used as a means of distinguishing mica from certain localities. Mica from Bengal is generally known as "ruby" mica, that from Madras as "brown" mica, and phlogopite from Canada is commonly called "amber" mica. Mica sheets from several different localities may have the same color, and consequently such color names are not significant as to the source.

Although the difference in hardness of various kinds of mica is not very noticeable, slight differences are of importance in the industries. The following scheme of hardness has been devised. No. 1 is the softest and No. 7 the hardest:

1. Amber, Canadian.
    (*a*) Soft, clear, transparent.
    (*b*) Medium, hard, streaked.
    (*c*) Hard, opaque.
2. White, Indian.
3. Soft green, Madras.
4. Ruby, Indian.
5. Hard green and brown, Madras.
6. Green, brown, and yellow, East African.
7. Green, United States.

FORMS AND CLASSIFICATION.

Blocks of mica as they come from the mine, with the adhering rock removed, are known as mine-run mica. These mica blocks are sometimes called "books." Mine-run, block mica, or book mica is often sold as such, without further preparation, by miners in the West and New Hampshire, but rarely by miners in the South.

Uncut mica is mica that has gone through the first stages of its preparation for use. Uncut mica is usually classified according to the extent of its trimming. "Thumb-trimmed" mica is mica from which the imperfect parts and foreign material have been removed by the fingers. "Knife-trimmed" mica has had additional imperfect parts removed with a knife. Mica as imported from India is often called "sickle-trimmed" mica. This is more closely trimmed than domestic knife-trimmed and rarely contains cracks or flaws. It approaches a rounded rectangle in shape, and the edges are beveled. "Shear-trimmed" mica from Madras is cut into roughly square patterns and the edges are cut perpendicular to the flat surface of the sheet instead of being beveled.

The basis of classification by size of rough-trimmed uncut mica in the United States depends on the dimensions of the clear and usable circle or rectangle which can be cut from the rough-trimmed piece of mica. Punch mica will not yield a clear rectangle as much as 1½ by 2 inches but should yield a round disk of usable mica 1½ inches in diameter if stained and 1¼ inches in diameter if clear. Circle mica will yield a somewhat larger circle and is considered as lying between punch and the smallest rectangular piece. Circle mica should contain a usable disk nearly 2 inches in diameter. The smallest rectangular uncut mica is 1½ by 2 inches. The next size is 2 by 2 inches, followed by 2 by 3, 3 by 3, 3 by 4, 3 by 5, 4 by 6, 6 by 6, 6 by 8, 8 by 10, and larger. A piece of uncut, rough-trimmed mica, classified as 2 by 3, should be large enough to yield a clear and usable rectangle 2 by 3 inches, the actual dimensions of the piece of mica itself being much larger, often nearly double the dimensions given. The dimensions of a well-trimmed piece of mica should not in general be more than 1½ times the dimensions of the contained usable rectangle. A 2 by 3 trimmed mica sheet should therefore not measure much more than 3 by 4½ inches.

Sheet mica is sometimes classified according to the uses to which it is put. Condenser mica and phonograph mica are of the highest quality. Mica for these uses must be free from all imperfections and must split evenly and cleanly. It is necessary to obtain films as thin as one-thousandth of an inch for use in condensers, and each film must be able to resist high voltages.

"Stove mica" is essentially clear and has only a few spots or stains.

"Electric mica," so called, is slightly stained or spotted and can not be used for high-voltage work but is good enough to be used in general electric insulation.

"Splittings" are thin films that are split from the smaller sheet mica and used in the manufacture of built-up mica board. They are not necessarily of first quality and are irregular in shape and outline. The splittings are reassembled so as to form a large plate of uniform thickness, and shellac or some other binder is spread evenly over the splittings. Heat and high pressure mold the splittings into a finished mica board. Special trade names such as "micanite," "micabeston," and "micabond" are given to the built-up mica boards manufactured by different companies.

Scrap mica is the waste mica that results from the trimming and cutting of sheets as well as the mica from the mines that has no value as sheet. Scrap mica is separated from the waste rock and ground to different sizes according to the use to which it is to be put.

USES.

Before electricity became an important source of industrial power, sheet mica was used chiefly as a glazing material. Now, however, 90 per cent of the sheet mica consumed in the United States is used for electric insulation. Films of mica are used extensively in condensers for magnetos and wireless apparatus, and sheets, tubes, and washers of mica are used in dynamos and other electric appliances.

As a glazing material mica sheets are used in stove doors, furnace peepholes, divers' helmets, and other apparatus where a transparent covering is needed that retards heat waves or is not easily broken.

Ground mica is used for decorative purposes, as a lubricant, an insulator, and a filler. Large quantities are used by manufacturers of wall paper to give luster and brightness to the paper. It is used in fancy paints and ornamental tiles and in concrete to imitate the texture of granite. Much of the imitation snow used in Christmas festivals is ground mica. Ground mica is used in the journals of railroad cars to prevent hot boxes, in pipe and boiler coverings, and in fireproof paints. It is used in rubber goods as a filler and a preservative. Ground mica is an essential component of some patent roofing materials and is used in making molded mica (ground mica mixed with shellac) for electric insulation; it is used in calico printing; as an absorbent for nitroglycerin in the manufacture of "mica powder"; in annealing steel; as a lubricant for wooden bearings, or, mixed with oil, as a lubricant for metal bearings; in tire powder; and for various other products. Roofing papers are often coated with coarsely ground mica, known as "bran," to prevent their sticking when rolled for shipment.

ASPHALT AND RELATED BITUMENS.

By K. W. Cottrell.[1]

INTRODUCTION.

The figures showing quantity and value of output in this report are based on data obtained from producers early in 1920 in a canvass for a preliminary statement and on a few reports obtained later from the Bureau of the Census. It is not possible at this time to distribute the asphalt properly by uses. A table showing the distribution of manufactured asphalt by uses in 1919 will be made when the reports for 1919 have been received from the Bureau of the Census and will be included in the report for 1920.

PRODUCTION AND SALES.

The quantity of native asphalt and related bitumens produced and sold in the United States in 1919 was 88,281 short tons, valued at $682,989. This was an increase of 47 per cent in quantity over 1918, but a decrease of about 13 per cent in value.

The sales of manufactured asphalt obtained from domestic petroleum amounted to 614,692 short tons, valued at $8,727,372, an average value of $14.20 a ton. Compared with 1918, these figures indicate an increase of less than 2 per cent in quantity and a decrease of less than 1 per cent in value. The sales of asphalt manufactured in the United States from Mexican petroleum amounted in 1919 to 674,876 short tons, valued at $7,711,510, an average value of $11.43 a ton, and showed an increase of 13 per cent in quantity but a decrease of 18 per cent in value from 1918.

The number of companies reporting the production of asphalt and related bitumens in 1919 was 45. Of these, 21 manufactured asphalt exclusively from petroleum of domestic origin, 9 used petroleum of Mexican origin, and 2 used petroleum from both sources.

The accompanying tables show the quantity and value of native asphalt and related bitumens sold in the United States by varieties and by States for recent years, and also the output of manufactured asphalt.

Bituminous rock, reported by eight operators (three each in California and Oklahoma, one each in Kentucky and Texas), more than doubled in 1919 the output of 1918.

In order that the confidential returns of operators may not be disclosed, the quantity and value of the following bitumens are combined for 1919: Elaterite reported by one operator from Carbon County, Utah; gilsonite reported by two operators from Uinta County, Utah; grahamite reported by one operator from Pushmataha

[1] Statistics of imports and exports compiled by J. A. Dorsey, of the United States Geological Survey, from records of the Bureau of Foreign and Domestic Commerce.

County, Okla.; and grahamite and impsonite reported in equal quantities by one operator in Illinois.

Asphalt sold at mines and refineries in the United States, 1913–1919, by varieties.

Variety.	1913		1914		1915		1916	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
Petroleum asphalt [a]	436,586	$4,531,657	360,683	$3,016,969	664,503	$4,715,583	688,334	$6,178,851
Bituminous rock	57,549	173,764	51,071	162,622	44,329	157,083	63,172	197,286
Gilsonite	35,055 (Gilsonite, Wurtzilite, Grahamite)	576,949 (Gilsonite, Wurtzilite, Grahamite)	19,148 (Gilsonite, Wurtzilite)	405,966	20,559	275,252	26,870	629,640
Wurtzilite							4	3,800
Grahamite			9,669	73,535	10,863	94,155	8,431	92,555
	529,190	5,282,370	440,571	3,659,092	740,254	5,242,073	786,811	7,102,132

Variety.	1917		1918		1919	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
Petroleum asphalt [a]	701,809	$7,734,691	[b] 604,723	[b] $8,796,541	614,692	$8,727,372
Bituminous rock	41,919	136,255	25,346	92,238	53,589	262,309
Gilsonite	[c] 35,049	[c] 532,989	30,848	606,639	(d)	(d)
Ozokerite	18	1,000	37	45,399		
Other bituminous substances [e]	4,618	103,180	3,803	36,532	34,692	420,680
	783,413	8,508,115	664,757	9,577,349	702,973	9,410,361

[a] Includes asphalt produced from domestic petroleum only.
[b] Revised figures.
[c] Includes wurtzilite.
[d] Included under "Other bituminous substances."
[e] 1917: Grahamite and maltha; 1918: Grahamite and wurtzilite; 1919: Elaterite, gilsonite, grahamite, and impsonite.

NATIVE ASPHALT.

Native asphalt and related bitumens sold in the United States, 1910–1919.

Year.	Quantity (short tons).	Value.	Year.	Quantity (short tons).	Value.
1910	98,893	$854,234	1915	75,751	$526,490
1911	87,074	817,250	1916	98,477	923,281
1912	95,166	865,225	1917	81,604	773,424
1913	92,604	750,713	1918	60,034	780,808
1914	79,888	642,123	1919	88,281	682,989

Native asphalt and related bitumens sold in the United States, 1913–1919, by States.

State.	1913		1914		1915		1916	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
California	27,870	$69,825	28,186	$77,810	17,794	$61,485	18,135	$45,102
Oklahoma	16,459	91,416	9,669	73,535	16,907	118,351	(a)	(a)
Utah	30,810	529,341	23,098	424,480	b21,739	b281,302	26,874	633,440
Other States c	17,465	60,131	18,935	66,298	19,311	65,352	53,468	244,739
	92,604	750,713	79,888	642,123	75,751	526,490	98,477	923,281

State.	1917		1918		1919	
California	6,009	$19,447	3,260	$12,516	d3,614	d$15,037
Oklahoma	(a)	(a)	(a)	(a)	e4,323	e18,187
Utah	35,192	569,325	31,072	663,258	f33,992	f406,610
Other States c	40,403	184,652	25,702	105,034	g46,352	g243,155
	81,604	773,424	60,034	780,808	88,281	682,989

a Included under "Other States."
b Includes Colorado.
c 1913–1915: Kentucky and Texas; 1916 and 1917: Colorado, Kentucky, Oklahoma, and Texas; 1918: Kentucky, Oklahoma, and Texas; 1919: Illinois, Kentucky, and Texas.
d Bituminous rock.
e Bituminous rock and grahamite.
f Elaterite and gilsonite.
g Bituminous rock, grahamite, and impsonite.

MANUFACTURED ASPHALT.

FROM DOMESTIC PETROLEUM.

In the production of asphalt manufactured from domestic petroleum in 1919 Oklahoma, with only two operators reporting, ranked first in quantity, displacing California, but was third in value; California, with ten operators reporting, ranked second in quantity but first in value. Texas, with four operators, ranked third in quantity but second in value. These three States reported more than 80 per cent of the total quantity and value.

Asphalt manufactured from domestic petroleum and sold at refineries, 1910–1919.

Year.	Quantity (short tons).	Value.	Average price per ton.	Year.	Quantity (short tons).	Value.	Average price per ton.
1910	161,187	$2,225,833	$13.81	1915	664,503	$4,715,583	$7.10
1911	277,192	3,173,859	11.45	1916	688,334	6,178,851	8.98
1912	354,344	3,755,506	10.60	1917	701,809	7,734,691	11.02
1913	436,586	4,531,657	10.38	1918	a604,723	a8,796,541	14.55
1914	360,683	3,016,969	8.36	1919	614,692	8,727,372	14.20

a Revised figures.

FROM MEXICAN PETROLEUM.

The quantity of asphalt manufactured in the United States from Mexican petroleum increased steadily from 1913 to 1917. In 1918 it decreased, but in 1919 it increased again and exceeded the quantity produced in any previous year. The value increased from 1913 to 1918 but decreased about 18 per cent in 1919. The average price per ton has fluctuated considerably since 1913, as is shown in the following table:

Asphalt manufactured in the United States from Mexican petroleum and sold at refineries, 1913–1919.

Year.	Quantity (short tons).	Value.	Average price per ton.
1913	114,437	$1,743,749	$15.24
1914	313,787	4,131,153	13.17
1915	388,318	3,730,436	9.61
1916	572,387	6,018,851	10.52
1917	645,613	7,441,813	11.53
1918	[a] 597,697	[a] 9,417,818	15.76
1919	674,876	7,711,510	11.43

[a] Revised figures.

IMPORTS.

NATIVE ASPHALT.

Native asphalt and bituminous rock imported for consumption in the United States, 1915–1919.

Year.	Crude.		Bituminous limestone.		Total.	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
1915	135,276	$661,356	2,976	$19,001	138,252	$680,357
1916	147,383	732,917	330	1,795	147,713	734,712
1917	187,473	978,087	413	15,028	187,886	993,115
1918	114,686	624,967	39	2,528	114,725	627,495
1919	104,913	609,923	735	5,576	105,648	615,499

Native asphalt and bituminous rock imported into the United States, 1917–1919, by countries.

[General imports.]

Source.	1917		1918		1919	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
North America:						
Canada	99	$1,889	221	$4,112	38	$1,088
Mexico	5,792	94,594	12,968	96,125	6,566	31,587
West Indies:						
British:						
Barbados	57	4,855	55	5,047	31	3,069
Trinidad and Tobago	110,273	553,969	58,791	327,091	51,062	350,431
Other British	6,453	24,568				
Dutch					(a)	10
Cuba	4,715	33,552	56	1,783	636	17,270
South America:						
Colombia	134	5,271			6	169
Venezuela	58,425	263,600	42,587	192,855	47,309	211,875
Europe:						
England	1,998	11,370	47	482		
	187,946	993,668	114,725	627,495	105,648	615,499

[a] Figures for quantity not available.

Native asphalt and bituminous rock imported into the United States in 1919, by countries and districts.

Source.	District of entry.	Quantity (short tons).	Value.
Barbados	New York	31	$3,069
Canada	Buffalo	17	493
	Chicago	8	200
	Michigan		4
	St. Louis		56
	Vermont	13	335
		38	1,088
Colombia	New York	6	169
Cuba	do	636	17,270
Dutch West Indies	do		10
Mexico	Galveston	5,137	22,836
	New York		1
	Rhode Island	3	45
	Sabine	1,426	8,705
		6,566	31,587
Trinidad and Tobago	Mobile	2,718	20,633
	New York	48,344	329,798
		51,062	350,431
Venezuela	do	47,309	211,875
		105,648	615,499

OZOKERITE.

The imports of ozokerite and other mineral waxes in 1919 were more than double those of 1918 in quantity and increased 208 per cent in value. The quantity exceeded the imports of 1916 by only 25 per cent, but the value increased 132 per cent over the value for that year.

Ozokerite and other mineral waxes imported for consumption in the United States, 1913–1919.

Year.	Quantity (pounds).	Value.	Average price per pound.
1913	7,141,514	$549,992	$0.077
1914	8,191,529	498,695	.061
1915	2,795,256	210,019	.075
1916	3,007,676	196,185	.065
1917	899,405	90,510	.101
1918	1,809,459	147,805	.082
1919	3,748,080	454,840	.121

ICHTHYOL.

Trade conditions prevailing from 1914 to 1918 rendered it almost impossible to obtain ichthyol, which before the World War was imported from Austria, the source of the world's supply. It is reported that the last ichthyol to enter the United States was a small quantity brought over by the submersible *Deutschland* and commanded the exorbitant prices of $30 and $35 a pound. During 1919 the prices for ichthyol and ichthyol substitutes were nominal, ranging from $0.50 to $2 a pound.

The following table, compiled from the records of the Bureau of Foreign and Domestic Commerce, shows the quantity and value of ichthyol and ichthyol substitutes imported for consumption in the United States from 1914 to 1919. Although the quantity decreased more than 50 per cent in 1919, the value remained about the same, decreasing only 1 per cent from that of 1918.

Ichthyol and ichthyol substitutes imported for consumption in the United States, 1914–1919.

Year.	Quantity (pounds).	Value.	Year.	Quantity (pounds).	Value.
1914	61,416	$86,415	1917	58,397	$36,232
1915	24,921	28,560	1918	65,752	39,452
1916	116,738	93,762	1919	30,976	38,975

The Geological Survey has published nothing on the production of ichthyol in this country. It is understood that the Meadows Chemical Corporation, 52 Vanderbilt Avenue, New York City (formerly the Meadows Oil & Chemical Corporation), began producing an ichthyol-like substance in 1920 from marine fossiliferous rocks quarried near Burnet, Tex. In United States Geological Survey Bulletin 450, "Mineral resources of the Llano-Burnet region, Tex.," published in 1911, is the following statement regarding oil at this locality: "A small oil seepage in a spring near the town of Burnet has deposited at the surface asphaltic material in the cracks and interstices of the neighboring limestones. In Post Mountain also a little oily residue is found about 20 feet above the base of the Cretaceous." It is at this locality that asphaltic limestone is being quarried as the source of a product being marketed under the name "Meadows ammonium ichthyolate." The limestone stratum varies in thickness up to 20 feet, is nearly horizontal, and is removed by stripping the overburden and quarrying in open cuts. The samples of this rock furnished to the Geological Survey by the Meadows Chemical Corporation range from limestone with a few shell casts to a very cellular rock formerly composed of shells cemented together with a modicum of lime. The shells have been dissolved out and the rock is a limestone skeleton surrounding cavities which are the casts of gastropods and lamellibranchs. These cavities are lined with a black asphaltic material, some of which is soft and sticky, some dry and hard. A light oil is distilled from this limestone in an experimental plant near Burnet and shipped to the laboratory at Durant, Rockland County, N. Y., where the drug is prepared. The company began operations at Burnet in April, 1920, and opened its plant at Durant in July, 1920.

EXPORTS.

According to the records of the Bureau of Foreign and Domestic Commerce, the export trade of the United States in unmanufactured asphalt increased more than 80 per cent in quantity and more than 90 per cent in value, compared with that of 1918; the value of manufactured asphalt exported increased about 5 per cent, and the increase in the total value of asphalt exported was about 48 per cent.

Asphalt exported from the United States, 1915–1919.

Year.	Unmanufactured.		Manufactures of (value).	Total value.
	Quantity (short tons).	Value.		
1915	42,787	$735,952	$438,685	$1,174,637
1916	40,816	759,769	494,895	1,254,664
1917	30,107	587,256	585,472	1,172,728
1918	22,108	577,654	577,936	1,155,590
1919	40,208	1,103,930	606,918	1,710,848

Asphalt exported from the United States in 1919, by countries.

Destination.	Unmanufactured.		Manufactures of (value).
	Quantity (short tons).	Value.	
North America:			
British Honduras			$15
Canada	14,039	$267,713	188,122
Central America:			
Costa Rica			97
Guatemala			25
Honduras			3
Nicaragua			605
Panama	11	508	13,873
Salvador			81
Mexico	99	2,059	5,800
Newfoundland			3,346
West Indies:			
British:			
Barbados			561
Trinidad and Tobago			357
Other British			148
Cuba	2,060	65,601	24,670
Dominican Republic	2	252	2,454
French			14
Haiti	22	800	
Virgin Islands of the United States			38
South America:			
Argentina	939	27,930	887
Bolivia	104	3,450	
Brazil	1,169	39,624	1,927
Chile	475	14,285	8,225
Colombia			1,448
Ecuador	26	400	8,275
Guiana:			
British	3	88	7
Dutch	2	75	
Peru	157	3,600	55
Uruguay			399
Venezuela	1	88	376
Europe:			
Belgium	531	17,944	3,068
Denmark	945	24,986	3,680
France	764	30,583	32,237
Germany	184	6,249	
Greece			18
Iceland and Faroe Islands			2,085
Italy	210	8,365	8
Netherlands	171	6,057	
Norway	67	2,510	40
Spain	2,296	122,250	22,592
Sweden	131	11,251	1,327
Switzerland	6	267	1,082
United Kingdom:			
England	10,643	319,700	93,410
Scotland	45	2,294	900

Asphalt exported from the United States in 1919, by countries—Continued.

Destination.	Unmanufactured.		Manufactures of (value).
	Quantity (short tons).	Value.	
Asia:			
China	561	$13,092	$50,410
Kwantung, leased territory			292
East Indies:			
British:			
India	953	17,336	18,345
Straits Settlements	13	420	2,044
Other British	10	287	50
Dutch	86	2,451	4,495
French	8	280	988
Hongkong	1,230	33,805	20,994
Japan	661	25,856	26,799
Siam			1,887
Africa:			
British:			
West			83
South			82
French			116
Oceania:			
British:			
Australia	794	15,429	29,608
New Zealand	705	13,898	10,786
German			6
Philippine Islands	85	2,147	17,678
	40,208	1,103,930	606,918

CONSUMPTION.

For reasons well understood by the industry it is impossible to arrive at an exact statement of asphaltic material consumed during 1919, but if from the sum of the quantity produced from domestic deposits and manufactured from domestic and Mexican petroleum plus the quantity imported is taken the quantity exported in a given year the result reached is approximately correct and is shown by the following table for the years 1915 to 1919, inclusive:

Asphaltic material consumed in the United States, 1915–1919.

Year	Short tons.
1915	1,225,447
1916	1,467,657
1917	1,587,284
1918	1,356,009
1919	1,445,178

ASPHALT INDUSTRY IN PRINCIPAL COUNTRIES.

The following table shows the output of natural asphalt (all forms) in the principal producing countries, by calendar years, except as otherwise stated, from 1906 to 1919, inclusive, as far as reliable statistics are available. The values for recent years have been calculated at the value of the pure metal content of the coin used in the country concerned, as declared by the United States Treasury—franc, lira, and peseta, 19.3 cents; mark, 23.82 cents; pound sterling, $4.8665—but, as is well known, exchange rates have fluctuated so greatly that the values shown in dollars should be considered with this fluctuation kept well in mind.

Native asphalt, related bitumens, and bituminous rock produced in principal producing countries, 1906–1919.

Year.	Austria-Hungary.			Cuba.			France.			Germany.		
	Quantity.			Quantity.			Quantity.			Quantity.		
	Metric tons.	Equivalent in short tons.	Value.	Metric tons.	Equivalent in short tons.	Value.	Metric tons.	Equivalent in short tons.	Value.	Metric tons.	Equivalent in short tons.	Value.
1906....	9,646	10,633	$778,781	5,186	5,717	$26,605	196,321	216,405	$345,599	117,380	129,388	$268,631
1907....	10,283	11,335	727,892	5,054	5,571	37,594	177,026	195,136	330,065	126,614	139,567	264,494
1908....	11,103	12,239	768,162	6,237	6,875	31,574	171,111	188,616	264,188	88,985	98,088	188,334
1909....	10,142	11,180	663,246	10,795	11,900	48,246	169,008	186,298	269,161	77,516	85,446	176,897
1910....	8,228	9,070	702,022	2,105	2,320	13,685	169,722	187,085	277,210	81,186	89,491	152,565
1911....	7,541	8,312	652,603	3,300	3,638	21,928	169,651	187,008	261,743	81,880	90,256	154,938
1912....	10,377	11,439	664,778	15,658	17,260	87,500	311,763	343,659	393,994	96,117	105,950	200,743
1913....	[a] 30,258	[a] 33,354	(b)	[c] 1,587	[c] 1,749	[c] 30,935	41,471	45,714	129,809	105,500	116,294	188,654
1914....	[a] 19,313	[a] 21,289	(b)	[c] 879	[c] 969	[c] 19,491	35,555	39,193	(b)	81,800	90,169	145,302
1915....	[a] 400	[a] 441	(b)	[c] 441	[c] 486	[c] 11,247	11,707	12,905	(b)	32,400	35,715	62,647
1916....	(b)	(b)	(b)	[c] 489	[c] 539	[c] 12,486	14,381	15,852	(b)	(b)	(b)	(b)
1917....	(b)	(b)	(b)	[c] 473	[c] 521	[c] 13,191	12,068	13,303	(b)	12,321	13,582	(b)
1918....	(b)	(b)	(b)	(b)	(b)	(b)	10,104	11,138	(b)	(b)	(b)	(b)
1919....	(b)	(b)	(b)	(b)	(b)	(b)	17,812	19,634	225,772	(b)	(b)	(b)

Year.	Italy.			Japan.			Mexico.			Russia.		
	Quantity.			Quantity.			Quantity.			Quantity.		
	Metric tons.	Equivalent in short tons.	Value.	Metric tons.	Equivalent in short tons.	Value.	Metric tons.	Equivalent in short tons.	Value.	Metric tons.	Equivalent in short tons.	Value.
1906....	131,363	144,802	$349,926	39	43	$3,572	1,389	1,531	$17,174	11,355	12,517	$110,294
1907....	161,596	178,127	442,014	585	644	5,436	4,486	4,945	182,265	12,806	14,116	101,705
1908....	134,657	148,433	368,306	2,404	2,650	25,564	5,272	5,811	330,903	22,644	24,961	491,302
1909....	111,911	123,361	305,159	4,186	4,614	45,205	5,471	6,031	106,484	2,418	2,665	4,599
1910....	162,625	179,261	452,911	477	526	29,004	2,849	3,140	39,681	24,988	27,544	176,518
1911....	188,629	207,926	591,550	1,260	1,389	13,728	8,085	8,912	125,322	(b)	(b)	(b)
1912....	181,947	200,560	581,383	2,902	3,199	32,518	30,491	33,611	462,230	(b)	(b)	(b)
1913....	171,097	188,602	521,398	2,260	2,491	27,242	(b)	(b)	(b)	(b)	(b)	(b)
1914....	119,853	132,115	400,164	2,007	2,212	25,836	(b)	(b)	(b)	(b)	(b)	(b)
1915....	47,650	52,525	184,621	1,975	2,177	(b)	388,318	428,047	3,733,000	(b)	(b)	(b)
1916....	16,829	18,551	68,301	2,302	2,538	(b)	(b)	(b)	(b)	(b)	(b)	(b)
1917....	8,645	9,529	38,965	3,873	4,269	(b)	(b)	(b)	(b)	(b)	(b)	(b)
1918....	22,309	24,591	128,134	2,997	3,304	52,210	(b)	(b)	(b)	(b)	(b)	(b)
1919....	78,000	85,980	587,563	6,656	7,337	173,928	(b)	(b)	(b)	(b)	(b)	(b)

[a] Austria only. Figures for Hungary not available.
[b] Figures not available.
[c] Exports. Figures for production not available.

Native asphalt, related bitumens, and bituminous rock produced in principal producing countries, 1906–1919—Continued.

Year.	Spain.			Trinidad.[a]			United States.			Venezuela (exports).[b]		
	Quantity.		Value.	Quantity.		Value.	Quantity.		Value.	Quantity.		Value.
	Metric tons.	Equivalent in short tons.		Metric tons.	Equivalent in short tons.		Metric tons.	Equivalent in short tons.		Metric tons.	Equivalent in short tons.	
1906....	7,790	8,587	$17,130	136,417	150,373	$832,964	66,280	73,062	$674,934	22,483	24,783	$98,250
1907....	8,216	9,057	16,001	155,375	171,271	832,274	77,938	85,913	928,381	38,240	42,153	167,938
1908....	12,370	13,635	24,084	130,230	143,552	403,023	71,273	78,565	517,485	32,045	35,324	141,912
1909....	5,282	5,822	10,282	144,621	159,416	459,446	89,866	99,061	572,846	37,890	41,767	180,061
1910....	6,416	7,072	18,308	142,538	157,120	421,419	89,714	98,893	854,234	32,402	35,717	151,000
1911....	[c] 3,741	[c] 4,124	[c] 8,754	[d] 182,604	[d] 201,284	[d] 603,800	78,992	87,074	817,250	50,968	56,183	238,000
1912....	5,387	5,938	13,003	[d] 192,539	[d] 212,236	[d] 742,800	86,333	95,166	865,225	66,932	73,780	312,000
1913....	[e] 5,582	[e] 6,153	[e] 13,402	[f] 230,271	[f] 253,830	[f] 733,187	84,008	92,604	750,713	85,170	93,884	400,000
1914....	5,765	6,355	13,847	[f] 112,059	[f] 123,524	[f] 362,754	72,473	79,888	642,123	45,305	49,941	(g)
1915....	4,521	4,984	10,706	[f] 5,599	[f] 6,172	[f] 26,819	68,720	75,751	526,490	28,983	31,949	(g)
1916....	7,316	8,064	(g)	130,847	144,234	408,246	89,336	98,477	923,281	44,611	49,176	(g)
1917....	1,817	2,003	4,124	133,593	147,261	421,867	74,030	81,604	773,424	49,360	54,410	(g)
1918....	3,692	4,070	8,586	72,376	79,781	216,657	54,462	60,034	780,808	42,922	47,314	(g)
1919....	4,564	5,031	9,735	95,312	105,063	275,858	80,087	88,281	682,989	37,722	41,582	(g)

[a] Includes small quantity of manjak, produced in Barbados.
[b] Presented through courtesy of the Barber Asphalt Co.
[c] Exclusive of 6,500 metric (7,165 short) tons of bituminous rock for which no value is given.
[d] Exports. Figures for production not available.
[e] Exclusive of 4,638 metric (5,112 short) tons of bituminous rock valued at $5,833.
[f] Fiscal year, April 1 to March 31.
[g] Figures not available.

ASPHALT ASSOCIATION.

The interests of the asphalt industry were materially advanced by the organization of the Asphalt Association in New York City on May 28, 1919.

The association opened its offices at 15 Maiden Lane, New York City, on June 16, and established a branch office at 29 South La Salle Street, Chicago, on July 1. Other branch offices will be established as the needs of the association dictate. The New York office has been moved to 25 West Forty-third Street.

The officers elected were as follows: President, J. R. Draney, of the United States Asphalt Refining Co.; vice-president, W. W. McFarland, of the Warner Quinlan Co.; treasurer, N. G. M. Luykx, of the Freeport Mexican Fuel Oil Co. J. E. Pennybacker, formerly chief of management of the United States Bureau of Public Roads and, during the war period, secretary of the United States Highway Council, was engaged as secretary.

At the head of the research department was placed Prevost Hubbard, who at the time of his appointment was chief of the division of tests and research of the United States Bureau of Public Roads.

Three district engineers were appointed—Fred W. Sarr, formerly deputy State highway commissioner of New York State; John B. Hittell, formerly chief engineer of Chicago, and past president of the Illinois Society of Engineers; and A. T. Rhodes, formerly street commissioner of Worcester, Mass., and later secretary of the Granite Paving Block Manufacturers' Association.

The purposes of the association are briefly summarized as follows:

1. To make widely known the established qualities, uses, comparative costs, and service of asphalt for various human needs and more particularly for the paving of streets and highways.

2. To seek improvements in methods of preparing asphaltic products and, in their application, and through cooperation with other industries, to bring about improvement in the preparation and in methods of application of materials used in combination with asphalt, giving at the same time due consideration to the dictates of economy.

3. To develop new uses for asphalt and, while stimulating the existing demand, to encourage new fields of economic demand for this product.

4. To seek to standardize and simplify specifications, methods of sampling and testing, and methods of use of asphalt and of the materials used in combination with it.

5. To cooperate with educational institutions and agencies for the purpose of giving students accurate and adequate instruction in the utilization of asphalt and to encourage graduate work in connection with asphalt and its uses.

6. To assemble and distribute data of use to producers and users of asphalt and to serve as a clearing house where matters of common interest may be made the subject of exchange of information and of views.

7. To aid the good roads movement generally, irrespective of the particular type of construction involved, and to cooperate with all legitimate agencies in the furtherance of sound programs of construction and maintenance and of the study of economic, engineering, and traffic problems relating to streets and highways.

The results of a census of city paving, compiled by the Asphalt Association, are contained in the following table:

64600°—M R 1919—PT 2——19

Pavement of different types in American cities, in square yards.

[Compiled from reports to the Asphalt Association to Jan. 1, 1920.]

State and city.	Total.	Gravel.	Water-bound macadam.	Bituminous macadam.	Asphaltic concrete.	Sheet asphalt.	Brick.	Portland cement concrete.	Asphalt block.	Wood block.	Stone block.	Other types.	
												Asphaltic.	Non-asphaltic.
Average width..feet..		21	25	26	30	30	29	27	37	31	35	37	27
Alabama:													
Birmingham	1,779,129			333,675	660,353	256,911	321,826	112,541		42,014	51,809		
Gadsden	180,000	100,000			60,000		20,000						
Mobile	1,174,572		588,000		66,618	125,843	99,819	11,000		256,665	26,627		
Montgomery	493,390	131,400			41,200	156,200	86,600	3,010		3,640	69,600	*a* 1,740	
Arkansas:													
Fort Smith	1,344,420		146,700		123,100		681,000	380,000		13,620			
Little Rock	3,804,980	2,400,000	250,000	80,915	303,160	188,230	176,000	*b* 180,675		226,000			
Pine Bluff	465,270	181,000		58,000	95,100		97,100	3,170		30,900			
California:													
Los Angeles	21,515,424	8,920,000	1,020,669		1,332,706	7,754,157	231,853	*c* 310,627		4,936	65,476		1,875,000
Monrovia	525,000	500,000	25,000										
Palo Alto	185,755		45,072		28,830	48,415		47,722				*d* 15,716	
Pasadena	2,842,350		1,817,200	542,450	199,800	226,000	2,500	54,400					
Porterville	365,653	180,000			28,100	11,733		145,820					
Richmond	944,900		81,900	500,000	228,000	60,000		*e* 75,000					
San Francisco *f*	5,165,000		560,000			2,680,000	125,000				340,000	*d* 1,440,000	*g* 20,000
Whittier	480,386	356,048	23,956		88,089	12,293							
Colorado:													
Boulder	1,040,000	740,000	240,000			60,000							
Colorado Springs	1,339,700	1,244,000	5,700			90,000							
Denver	1,236,274		191,758	28,966	202,472	655,060	10,810				147,208		
Leadville	28,445	17,600	10,845										
Connecticut:													
Bridgeport	1,670,000		750,000		750,000		75,000			75,000	20,000		
Hartford	3,641,129		3,082,407	9,000	10,800	454,769	400	57,636		500	25,617		
Manchester	1,531,850	1,250,000	176,000	15,250		35,200		55,400					
New Haven	2,097,999		503,550	427,000	88,630	379,301	98,876	135,555		296,540	29,835	*d* 65,469 *h* 71,195	*g* 2,048
Delaware:													
Wilmington	1,330,464		289,174	123,903	50,982	196,084	294,944	72,336	20,793	1,805	231,673		*g* 48,770
District of Columbia:													
Washington	8,364,302	1,863,000	1,931,124		129,796	3,157,757	17,390	168,239	630,636		404,225		*g* 62,135
Florida:													
Gainesville	114,000		14,000				100,000						
Jacksonville	679,031	137,800		46,400	82,680		311,201		29,100	1,450			70,400

Georgia:													
Dublin	72,000				40,000		32,000						
Savannah	1,053,900					140,800	392,850	55,950	342,200		122,100		
Idaho:													
Pocatello	546,750	410,000			131,250			4,700		800			
Illinois:													
Aurora	675,000					525,000	150,000						
Cairo	641,835	50,000	300,000				291,835						
Canton	207,960						204,000	3,960					
Champaign	528,500					10,000	500,000	18,000		500			
Chicago	38,430,330		7,956,330	2,508,000	1,547,000	15,188,000	5,749,000	100,000		3,472,000	1,901,000	d 9,000	
Danville	793,160	61,700		38,200	28,200		652,000	3,960		9,100			
Edwardsville	191,710		8,210				136,000	47,500					
Joliet	555,150		17,300	37,100	234,500	123,000	138,700			4,550			
Kewanee	189,071				71,750	26,726	89,750	845					
Rock Island	709,900				39,600	164,000	506,300						
Indiana:													
Huntington	382,583	90,000	26,068	7,858	3,379	46,388	180,857	28,033					
Indianapolis [i]	4,419,697		198,867		355,660	2,505,407	879,868	21,973		446,527	11,395		
Lafayette	1,495,109	936,800	301,300			83,177	158,410	8,800	5,200	1,422			
South Bend	1,616,584		122,910		164,769	291,914	1,036,991						
Terre Haute	1,626,600	690,000			74,000	61,600	681,000	110,900		9,100			
Iowa:													
Cedar Rapids	1,070,572		64,000	76,876	114,840	81,312	627,763	92,781		13,000			
Des Moines	3,518,440	308,000	9,933		542,811	1,242,132	1,179,821	169,683		63,760	260	h 2,040	
Iowa City	288,200		10,000		87,920		175,000	10,000		5,280			
Keokuk	883,290		549,120	84,480			154,590	95,100					
Waterloo	1,173,900					1,056,000	105,800	5,400		6,700			
Kansas:													
Eldorado	244,120				176,000	17,600	42,600	7,920					
Chanute	151,500		25,000				126,500						
Concordia	281,400				281,400								
Great Bend	140,700				140,700								
Parsons	360,400		243,000		24,600		92,800						
Salina	454,050			1,830	114,300		330,000	7,920					
Wichita	1,708,860			30,500	176,000	616,000	596,000	110,900		5,460			174,000
Louisiana:													
Monroe	69,100	15,000		50,000			3,500			600			
Maine:													
Portland	792,187		257,122	66,878	62,261		4,084	92,814			295,040		g 13,988
Waterville	30,000	12,000	3,000					7,000			8,000		
Maryland:													
Baltimore	8,969,998		682,370	80,977	570,842	2,972,589	1,236,732	46,927	398,994	58,702	998,878		2,612 g 1,920,375

a Mineral rubber.
b Includes 44,505 square yards of Dolarway bituminous protected concrete.
c Including 87,551 square yards of protected Portland cement concrete.
d Rock asphalt.
e Thin asphalt rock (penetration) top.
f Data from fire of 1906 to 1919.
g Cobbles.
h Soil asphalt.
i Includes alleys.

Pavement of different types in American cities, in square yards—Continued.

[Compiled from reports to the Asphalt Association to Jan. 1, 1920.]

State and city.	Total.	Gravel.	Water-bound macadam.	Bituminous macadam.	Asphaltic concrete.	Sheet asphalt.	Brick.	Portland cement concrete.	Asphalt block.	Wood block.	Stone block.	Other types.	
												Asphaltic.	Non-asphaltic.
Average width..feet..		21	25	26	30	30	29	27	37	31	35	37	27
Massachusetts:													
Beverly	148,397			109,477							38,920		
Boston	11,158,919	537,726	4,818,300	1,997,243	349,202	621,432	115,089	26,062	774	240,761	2,451,200		a 1,130
Brockton	1,862,176	1,096,000		479,670	42,490	8,600		28,526			206,890		
Brookline	1,051,800	110,500	531,000	337,000	25,500		6,300			22,000	19,500		
Cambridge	1,714,893		733,690	291,453	227,227		71,914			81,541	309,068		
Greenfield	308,850	123,100	161,200	11,450			8,000	4,500			600		
Haverhill	674,576	60,725	244,910	223,124	32,041			9,776			104,000		
Holyoke	575,200		235,000		15,200	97,000	50,000	85,000		23,000	70,000		
Lowell	1,228,067		577,849	207,719		38,210	1,997	11,811		5,112	385,369		
Medford	4,500					1,000					3,500		
Northampton	588,000	197,000	220,000	76,000	88,000		7,000						
Springfield	1,092,300	444,000	572,000	76,300									
Somerville	1,340,830		471,000	517,500	145,495	42,215	20,958	23,990			119,672		
Westboro	819,820	776,000	40,000	3,820									
Michigan:													
Ann Arbor	1,160,005	880,000			49,976		56,610	145,189	28,200				
Flint	410,000					410,000							
Grand Rapids	3,579,002	1,992,000	144,355	9,386	188,198	77,137	938,666	117,333	102,666	9,261			
Holland	384,090	259,000	3,770		83,600		29,800	7,920					
Monroe	132,474		14,670				44,855	55,931	16,508	510			
Port Arthur	116,537	38,352				78,185							
Minnesota:													
Chisholm	256,000							176,000		80,000			
Eveleth	73,000				56,000					8,000	9,000		
St. Paul	2,271,137			2,376	220,927	562,980	255,617	22,142		711,715	495,380		
Mississippi:													
Greenwood	84,250	6,150		22,900	26,400	8,800				20,000			
Missouri:													
Hannibal	8,500						7,500	1,000					
Kansas City	8,811,400			2,000,000		3,863,000	770,000	1,850,000		170,400	158,000		
St. Joseph	1,841,900		272,000			762,000	471,000	311,000			25,900		
Webb City	209,262	70,000	22,000	17,330	50,310		47,400	2,222					
Montana:													
Billings	350,675				248,730		32,505	3,964		65,476			
Bozeman	300,000				300,000								

Butte	162,120	9,000					20,600			12,720	24,800		95,000
Great Falls	120,259	19,058	10,523		282,339			41,084		67,255			
Nebraska:													
Lincoln	1,471,270		3,770		402,000	522,500	491,000			52,000			
Omaha	4,737,615		51,960		388,407	1,554,048	2,074,272	135,321		31,290	502,317		
New Hampshire:													
Keene	105,150		66,500	21,356			15,744				1,550		
New Jersey:													
Asbury Park	610,000	500,000			25,000		40,000			45,000			
Jersey City	808,620				109,793	410,779	121,397		8,205	91,780	66,666		
West Orange	121,380		29,340	30,500	35,200			5,230			10,260	*b* 10,850	
New Mexico:													
Santa Fe	8,000				3,000		5,000						
New York:													
Albany	2,036,671		109,375		33,387	330,167	791,728	22,488	2,446	9,623	620,676		116,281
Binghampton	701,071	150,000	9,000	50,000	43,648		418,459	29,964					
Buffalo	7,476,945		269,401			4,830,737	693,828			1,616	1,681,363		
Dunkirk	448,630					129,600	242,000	61,200					15,830
Elmira	1,097,871	512,713	46,722	17,000	29,863	91,314	370,742			1,530	27,987		
Gloversville	373,080		9,980	29,100			96,000	46,500	17,400				174,100
Jamestown	613,257			23,555	22,801		529,883		33,265	1,546	2,207		
New York (all boroughs)	41,375,576		5,844,417	1,011,661	2,365,519	18,084,328	316,022	42,372	3,461,112	1,369,359	8,834,244		*a* 46,542
Niagara Falls	1,043,350		36,400		176,000	249,000	174,200	*c*132,900	248,000	24,900	1,950		
Norwich	104,001		1,458	21,129	24,060		45,054	12,300					
Olean	76,000						76,000						
Oneonta	156,376	54,176	4,620	17,500			79,200				880		
Rochester *d*	3,723,689	78,045	374,578		46,676	2,036,472	1,091,174		41,142	55,602			
Salamanca	402,300	184,800	38,100		32,700		129,300	17,400					
Syracuse	2,093,445			48,617	15,138	1,101,148	811,470			3,100	113,972		
Utica	1,570,481		19,581	75,663	426,021	804,787	124,650	8,470	887	1,428	108,994		
	659,060		411,000			70,500	76,600	63,400		27,300	10,260		
North Carolina:													
Asheville	715,797		5,197	10,963	418,369	5,330	154,745	88,932			32,261		
Charlotte	885,960		537,000	7,243	178,038	89,732	14,274	59,673					
Concord	167,812					136,321	1,788	29,703					
Durham	86,000				20,000	60,000	1,000				5,000		
Wilmington	240,900	123,100		38,100	35,200			11,900	32,600				
North Dakota:													
Bismarck	184,634				41,490	143,144							
Fargo	449,240				302,740		39,000	29,600		77,900			
Ohio:													
Bellefontaine	122,000		60,000				50,000	12,000					
Cambridge	285,000						285,000						
Cincinnati *d*	10,169,709	309,183	4,953,947	152,027	311,011	748,504	1,140,044	309,183		402,448	1,843,362		
Columbus	5,683,650		50,000	10,000	50,000	1,295,000	4,045,000	10,650			223,000		
Conneaut	175,500					15,000	160,500						
Lancaster	265,000						265,000						
Lorain	1,011,000		86,000			700,000	185,000	40,000					
Marion	789,275					138,000	540,000	18,000	87,000	6,275			

a Cobbles.
b Soil asphalt.
c Includes 126,600 square yards of Hassam type.
d Includes alleys.

Pavement of different types in American cities, in square yards—Continued.

[Compiled from reports to the Asphalt Association to Jan. 1, 1920.]

State and city.	Total.	Gravel.	Water-bound macadam.	Bituminous macadam.	Asphaltic concrete.	Sheet asphalt.	Brick.	Portland cement concrete.	Asphalt block.	Wood block.	Stone block.	Other types.	
												Asphaltic.	Non-asphaltic.
Average width..feet..		21	25	26	30	30	29	27	37	31	35	37	27
Ohio—Continued.													
Martins Ferry	66,000						66,000						
Norwood	767,340		73,400	305,000	8,800	7,040	27,200	20,600		47,300	72,000		206,000
Toledo	4,287,798		92,297	60,377	136,707	667,371	2,361,907	164,518	212,711	338,439	253,471		
Urbana	276,500	158,400	14,000			10,700	88,000		5,400				
Xenia	224,011					113,288	108,523	2,200					
Oklahoma:													
Bartlesville	247,550				95,800		90,000	49,600				a 12,150	
Enid	358,330					317,000	25,500	15,830					
Shawnee	300,000					200,000	100,000						
Oregon:													
Portland	8,959,440	1,024,000	860,000	2,440	3,630,000	1,891,000	33,900	b 1,267,000		41,600	209,500		
Pennsylvania:													
Allentown	684,455		71,900	18,137	66,971	514,667	5,800				6,980		
Altoona	744,619		8,126	3,600		40,336	611,095		14,739	3,937	16,186		46,600
Berwick	557,500	468,000			2,400		85,100				2,000		
Du Bois	454,810	283,000			17,600		136,200	15,830		2,180			
Dunmore	42,100			5,000		24,000	12,000				1,100		
Hanover	138,300		73,300		25,000	30,000	10,000						
Hazleton	665,666		530,000		72,712		57,052	4,111	1,791				
Lebanon	736,138		650,000		9,327			3,146		73,665			
Oil City	352,303					7,390	334,592	961	7,870	1,490			
Philadelphia	22,609,962		2,775,452		1,320,562	8,711,468	2,811,160	98,378	67,838	297,222	6,414,140		c 113,742
Pittsburgh	10,403,200		172,100		26,400	3,630,000	1,441,000	38,000	41,200	114,500	d 4,940,000		
Ridgeway	71,500						71,500						
York	428,780		146,700			176,000	73,800	5,230	4,350	22,700			
Scranton	1,066,642				32,539	749,919	131,967			299	74,649	e 67,432 f 9,837	
Wilkes-Barre	784,846		4,000			417,844	363,002						
Wilkinsburg	452,849						426,418	1,994	3,534	6,292	14,611		
Rhode Island:													
Pawtucket	1,356,790	795,000	318,000		130,618	1,838	2,547				108,787		
Providence	7,014,196		5,590,000	127,078	224,852	259,284	6,277			71,727	734,978		
South Carolina:													
Charleston	764,680	88,700	59,000		12,680	143,300	95,400			36,400	329,200		
Rock Hill	17,200					17,000					200		

South Dakota:													
Aberdeen	111,000	20,000								91,000			
Mitchell	119,311				74,711			41,276		3,324			
Sioux Falls	465,049				g 366,659			45,256		16,125	37,009		
Tennessee:													
Bristol	171,000		110,000				18,000	43,000					
Cleveland	86,000	50,000	18,000			18,000							
Jackson	416,486	288,000			7,040	56,994	55,734	8,718					
Johnson City	259,800		28,600		53,300	160,000	17,900						
Memphis	2,585,389	1,287,760		371,969	9,727	565,218	171,179	94,200		85,336			
Texas:													
Amarillo	179,000				51,000	38,000	76,000	12,000		2,000			
Cleburne	18,000			18,000									
Fort Worth	1,446,047			10,330	738,943	253,353	368,994	21,155		53,272			
Port Arthur	324,185	246,000				78,185							
San Antonio	4,642,500	3,270,500		11,594	313,940	50,565	226,551	383,916		161,929		a 223,505	
Temple	450,000				325,000		125,000						
Texarkana	46,000	24,000					20,000			2,000			
Utah:													
Ogden	686,875		267,284		11,875	350,471		57,245					
Provo	80,400							80,400					
Salt Lake City	2,429,966		24,830		557,340	1,250,585		101,095			119,516	a 376,600	
Virginia:													
Danville	219,000						57,000			2,000	160,000		
Newport News	239,789		14,220	10,088	39,325	54,114	31,472	53,236	33,134		4,200		
Richmond	1,721,447	92,509	1,003,611	17,833	193,471			18,290	360,000		35,733		
Suffolk	77,500			2,400	4,000		49,500	19,100			2,500		
Washington:													
Seattle	4,613,599				37,993	2,804,644	1,330,494	103,776		34,209	302,483		
Walla Walla	432,273				270,926	138,679		22,668					
West Virginia:													
Beckley	166,480			163,680				2,800					
Clarksburg	197,911						194,000	3,911					
Parkersburg	435,300						340,200	95,100					
Wisconsin:													
Grand Rapids	100,170		14,670				25,500	60,000					
La Crosse	537,110		275,410	34,150			215,520			12,030			
Menomonie	85,300	27,500			18,000		14,000	25,800					
Merrill	101,500		75,000	6,500			20,000						
Sheboygan	911,636	100,000	267,682	15,898			160,429	365,522		425	1,680		
Superior	887,850		256,500		24,000	148,000	14,350	424,000		21,000			
Wyoming:													
Cheyenne	19,000	19,000											
Square yards	364,901,611	37,376,345	58,412,780	h 14,279,494	26,430,112	105,712,821	50,963,748	10,744,695	6,259,695	10,313,420	37,098,414	2,305,534	5,004,553
Percentage of total	100.00	10.23	16.00	3.91	7.25	28.97	13.96	2.95	1.72	2.83	10.18	0.63	1.37

a Rock asphalt.
b Includes 800,000 square yards of Hassam type.
c Cobbles.
d Ligonier block.
e Combination asphalt and stone block.
f Soil asphalt.
g Includes 9,059 square yards of tar concrete.
h Includes 7,303,596 square yards of bituminous macadam, 5,022,471 square yards of asphalt macadam, and 1,953,427 square yards of tar macadam.

The average width was obtained from those cities that reported area in both square yards and miles. The average width was then used in obtaining the yardage for the few cities reporting mileage only.

A portion of the information given in this table was obtained by the Granite Paving Block Manufacturers' Association.

The summary in the table shows that the asphaltic types, comprising 55 per cent of all pavements higher than water-bound macadam and gravel, appear to have crowded out the older rigid types of payment and are favored in present practice. Among the asphaltic types sheet asphalt shows the largest percentage, although asphaltic concrete, including bitulithic and certain other specialized types, is rapidly finding favor.

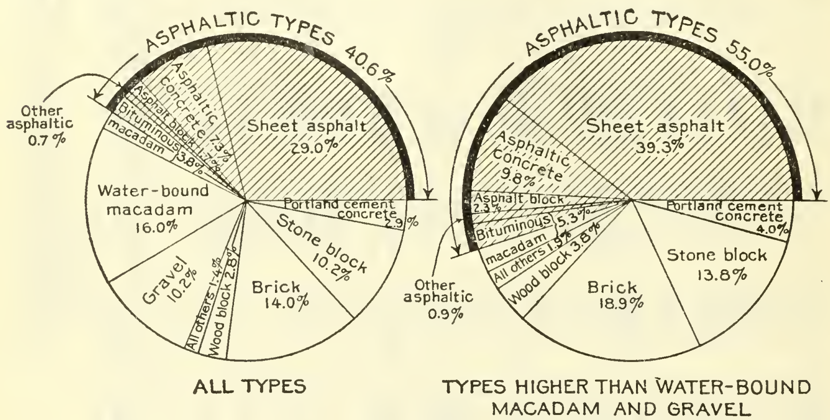

FIGURE 10.—Diagrams showing percentages of pavements of different types in American cities.

Just how the different types of pavement go to make up the total is graphically shown in the accompanying illustration. The first diagram gives the percentages of all types, including water-bound macadam and gravel, and the second diagram gives the percentages of all types higher than water-bound macadam. These diagrams are copied from a report prepared by the Asphalt Association.

PRODUCERS.

The following operators reported to the United States Geological Survey that they produced asphaltic material from crude petroleum in the United States in 1919:

Asphaltum & Oil Refining Co., 2475 East Ninth Street, Los Angeles, Calif.
Atlantic Refining Co., 3144 Passyunk Avenue, Philadelphia, Pa.
Central Refining Co., Lawrenceville, Ill.
Craig Oil Co., Toledo, Ohio.
Fairchild-Gilmore-Wilton Co., 396 Pacific Electric Building, Los Angeles, Calif.
Freeport & Mexican Fuel Oil Corporation, 120 Broadway, New York, N. Y.
Gulf Refining Co., Frick Building Annex, Pittsburgh, Pa.
Hercules Oil Refining Co., 396 Pacific Building, Los Angeles, Calif.
Indian Refining Co., 244 Madison Avenue, New York, N. Y.
International Oil & Gas Co., Shreveport, La.
King Refining Co., 255 Holbrook Building, San Francisco, Calif.
Magnolia Petroleum Co., Box 1667, Dallas, Tex.
Mexican Petroleum Corporation, Destrehan, La.

Paraffine Co. (Inc.), Emeryville, Calif.
Pierce Oil Corporation, 25 Broad Street, New York, N. Y.
Pine Island Refining Co., Shreveport, La.
Pioneer Asphalt Co., Lawrenceville, Ill.
Pioneer Paper Co., 251 South Los Angeles Street, Los Angeles, Calif.
Producers Refining Co., Bakersfield, Calif.
Prudential Oil Corporation, 17 Battery Place, New York, N. Y.
Seaside Oil Co., Summerland, Calif.
Standard Asphalt & Refining Co., 208 South La Salle Street, Chicago, Ill.
Standard Oil Co. of California, 200 Bush Street, San Francisco, Calif.
Standard Oil Co. of Indiana, 910 South Michigan Avenue, Chicago, Ill.
Standard Oil Co. of Louisiana, Baton Rouge, La.
Standard Oil Co. of New Jersey, 26 Broadway, New York, N. Y.
Sun Co., Philadelphia, Pa.
Texas Co., Houston, Tex.
Turner Oil Co., 1006 California Building, Los Angeles, Calif.
Union Oil Co. of California, Union Oil Building, Los Angeles, Calif.
United States Asphalt Refining Co., 90 West Street, New York, N. Y.
Warner Quinlan Asphalt Co., 79 Wall Street, New York, N. Y.

Native asphalt and related bitumens were produced commercially in this country in 1919 by the following companies:

American Asphalt Association, 918 Wainwright Building, St. Louis, Mo.
Ardmore Construction Co., Simpson Building, Ardmore, Okla.
Central Commercial Co., 111 North Market Street, Chicago, Ill.
City Street Improvement Co., 3001 Seventeenth Street, San Francisco, Calif.
Consolidated Bituminous Rock Co., 511 Nevada Building, San Francisco, Calif.
Fort Smith Asphalt Co., Fort Smith, Ark.
Gilson Asphaltum Co., 1900 Land Title Building, Philadelphia, Pa.
Kentucky Rock Asphalt Co., 712 Paul Jones Building, Louisville, Ky.
Raven Mining Co., Marquette Building, Chicago, Ill.
Rock Creek Sand & Gravel Co., Simpson Building, Ardmore, Okla.
Sattler & Stevens, Carpinteria, Calif.
J. O. Tipton, Ada, Okla.
Uvalde Rock Asphalt Co., San Antonio, Tex.

PUBLICATIONS.

An extensive bibliography of asphalt was published in Mineral Resources for 1918. The Asphalt Association, which carries on research and publicity work, has issued the following brochures:

No. 2. Asphalt a world-old material.
5. Terms used in connection with asphalt for highway work.
6. Asphalt macadam.
7. Asphalt fillers.
8. Asphalt specifications.
9. Sheet asphalt.
10. Asphaltic concrete.
11. Asphalt paving mixtures.

ASBESTOS.

By J. S. Diller.

DOMESTIC OUTPUT.

Both the production of asbestos from known deposits and the prospecting for new deposits were carried on vigorously in 1919. The domestic output increased 36 per cent over that of 1918, when conditions were so unfavorable that the quantity produced and sold was only 60 per cent of the output of 1917. The shipments from the mines in 1919 amounted to 1,361 short tons, valued at $251,265, as compared with 1,002 short tons, valued at $124,687, in 1918. Although the shipments were less in 1918 than in any other year since 1908, the recovery in 1919 indicates the healthy condition of the industry.

The seven producing States in 1919 were Arizona, California, Georgia, Maryland, North Carolina, Washington, and Wyoming. Oregon was a producer in 1918, but had no output in 1919; Washington and Wyoming made no production in 1918. Arizona had four producers in 1919, California and Wyoming had two, and the other four States had one producer each. Arizona produced 341 tons of spinning fiber in 1919, which was equal to nearly 8 per cent of the total output of Canada during the same time. Arizona is the only large producer of chrysotile spinning fiber in the United States and on account of the high price of Canadian fiber is receiving much attention from manufacturers of asbestos fabrics. The quantity, value, and average price per ton of asbestos produced and marketed in the United States in the last six years are shown in the following table:

Domestic asbestos marketed in the United States, 1914–1919.

Year.	Quantity (short tons).	Value.	Average selling price per ton.
1914	1,247	$18,965	$15.21
1915	1,731	76,952	44.46
1916	1,479	448,214	303.05
1917	1,683	506,056	300.69
1918	1,002	124,687	124.44
1919	1,361	251,265	184.62

Domestic asbestos marketed in 1919, by States.

State.	Quantity (short tons).	Value.
Arizona	423	$219,950
California, Washington, Wyoming	279	12,315
Georgia, Maryland, North Carolina	659	19,000
	1,361	251,265

PRODUCERS OF DOMESTIC ASBESTOS.

Alene Asbestos Association, Earle Pierce, Globe, Ariz.
American Fireproofing & Mining Co., Lander, Wyo.
American Ores & Asbestos Co., A. B. Shutts, manager, Globe, Ariz.
Arizona Asbestos Association, N. A. Nelson, manager, Chrysotile, Ariz.
Asbestomine Co., Wenatchee, Wash.
Denver Arizona Asbestos Mining Co., E. E. Miller, manager, Globe, Ariz.
N. C. McFalls, Cane River, N. C.
Powhatan Asbestos Mining Co., F. A. Mett, manager, Woodlawn, Baltimore, Md.
Sall Mountain Co., 230 South La Salle Street, Chicago, Ill.
Sierra Asbestos Co., 710 Union Savings Building, Oakland, Calif.
Wyoming Asbestos Producing Co., F. Patee, Casper, Wyo.
Wyoming Asbestos Syndicate, A. E. Minium, president, 226 Denham Building, Denver, Colo.

ARIZONA.

Asbestos is mined in Arizona in two regions—in the Grand Canyon and in the field about 25 to 40 miles in a direct line north and east of Globe. The production in the Grand Canyon has been small and not continuous. The Globe field is about 50 miles in length from northwest to southeast and 20 miles in width in a deeply cut mountainous region along Salt River and covers an area of approximately 700 square miles. The larger part of the field lies beyond the western border of the Apache and San Carlos Indian reservations, but a considerable portion is within these reservations. Several hundred asbestos claims have been located outside of the reservations.

Edward Sampson, of the United States Geological Survey, made an examination of the asbestos deposits in the Apache and San Carlos Indian reservations in 1920, and his report will be published later.

Asbestos was being mined chiefly at four points in the Globe field—on Ash Creek, by the Arizona Asbestos Association; near Salt Bank on Salt River, by the Denver Arizona Asbestos Mining Co.; near the summit of Coon Creek Butte, at the south end of the Sierra Ancha, by the American Ores & Asbestos Co.; and near the head of Sloane Creek, a branch of Canyon Creek, by the Alene Asbestos Association.

GEOLOGY AND STRUCTURE OF THE GLOBE ASBESTOS FIELD.

The rocks of the asbestos field are well exposed also in the immediate vicinity of Globe, the geology of whose copper deposits has been described by F. L. Ransome.[1] Near Roosevelt dam and a few miles below it in Salt River canyon the succession of formations given below in vertical order is well exposed:

Vertical section in the Globe region, Ariz.

Formation.	Age.	Thickness (feet).
Tornado limestone	Carboniferous	1,000
Martin limestone	Devonian	325
Troy quartzite	Cambrian	400
Vesicular basalt flow		25–75
Mescal limestone		225
Dripping Spring quartzite		450
Barnes conglomerate		35
Pioneer shale		150
Scanlan conglomerate		0–15
Pinal schist and intrusive granitic rocks	Pre-Cambrian	....

[1] Ransome, F. L., The copper deposits of Ray and Miami, Ariz.: U. S. Geol. Survey Prof. Paper 115, 1919.

A part of the same series of rocks is exposed along the shores of Roosevelt reservoir and to the northeast on Coon Creek Butte, in the Sierra Ancha, as illustrated in the accompanying section (fig. 11).

The limestone of Cerro del Temporal (Windy Hill), on the southwest side of the Roosevelt reservoir, belongs in the regular succession of strata overlying the Troy quartzite, which forms the summit of Coon Creek Butte. It is evident, therefore, that the rocks have been displaced, possibly by folding, but more likely, at least in part, by the faults that dropped the southwestern portion of the region and thus created the Tonto Basin, which contains the reservoir.

OCCURRENCE OF ASBESTOS.

Asbestos occurs only in the Mescal limestone, which has been somewhat altered near its contact with intruded diabase. The mine of the American Ores & Asbestos Co. is near the summit of Coon Creek Butte, as shown in the figure, where the Mescal limestone crops out between two sheets of diabase. The asbestos occurs chiefly near the upper contact of the limestone. Another portion

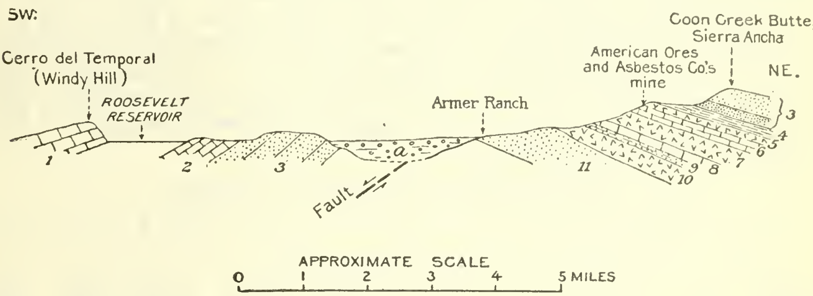

FIGURE 11.—Section from Cerro del Temporal (Windy Hill) across Roosevelt reservoir and by the American Ores & Asbestos Co.'s mine to the summit of Coon Creek Butte, in the Sierra Ancha, Ariz. *a*, Gila conglomerate; 1, Carboniferous limestone; 2, Martin limestone; 3, Troy quartzite; 4, red and gray thin-bedded siliceous strata and vesicular basalt flow, 40 feet; 5, diabase sill, 5–12 feet; 6, Mescal limestone, chiefly gray limestone, 25–30 feet; 7, diabase, 500 feet; 8, Mescal limestone, gray banded, somewhat cherty limestone, 150 feet; 9, Dripping Spring quartzite; 10, diabase; 11, Dripping Spring quartzite. Length of section, about 12 miles.

of the Mescal limestone lies below the large sheet of diabase, but so far as known it contains only a small quantity of asbestos.

MINING OPERATIONS.

The American Ores & Asbestos Co.'s mine, opened on Coon Creek Butte by C. F. Sloane, was actively producing asbestos.

Southwest of Coon Creek Butte the Mescal limestone contains veins of asbestos at only a few places. Asbestos claims were located near the head of Pinto Creek, west of Globe, in 1903, and later near El Capitan post office, south of Globe, but neither locality proved of commercial importance.

Northeast of Coon Creek Butte numerous asbestos outcrops have been discovered in the Mescal limestone, especially in the Sierra Ancha and the Cherry Creek region, and mines have been opened.

Earle Pierce continued a small production near Rock House.

The Denver Arizona Asbestos Mining Co., E. E. Miller, president, enlarged its equipment and renewed production near Salt Bank.

The most active producing center is the Arizona Asbestos Association's mine at Chrysotile, on Ash Creek. This mine is 41 miles from the nearest railroad shipping point, but it employed as many as 140 men at one time in 1919. The underground workings amount to about 10,000 feet, and the production was greater in 1919 than that of any other asbestos mine in the Western States.

CHEMICAL COMPOSITION OF ARIZONA ASBESTOS.

The chrysotile asbestos found in Arizona is peculiar not only in mode of occurrence but also in chemical composition, and it may be most conveniently designated the Arizona variety of chrysotile asbestos to distinguish it from other varieties of chrysotile in the United States. A considerable portion of the Arizona asbestos is somewhat harsh and splintery as compared with the best grade of that variety, which is soft and silky. In the Globe field both grades occur in the same vein near together without a definitely visible boundary. A comparison of the two grades discloses the fact that the harsh fiber generally, and perhaps always, has a deposit, in places only a thin film, of calcite between the fibers of the asbestos. Searching for a chemical cause adequate to explain the differences of harsh and soft fiber, Dr. R. E. Zimmerman, assistant director of the research laboratory of the American Sheet & Tin Plate Co., of Pittsburgh, made analyses of four samples selected by the writer at the mines on Ash Creek and the Sierra Ancha; the results are shown in columns 1 to 4 of the accompanying table.

Chemical analyses of Arizona chrysotile asbestos.

	1	2	3	4	5
MgO	42.05	41.85	40.69	41.41	40.64
SiO_2	41.56	41.35	40.75	42.28	43.68
Al_2O_3	1.27	.91	1.82	1.07	.34
FeO	.64	.69	.74	.88	a.51
MnO					.17
CaO	None.	.07	None.	.10	.09
K_2O					.11
Na_2O					.14
H_2O-	1.39	1.38	1.86	1.33	1.18
H_2O+	12.92	11.96	12.65	12.23	13.12
	99.83	98.21	98.51	99.30	99.98

a Fe_2O_3.

1. Ash Creek mine; soft fiber. Analyst, R. E. Zimmerman, Jan. 24, 1918.
2. Ash Creek mine; harsh fiber. Analyst, R. E. Zimmerman, Jan. 24, 1918.
3. Coon Creek Butte of the Sierra Ancha; soft fiber. Analyst, R. E. Zimmerman, Jan. 24, 1918.
4. Coon Creek Butte of the Sierra Ancha; harsh fiber. Analyst, R. E. Zimmerman, Jan. 24, 1918.
5. Grand Canyon, under Grand View; harsh fiber. Analyst, R. C. Wells, U. S. Geol. Survey, Apr. 22, 1915.

Dr. Zimmerman remarks that

A study of the results in the table will show that the magnesia and silica contents are practically normal in every case, and this is also true, within reasonable limits, of the water of constitution. We are especially glad to note that the ferrous oxide is below 1 per cent in every case. * * *

One feature of the information contained in the results is the occurrence of lime in samples Nos. 2 and 4 and its absence in samples Nos. 1 and 3. While the amount of calcium oxide in the fiber is small, it may be a matter of significance that it was detected only in the samples of harsh fiber. Whether or not the infiltration of such small amounts of lime could impart the quality of brittleness, its presence seems to go hand in hand with the tendency of the serpentine to produce harsh fiber.

Another item of interest, although it may not have any great significance, is the fact that the samples of soft fiber, Nos. 1 and 3, contained higher percentages of alumina than samples Nos. 2 and 4.

Although it is thus possible to point out small differences in the chemical constitution of harsh and soft material, it does not seem to us that the variations are of such magnitude that they can account for the difference in physical properties. The presence of calcite would no doubt make for brittleness of fiber, but it would appear that this quality is dependent more particularly upon the physical structure of the material. If we assume that the peculiar fibrous structure of asbestos is due to an extreme elongation of the crystals, it seems that the original orientation of the crystals ought to play an important rôle in determining the characteristics of the asbestos in its final form. In view of the properties of the unaltered serpentine rock it is not difficult to believe that the quality of softness might vary with the degree of transformation.

Most of the asbestos in the Grand Canyon has harsh fiber, and its chemical composition, as shown in the table, accords closely with that of the harsh fiber of Ash Creek and Sierra Ancha.

A. B. Shutts, general manager of the American Ores & Asbestos Co.'s mine, has given much attention to harsh and soft fiber; both are said to occur in the same vein, and he reports them as grading into each other. He called the writer's attention to veins of fibrous calcite in which the asbestos appears to have been so completely replaced by fibrous calcite that the calcite is pseudomorphous and preserves the fibrous structure of the chrysotile. Mr. Sampson suggests that the fibrous calcite may be a parallel growth instead of a replacement of chrysotile. The degree of harshness varies and appears to be proportionate to the degree of replacement of the asbestos by the calcite. These facts seem to furnish strong and convincing evidence that calcite causes the harshness of the fiber.

An important difference between the chemical composition of the Arizona variety of chrysotile asbestos and that of the Canadian chrysotile is the small quantity of iron oxide the former contains. This feature was pointed out in the report on asbestos in Mineral Resources of the United States for 1912, where it was suggested that on account of the small quantity of the iron oxide present the Arizona variety of asbestos might be better than the Canadian variety for electric insulation. In order to ascertain the quantity of iron present in the best Canadian fiber, the writer sent to Dr. Zimmerman a sample of soft silky Canadian chrysotile which had been furnished by Dr. Huber, president of the Asbestos Fiber Spinning Co., of North Wales, Pa., as the best asbestos he had ever seen from Canada. Dr. Zimmerman reported January 24, 1918:

We have determined the iron content of the Canadian asbestos you sent, and it contains at least 2.5 per cent of FeO. We believe this is an important result and proves to our satisfaction that the Canadian material carries more than twice as much iron as the Arizona asbestos.

This low content of iron is characteristic of the Arizona variety of chrysotile, which deserves the attention of engineers who are searching for asbestos low in iron.

A. L. Hall,[4] in describing the asbestos of Transvaal, notes a variety in the Carolina district like that of the Grand Canyon. Both are chrysotile and are similar in mode of occurrence and chemical composition, and it may well be that both the harsh and the soft fibers occur in the Carolina district.

In strong contrast with the practically iron-free asbestos of Arizona and of the Carolina district in Transvaal is the "blue asbestos," the crocidolite of South Africa, which contains as much as 33 per cent of iron oxides. As pointed out recently by the United States

[4] Hall, A. L., Mode of occurrence and distribution of asbestos in the Transvaal: South Africa Geol. Soc. Trans., vol. 31, pp. 1–36, 1918.

Geological Survey, an excellent grade of crocidolite occurs in northern Ecuador. The locality has been visited by B. Marcuse, the president of the Asbestos & Mineral Corporation, who reports that the fiber is of too low tensile strength for spinning.

CALIFORNIA.

Asbestos occurs in both the Coast Range and the Sierra Nevada of California, but the only important producer in that State in 1919 was the Sierra Asbestos Co., from a mine near Washington, in Nevada County. The product is mainly cross-fiber chrysotile and a small part of it is spinning fiber. The bulk of it appears to be used by the J. D. Hoff Co., San Francisco, to manufacture flooring.

GEORGIA.

An asbestos mine was opened more than 20 years ago at Sall Mountain, White County, Ga., and has been in practically continuous operation ever since. The rock is composed wholly of radial fibrous anthophyllite, a form of amphibole asbestos, which is mined only at or near the surface, where it is softened by weathering. It is used chiefly by the Sall Mountain Co., of Chicago, for manufacturing fireproof paints and cements.

MARYLAND.

The recent World War cut off our commercial supply of chemical filter fiber, which was obtained chiefly from Italy. The Powhatan Asbestos Mining Co., of Woodlawn, Baltimore, Md., was organized to supply the needed material and soon began to mine small masses of asbestos slip-fiber among the weathered crystalline rocks of Harford County, Md. The industry is growing.

NORTH CAROLINA.

In Yancey County, N. C., near Cane River, N. C. McFalls mined a mass of amphibole fiber related to that of Sall Mountain, Ga. North Carolina ranked third in order of output in 1919, and its production indicates a growing interest in the use of asbestos for fireproof construction.

WASHINGTON.

Near Pateros, Wash., the Asbestomine Co. obtained considerable amphibole asbestos, which was shipped to the company's plant at Wenatchee for manufacture.

WYOMING.

In the vicinity of Casper, Wyo., short fiber is obtained and used by Fred Patee in manufacturing fireproof blocks for building chimneys. The American Fireproofing & Mining Co., of Denver, operating the asbestos mine 23 miles southwest of Lander, reports a small production of crude fiber No. 1 and No. 2. The greater portion of this company's work in 1919 consisted in building an asbestos mill.

PRICES.

The strong demand especially for asbestos spinning fiber in 1919 caused a continued rise in prices for practically all grades of Canadian asbestos in the New York market, as quoted below by the Bennett

Martin Asbestos & Chrome Mines (Ltd.), 220 Broadway, New York City.

Range of New York prices per short ton for Canadian chrysotile fiber, 1915–1919.

	1915	1916	1917	1918	1919
No. 1 crude	$350–$400	$350–$1,250	$700–$1,500	$1,200–$2,000	....
No. 2 crude	225– 275	250– 900	500– 900	700– 1,200	$700–$1,250
No. 1 fiber	110– 150	150– 350	150– 450	400– 600	500– 600
No. 2 fiber	80– 125	75– 150	75– 150	250– 300	250– 300
Shorter fibers	10– 30	15– 60	18– 75	18– 125	18– 130

Owing to the small production of the various grades of fiber in the United States there is no established price for them in the regular markets, but they are sold to consumers who, appreciating their value, are endeavoring by fair prices to encourage production and develop the domestic asbestos industry.

In Canada in 1919 the average price of crude fiber sold was $818.23 a short ton, an increase of $147 over the average sales price of crude in 1918. The average price in 1919 of the mill fiber was $57.93 a ton and of asbestic $2.93.

Owing to the fact that in practically all the Arizona fiber the harsh and soft materials are intermingled in such a way that it is difficult to separate them, these fibers do not bring as high prices as the Canadian.

IMPORTS.

The production of asbestos in the United States is very small as compared with the imports of crude asbestos used to manufacture articles for domestic consumption and for export. Of the crude fiber imported more than 99 per cent comes from Canada, the great source of the world's supply. South Africa and France furnish the remainder. The following table shows the sources, quantity, and value of asbestos imported in 1918 and 1919:

Asbestos imported into the United States in 1918 and 1919.[a]

Country.	1918			1919		
	Unmanufactured.		Manufactured (value).	Unmanufactured.		Manufactured (value).
	Quantity (short tons).	Value.		Quantity (short tons).	Value.	
British India	....	....	....	1	$80	....
British South Africa	837	$82,217	....	900	132,465	....
Canada	134,813	6,207,845	$10,208	133,662	6,935,804	$17,188
Colombia	1	1,138				
Cuba	....	....	238	....	....	....
England	....	....	14,870	156	53,057	211,957
France	....	....	278	450	204,412	24,939
Germany	....	....	....	....	....	10
Hongkong	....	....	....	1	30	....
Ireland	....	....	451	....	....	....
Italy	....	....	516	....	....	2,989
Japan	....	....	80	....	11	....
Philippine Islands	....	....	....	....	35	....
Portuguese Africa	2,049	46,385	....	100	43,791	....
Scotland	....	....	835	....	....	298
	137,700	6,337,585	27,476	135,270	7,369,685	257,381

[a] Figures compiled from records of Bureau of Foreign and Domestic Commerce, U. S. Department of Commerce.

Of the asbestos imported in 1919, by far the larger part—135,270 tons, valued at $7,369,685—was unmanufactured. The imports of manufactured asbestos were valued at only $257,381.

EXPORTS.

The exports in 1919 included only 1,119 tons of unmanufactured asbestos, valued at $157,416. The bulk of the asbestos exported is in manufactured products, the making of which constitutes a large and important industry growing out of the free importation of the crude asbestos from Canada. The value of asbestos products exported in 1919 was $3,531,978, making the total value of asbestos exports $3,689,394.

PRINCIPAL FOREIGN SOURCES.

CANADA.

The total annual production of asbestos in Canada is increasing, but for the last few years the output of crude fiber, as noted in the following table, has been falling off.

Asbestos produced in Canada, 1917–1919, in short tons.

	1917	1918	1919
Crude	6,268	4,313	4,065
Mill stock	135,475	139,143	153,507
	141,743	143,456	157,572

Crude fiber is in great demand, but the market for mill fiber is overstocked and offers opportunities to develop new uses to absorb the surplus.

SOUTH AFRICA.

Commercial asbestos occurs in abundance and is widely distributed in greater variety in South Africa than in any other known region of the world. It is mined in Rhodesia, Transvaal, Natal, and Cape Colony, and its production is rapidly increasing. Chrysotile fibrous serpentine similar to that of Canada and the United States is produced chiefly in Rhodesia and Transvaal. Blue crocidolite, an amphibole asbestos spinning fiber rich in iron, is mined mainly in Cape Colony and also in Transvaal. Considerable crocidolite is used in the United States, and to facilitate its acquisition in properly prepared form, a plant has been established by the Asbestos Limited (Inc.), 8 West Fortieth Street, New York City.

Amosite is a new variety of amphibole asbestos spinning fiber which abounds in Transvaal and is attracting much attention.

RUSSIA AND CHINA.

There is a large asbestos field in Russia, but the present civil conditions of the country do not permit its development. A large field has recently been reported in China which produces mostly material of low grade but contains some fair spinning chrysotile, of which samples have been presented by J. Morgan Clements to the United States National Museum in Washington, D. C.

ASBESTOS JOURNAL.

One of the most interesting and useful features developed recently in the asbestos industry is the publication of a monthly magazine called Asbestos. Although of small size, it appears to be of large scope and may well promote the welfare of the whole industry. It is published by the Secretarial Service, 721 Bulletin Building, Philadelphia, Pa.

GRAPHITE.

By L. M. Beach.[1]

INTRODUCTION.

The annual report on the graphite industry is usually published within six or eight months after the end of the calendar year. The report for 1919 has been delayed by reason of the fact that an attempted cooperation with the Bureau of the Census resulted in practically no reports being received by the Geological Survey up to August, 1920, when it became necessary to make a separate canvass of the industry eight months later than in other years.

In addition to the usual statistical information, this chapter contains a history of graphite mining in Pennsylvania, kindly contributed by Prof. F. Bascom, of Bryn Mawr College and the United States Geological Survey.

PRODUCTION.

NATURAL GRAPHITE.

The graphite industry during 1919 was affected by the cautious readjustment in the business world that began after the World War, by modification or repeal of war-time commercial regulations, and by the usual uncertainties preceding a presidential election. Marked depression was the consequence.

The total sales of domestic natural graphite in 1919 were 7,422 short tons, valued at $778,857, a decrease of 43 per cent in quantity and 49 per cent in value from the sales in 1918; but the business done was nevertheless of larger value than in any year prior to 1916.

Domestic natural graphite sold, 1913–1919.

Year.	Amorphous.		Crystalline.		Total.	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
1913	2,243	$39,428	2,532	$254,328	4,775	$293,756
1914	1,725	38,750	2,610	285,368	4,335	324,118
1915	1,181	12,358	3,537	417,273	4,718	429,631
1916	2,622	20,723	5,466	914,748	8,088	935,471
1917	8,301	73,481	5,292	1,094,398	13,593	1,167,879
1918	6,560	69,455	6,431	1,454,799	12,991	1,524,254
1919	3,379	47,716	4,043	731,141	7,422	778,857

[1] H. G. Ferguson, of the United States Geological Survey, who prepared the reports for 1916, 1917, and 1918, relinquished charge of the statistical work on graphite in the division of Mineral Resources in January, 1920, and this report is written by the statistical clerk.

It appears from this table that the total sales in the last seven years have been about equally divided between crystalline and amorphous graphite—29,911 tons of crystalline and 26,011 tons of amorphous. In 1915, however, the quantity of the amorphous graphite sold was only one-third that of the crystalline graphite, and in both 1917 and 1918 more amorphous than crystalline graphite was sold.

From the following table, showing the number of operators in the producing States in the last four years, it appears that Alabama has had by far the largest number of operators, and that Pennsylvania is second and New York third. Production was reported from Alaska only in 1917, and there has been none from North Carolina since 1916.

The decreased demand and sales in 1919 are reflected in a 50 per cent reduction in the number of operators.

Number of operators reporting production of graphite, 1916–1919.

State.	1916	1917	1918	1919
Alabama	7	14	25	10
Alaska	....	1	....	....
California	1	1	1	1
Colorado	1	2	1	1
Michigan	1	1	....	....
Montana	1	1	1	....
Nevada	1	1	1	1
New York	3	4	3	2
North Carolina	1	....	....	....
Pennsylvania	5	5	6	3
Rhode Island	1	2	2	1
Texas	1	1	2	1
	23	33	42	20

CRYSTALLINE GRAPHITE.

In 1919 crystalline graphite was mined and sold in Alabama, New York, Pennsylvania, California, and Texas. The total quantity was 8,086,191 pounds, valued at $731,141, a decrease of 37 per cent in quantity and of 50 per cent in value in comparison with 1918.

Domestic crystalline graphite sold in the United States, 1917–1919.

State.	1917		1918		1919	
	Quantity (pounds).	Value.	Quantity (pounds).	Value.	Quantity (pounds).	Value.
Alabama	6,223,095	$719,575	7,795,475	$999,152	3,569,030	$272,413
New York	2,941,040	261,548	3,266,518	273,188	(a)	(a)
Pennsylvania	804,945	77,475	1,016,900	112,059	484,060	26,003
Other States [b]	615,000	35,800	782,946	70,400	4,033,101	432,725
	10,584,080	1,094,398	12,861,839	1,454,799	8,086,191	731,141

[a] Included under "Other States."
[b] 1917: Alaska, California, Montana, Texas; 1918: California, Montana, Texas; 1919: California, New York, Texas.

Alabama led in production and sales, with 3,569,030 pounds, valued at $272,413—a decrease in quantity of 4,226,445 pounds, or 54 per cent. The number of firms that reported active operations in Alabama in 1919 was 10, whereas in 1918 it was 25. The firms reporting were as follows:

Alabama Graphite Co., Ashland, Ala.
C. B. Allen Graphite Co., Ashland, Ala.
Clay County Graphite Co. (Inc.), Ashland, Ala.
Crystalline Flake Graphite Co., Birmingham, Ala.
Ceylon Co., Birmingham, Ala.
Diamond Graphite Co., Alexander City, Ala.
Flaketown Graphite Co., Mountain Creek, Ala.
Griesemer Graphite Co., Ashland, Ala.
May Brothers, Ashland, Ala.
Quenelda Graphite Corporation, Louisville, Ky.

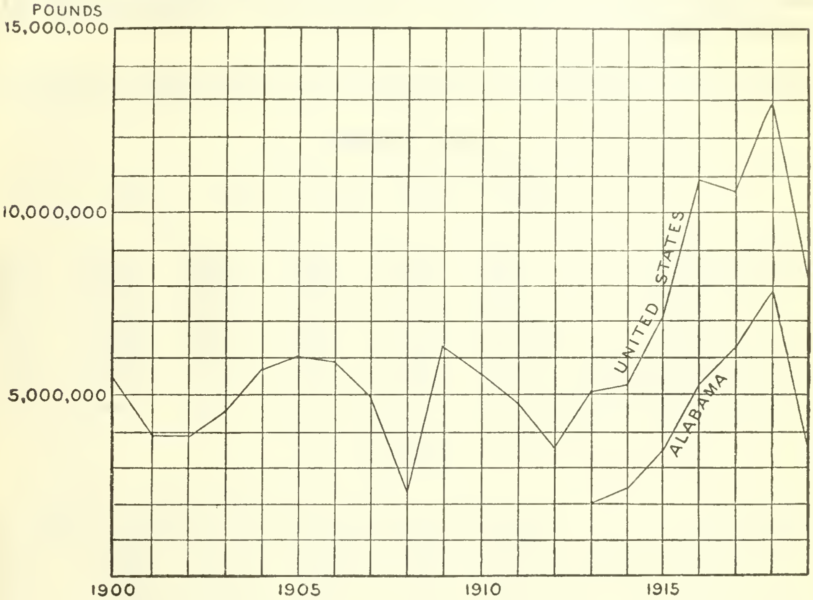

FIGURE 12.—Diagram showing production of crystalline graphite in the United States, 1900–1919, and in Alabama, 1913–1919.

New York ranked second in quantity but first in value of graphite sold in 1919. The figures can not be published without revealing individual production because there were only two producers—Hooper Bros., Whitehall, N. Y., and Joseph Dixon Crucible Co., Jersey City, N. J.

Pennsylvania producers reported sales of 484,060 pounds of graphite, valued at $26,003, in 1919. This was 532,840 pounds less than in 1918, or a decrease of 52 per cent; the value was 77 per cent less than in 1918.

The Pennsylvania producers were:

Graphite Products Co., Uwchlan, Pa.
T. D. Just Co., Chester Springs, Pa.
Rock Crucible Graphite Co., Jeanette, Pa.

Harry Schmehl, of Chester Springs, reported a small quantity of high-grade graphite recovered from old crucibles in 1919.

California reported one mine in operation in 1919. It is 20 miles from Palmdale in Los Angeles County and is owned by the California Graphite Co., of Los Angeles.

One operator at Burnet, Tex., produced crystalline graphite.

The following table shows the quantity and value of crystalline graphite imported into and produced in the United States since 1914, together with the percentage of the total supply represented by the domestic production. In 1918 imports decreased nearly 59 per cent from 1917, while domestic production increased approximately 22 per cent, and the ratio of domestic graphite produced in 1918 to imports for that year was about 48 per cent. Under this trade stimulus a large amount of new capital was invested and many new operators appeared in the graphite-producing States. In 1919, however, imports increased, especially from Madagascar; domestic production fell; and the ratio of production to imports was only 19.2 per cent.

Crystalline graphite imported into and produced in the United States, 1914–1919, by countries.

Quantity (short tons).

	1914	1915	1916	1917	1918	1919
Imports: [a]						
Ceylon	8,882	14,491	26,232	24,575	9,029	9,451
Madagascar	349	1,468	1,631	4,393	970	10,016
Other countries	1,852	3,036	4,297	3,494	3,314	1,505
	11,083	18,995	32,160	32,462	13,313	20,972
Domestic production	2,610	3,537	5,466	5,292	6,431	4,043
Total available supply	13,693	22,532	37,626	37,754	19,744	25,015
Percentage represented by domestic production	19.1	15.7	14.5	14.0	32.6	16.2

Value.

	1914	1915	1916	1917	1918	1919
Imports: [a]						
Ceylon	$972,408	$1,826,238	$6,356,532	$7,179,208	$2,397,735	$1,530,281
Madagascar	38,704	184,067	241,863	1,057,081	265,338	1,205,350
Other countries	96,180	119,572	335,736	353,481	270,136	102,390
	1,107,292	2,129,877	6,934,131	8,589,770	2,933,209	2,838,021
Domestic production	285,368	417,273	914,748	1,094,398	1,454,799	731,141
Total available supply	1,392,660	2,547,150	7,848,879	9,684,168	4,388,008	3,569,162
Percentage represented by domestic production	20.5	16.4	11.7	11.3	33.2	20.5

[a] Compiled from records of the Bureau of Foreign and Domestic Commerce. See page 313 for explanation of arrangement by country of origin.

AMORPHOUS GRAPHITE.

Sales of amorphous graphite in 1919 amounted to 3,379 short tons, valued at $47,716, which represents a decrease of 48 per cent in quantity and of 31 per cent in value from sales in 1918. Rhode Island, Colorado, and Nevada furnished the supply in 1919. The figures for each State may not be published without revealing individual production. The Graphite Mines Corporation, of New York, operated the mine at Providence, R. I.; Woodruff & Woodruff, of Greeley, Colo., reported production from their mine at Pitkin, Colo.; the Carson Black Lead Co., of Oakland, Calif., produced the Nevada output from its mine at Carson.

MANUFACTURED GRAPHITE.

The production of graphite manufactured by the Acheson Graphite Co., of Niagara Falls, N. Y., from 1915 to 1919, is given below, and the accompanying chart shows the development of this industry since 1897.

Graphite manufactured by the Acheson Graphite Co., 1915–1919.[2]

	Pounds.
1915	5,084,000
1916	8,397,281
1917	10,474,649
1918	9,182,272
1919	8,163,177

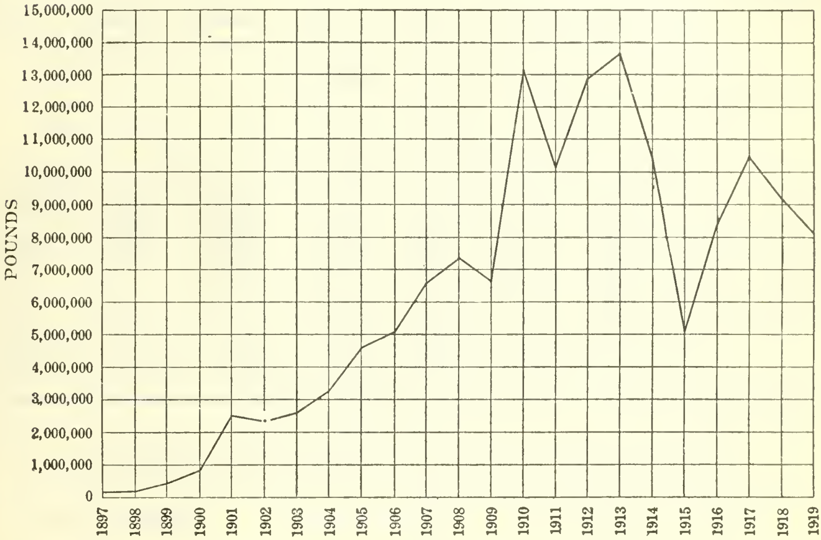

FIGURE 13.—Diagram showing production of manufactured graphite in the United States from the inception of the industry in 1897 to 1919, inclusive.

IMPORTS.

Statistics on graphite imports given in the following tables were obtained from the Bureau of Foreign and Domestic Commerce of the Department of Commerce. The reports of that bureau show only the country shipping the goods, which is not always the country of origin. For example, graphite entered in the bureau's statements as imported from France probably originated in Madagascar, and imports from Great Britain should probably be credited to Ceylon and, possibly, to Madagascar. Shipments from Japan probably consisted of graphite from Chosen. Imports from Canada in 1914, 1915, and 1919 slightly exceeded Canadian production in those years, and it is assumed that this excess represents reshipments of Canadian imports or of stocks. Imports of more doubtful origin are included under "Other countries."

[2] Figures published by permission of the Acheson Graphite Co.

Graphite imported into the United States, 1913–1919.[a]

[General imports.]

Country of origin.	Quantity (short tons).						
	1913	1914	1915	1916	1917	1918	1919
Ceylon	16,996	8,882	14,491	26,232	24,575	9,029	9,451
Madagascar		349	1,468	1,631	4,393	970	10,016
Canada	1,662	1,806	2,995	4,127	3,476	3,084	1,504
Brazil				1	18	45	
Mexico	4,435	4,259	1,680	5,331	7,570	5,600	5,506
Chosen (Korea)	4,170	6,327	2,373	5,375	2,462	568	126
Italy	236	254	27	151	115	17	22
Austria	660	78					
Germany	90						
Other countries	630	47	41	169		185	1
	28,879	22,002	23,075	43,017	42,609	19,498	26,626

Country of origin.	Value.						
	1913	1914	1915	1916	1917	1918	1919
Ceylon	$1,674,764	$972,408	$1,826,238	$6,356,532	$7,179,208	$2,397,735	$1,530,281
Madagascar		38,704	184,067	241,863	1,057,081	265,338	1,205,350
Canada	98,665	92,536	116,407	314,177	349,034	236,226	102,163
Brazil				75	4,380	7,351	
Mexico	198,000	190,075	75,000	238,000	285,568	134,183	135,464
Chosen (Korea)	58,199	96,433	35,292	103,619	83,558	24,455	3,948
Italy	4,061	3,203	994	4,133	3,092	628	663
Austria	9,957	1,258					
Germany	4,034						
Other countries	62,111	3,644	3,165	21,484	67	26,559	227
	2,109,791	1,398,261	2,241,163	7,279,883	8,961,988	3,092,475	2,978,096

[a] Compiled from records of the Bureau of Foreign and Domestic Commerce and arranged by countries of origin.

Graphite imported for consumption in the United States, 1910–1919.

Year.	Quantity (short tons).	Value.	Year.	Quantity (short tons).	Value.
1910	25,235	$1,872,592	1915	23,075	$2,241,163
1911	20,702	1,495,729	1916	42,930	7,279,884
1912	25,643	1,709,337	1917	42,577	8,961,988
1913	28,879	2,109,791	1918	19,498	3,092,475
1914	21,990	1,398,209	1919	26,626	2,978,096

EXPORTS.

Exports of graphite from the United States are comparatively small. A considerable increase of articles manufactured from graphite exported in 1915 and 1916 was accompanied by a corresponding decrease in exports of the raw material. In 1917 this condition was reversed by a 33 per cent decrease in value of manufactured articles exported and a 256 per cent increase in value of exports of the unmanufactured material. In 1918 the exports of both manufactured graphite and raw graphite decreased, the manufactured by 18 per cent and the raw by 65 per cent. In 1919 there was a small increase in exports of manufactured graphite and a slight decrease in exports of the crude material.

The exports of lead pencils are not included in the classification of articles of manufactured graphite. The statistics of the export of pencils are given in a separate table.

Graphite exported from the United States, 1913–1919.[a]

Year.	Unmanufactured graphite.		Manufactures of graphite.
	Quantity (pounds).	Value.	
1913	5,383,981	$391,906	$238,302
1914	3,920,693	277,386	215,878
1915	1,057,764	52,583	536,572
1916	1,595,608	98,118	1,339,259
1917	5,146,816	349,563	891,687
1918	1,907,719	121,555	731,518
1919	1,258,040	90,185	788,755

[a] Compiled from records of the Bureau of Foreign and Domestic Commerce.

Value of pencils and pencil leads exported from the United States, 1918–1919.[a]

Country.	1918	1919	Country.	1918	1919
France	$32,326	$75,375	China	$17,905	$50,062
Italy	77,240	45,498	British India	65,088	143,452
Spain	179,706	104,411	Straits Settlements	10,148	16,224
England	542,720	1,062,888	Dutch East Indies	33,037	41,429
Canada	425,927	415,926	Japan	50,740	70,552
Mexico	104,154	207,573	Australia	155,157	180,500
Cuba	127,177	192,600	New Zealand	20,134	26,311
Argentina	166,069	182,049	Philippine Islands	96,525	140,947
Brazil	110,741	202,637	British South Africa	76,901	71,789
Chile	58,198	49,251	Other countries	85,816	195,722
Colombia	12,807	19,002			
Peru	26,806	27,479		2,497,208	3,565,347
Uruguay	21,886	43,670			

[a] Compiled from records of the Bureau of Foreign and Domestic Commerce.

PRICES.

Prices in 1919 for domestic flake ranged between 4.9 cents and 14 cents a pound. In 1918 the corresponding figures were 7 and 17¾ cents.

The average price of domestic flake at the mines in 1919 was 9 cents a pound, or 2.3 cents less than in 1918. In New York the average price per pound in 1919 was 11½ cents, against 8.4 cents in 1918. Producers in Texas averaged 10 cents a pound for their graphite in 1919 and 7.9 cents in 1918. In Alabama, however, the average price dropped from 12.8 cents in 1918 to 7.6 cents in 1919; and in Pennsylvania prices dropped from 11 cents in 1918 to 5.4 cents in 1919.

Prices were reported higher during the first part of 1919, following upon the higher prices reported during the last part of 1918.

The following table, showing the prices of Ceylon graphite for the years 1914–1919, is based on information furnished by importers:

Average prices of Ceylon graphite c. i. f. New York, 1914–1919.

[Cents per pound.]

Year.	Lump		Chip		Dust.		Remarks.
	First grade.	Second grade.	First grade.	Second grade.	First grade.	Second grade.	
1914	6½- 9½	7½- 8½	7¼- 7¾	6½- 7	4¾- 5¼	3½- 4	Low, first half; high, second half.
1915	9⅝-20	8 -14	7 -14	6½-12	7½-9½	6½- 9½	Do.
1916	20 -28	14 -21	13½-20	11½-17	9½-12	9½-10	Do.
1917	28 -32	21 -23	20 -23	17 -19	11 -13	10 -12	High level maintained throughout the year.
1918	28½-15¼	22 -14	21½-12½	18½-11	12 -10½	10 - 9	High, first half; low, second half.
1919	14 -15¼	12 -13	10 -11	8 - 9	6¾- 7½	5 - 6	Low throughout the year.

WORLD'S PRODUCTION.

The following table and the diagram on page 317 are taken from a report on foreign graphite in 1919, by Arthur H. Redfield, published as a separate chapter in Mineral Resources of the United States for 1919:

World's production of natural graphite, 1913–1919, in metric tons.

Country.	1913	1914	1915	1916	1917	1918	1919
United States: [a]							
Amorphous	2,035	1,565	1,071	2,378	7,530	5,951	3,065
Crystalline	2,297	2,368	3,209	4,959	4,801	5,834	3,668
Canada [a]	1,961	1,495	2,391	3,588	3,369	2,826	1,199
Mexico [b]	4,023	3,865	1,525	4,836	6,869	5,080	4,995
Brazil [b]	2½	....	2	1	15	45	2
Austria and Styria	17,282	11,062	14,815	[c] 21,000	[c] 18,000	17,415	[c] 17,000
Bohemia and Moravia	32,175	26,973	20,231	26,313	29,073	27,355	31,234
France	1,194	300	....	....	1,650	2,132	375
Germany	12,057	13,619	17,292	30,574	42,825	64,080	([d])
Italy	11,145	8,567	6,176	8,182	12,117	11,653	7,626
Spain	....	....	30	1,240	1,980	710	1,958
Sweden	88	56	87	194	4	102	....
Ceylon [b]	28,996	14,463	22,173	33,956	27,572	15,701	6,504
French Indo-China [b]	....	....	....	....	8,000	15,000	([d])
British India	....	....	71	1,525	105	82	129
Japan	667	573	666	1,149	1,331	1,886	([d])
Chosen (Korea) [b]	14,543	9,149	7,044	16,963	16,183	13,659	[c] 12,000
Madagascar	7,997	11,232	15,940	26,524	35,000	16,000	2,000
Union of South Africa	35	31	37	55	78	72	78
Australia	....	7	71	72	89	208	102
Total	136,497½	105,325	112,831	183,509	216,591	205,791	....

[a] Shipments and sales. [b] Exports. [c] Estimated. [d] No data.

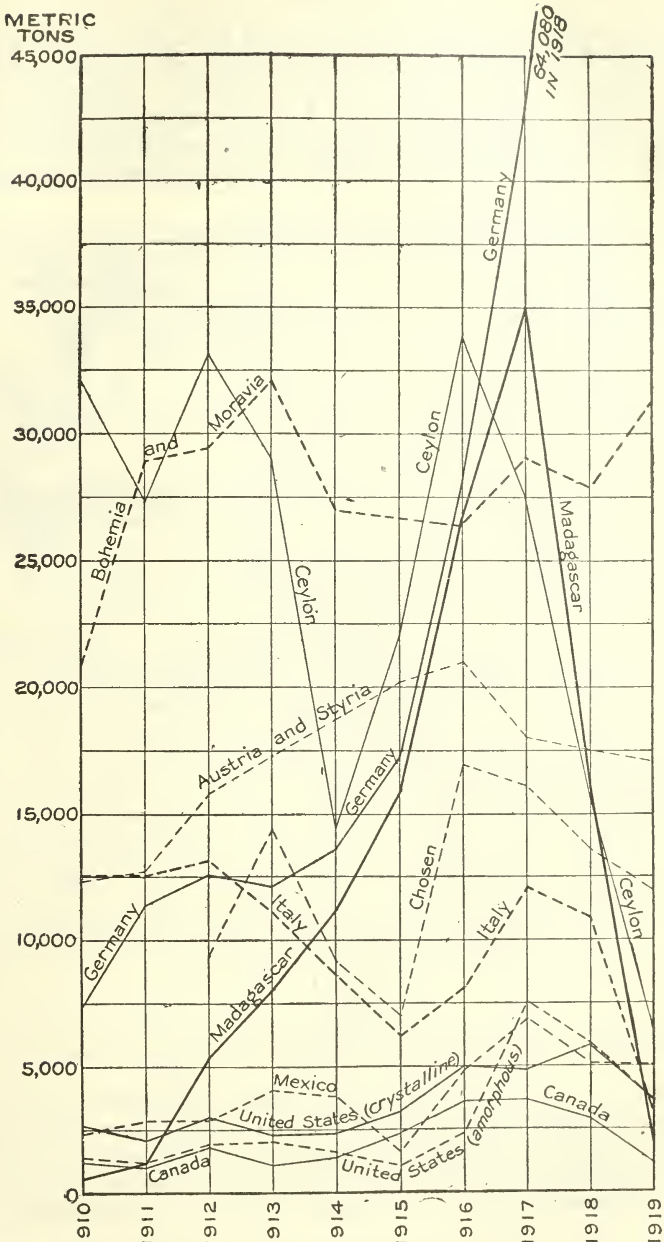

FIGURE 14.—Diagram showing production of graphite in principal countries, 1910–1919.

HISTORY OF GRAPHITE MINING IN PENNSYLVANIA.

By F. Bascom.

Graphite has been mined intermittently from an early date in the gneiss of Pickering Valley, Chester County, Pa. Many graphite-mining companies have had a brief existence, succeeding earlier companies, and in turn being succeeded by later companies; graphite properties have thus changed hands with a rapidity which renders it difficult to keep track of the history of the graphite industry in Chester County.

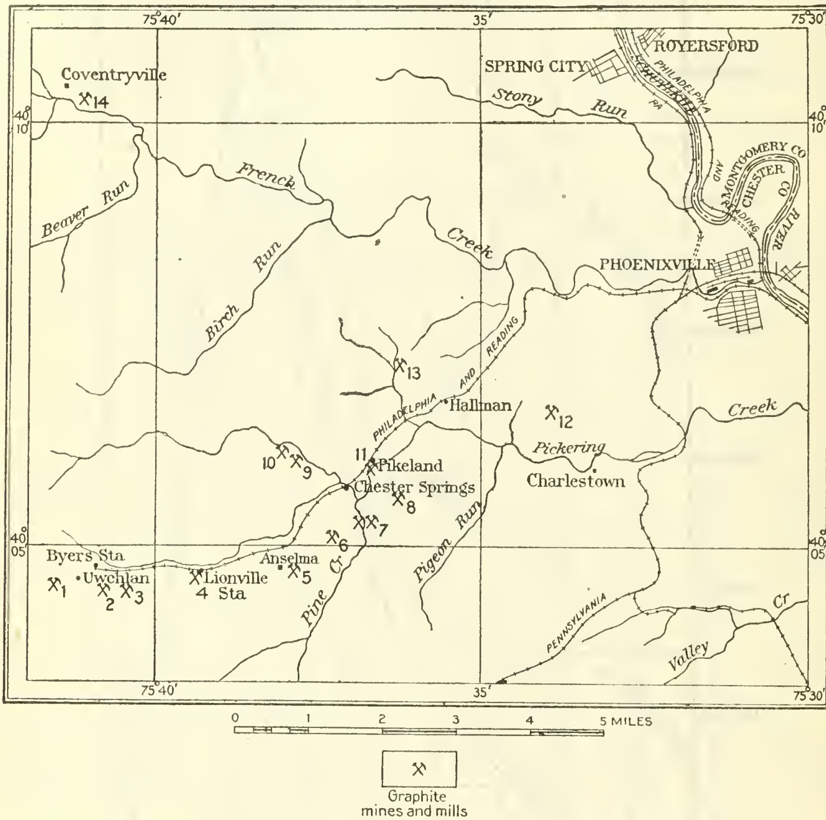

Figure 15.—Map showing location of graphite mines and mills in Chester County, Pa.

The mines are for the most part in a belt of graphite-bearing calcareous gneiss which extends from Byers to Charlestown and northeast. The history of graphite mining in this belt will be given by localities, beginning at the southwest end of the belt. Numbers heading paragraphs refer to locations on the accompanying map (fig. 15).

1. The first attempt to mine graphite at a locality five-eighths of a mile west-southwest of Byers (Uwchlan post office) was made in 1882 by the Eagle Plumbago Co. on property adjoining the site of the present mine. The ore was hauled to concentrating mills at

Lionville. This enterprise was early abandoned. In May, 1906, the Continental Graphite Co. was incorporated, and the following December a mill was erected and a tunnel cut into the hill. In 1909 this company discontinued operations and sold out to the Acme Graphite Co., which rebuilt the mill and operated the mine until December, 1910. Recently the property was sold to John C. Hill, of New York, but the old name is retained. The mine was idle in 1920. The graphite-bearing beds are coarsely crystalline calcareous gneiss and a micaceous gneiss striking N. 85° E. and dipping 45° S. An inclined shaft following the dip of the beds has east and west drifts.

2. One of the oldest graphite mines in Pickering Valley is one-fourth of a mile south of Byers station (Uwchlan post office). The mine was first worked in the seventies by the Pennsylvania Graphite Co. In 1880, when the company's name was changed to the Pennsylvania Graphite Mining & Manufacturing Co., it was the only graphite mine operating in the county. In 1881 the property was sold to the Pennsylvania Plumbago Co. In 1889 the American Plumbago Co., which at that time owned the adjoining mining property (Pettinos Bros.), leased and worked one of the open cuts. That company soon gave up the lease, and Bullitt, Edmonds & McIntyre purchased the property and put up the mill which now stands on the hill close to the inclined shaft sunk by them. In 1903 the property was bought by J. P. McCaren, who organized the Pennsylvania Graphite Co. and operated the mine until 1904, when the United States Graphite Co. leased the property at an excessive rental and 10 per cent royalty on sales. This company built an expensive new mill at the foot of the hill near the road, but in 1907 ceased operations with expenses exceeding the value of sales. In the summer of 1908 the lease was annulled for nonpayment of rental and an injunction was issued restraining the United States Graphite Co. from using the name because of its prior use by a Michigan company. The Imperial Graphite Co., newly incorporated, took over the new mill. The old mill and mine remained idle until 1910, when they were sold to the Acme Graphite Co., which had purchased the property to the west. That company operated this mine during the summer and fall of 1910 and closed it in December. Until 1915 the mine was idle, with the Pennsylvania Graphite Co. again in possession (from 1911) and maintaining a watchman, who kept the water pumped out. From 1915 to 1919 the Graphite Products Co. (John A. Lilly in charge) operated this mine. At the present date (1921) the mine is idle. The mill was burned in 1913 and rebuilt in the summer of 1914. In 1920 it was struck by lightning and damaged by fire but not burned down. The graphite-bearing beds, a coarsely crystalline calcareous gneiss and a micaceous gneiss, aggregate about 75 feet in thickness, of which only 10 feet is rich enough to pay for working. The beds strike N. 85° E. and dip 45° SE. The beds are cut by several faults and by abundant pegmatite dikes which are for the most part barren of graphite. The percentage of graphite in the ore is very irregular, ranging between 4 and 8 per cent and rarely reaching 10 per cent. An inclined shaft follows the dip to a depth of 70 feet and vertically to 154 feet, with drifts to the east aggregating 900 feet, and to the west aggregating 800 feet, of which only 300 feet are accessible owing to caving in of the walls. There

are in addition several open pits, earlier abandoned but reopened in 1918 for the quarrying of the ore.

3. The oldest graphite mine in Pickering Valley and in Chester County is a quarter of a mile east of the Pennsylvania Graphite Co.'s mines. It was first operated in 1860, when it was known as the Phoenix graphite mine. In 1894 the property was first leased and subsequently purchased by the Pettinos Bros., and was operated continuously for four years. Since 1899, when the mill was destroyed by fire and rebuilt, the mine has been operated only intermittently. The ore was concentrated in the mill on the premises and shipped to the refining mill of Pettinos Bros. at Bethlehem. In 1903 the mill was again burned and was later rebuilt, and in 1911 the plant was in operation. In 1915 the property was leased to the Tonkin Graphite Co., which built a new mill and operated the mine until 1918, when it was leased to E. C. Hargrave, who operated the mine a short time. At the present date (1921) the mine is idle. The graphite is in the same belt of graphitic gneiss that is mined at localities 1 and 2 and, it is claimed, constitutes 5 to 6 per cent of the ore. The graphite-bearing calcareous gneiss or crystalline limestone is about 10 feet thick 70 feet below the surface. There is a large open cut in which the gneiss is so thoroughly disintegrated that little of the original rock or original structures can be seen; kaolin, quartz, limonite, marcasite, chloropal, chlorite, epidote, and zoisite are decomposition products and pyrite and tremolite are original metamorphic minerals. There are also several small pits and one shaft. The latest mining was done in an open cut. The ore is in some places of high grade, but is unevenly distributed. Both here and on the property to the west the ore is so much weathered that it is easily worked.

4. About one-eighth of a mile west of Lionville station, on property belonging to J. H. Dewees, a prospecting shaft was sunk and a drift cut into the hill. No mill was erected, and the mine was soon abandoned. The property has been leased to the Pickering Valley Graphite Co., but is not utilized for mining.

5. About one-sixth of a mile east of Anselma village are the mine and mill of the National Graphite Co., since reorganized under the name Anselma Graphite Co. The mine was first opened in 1905, but was operated for only a short time. In 1910 it was worked once more and again soon abandoned. The property was later purchased by John A. Lilly, but the mine and mill are at present idle. Here the graphite-bearing rock is hard and relatively undecomposed, consisting largely of quartz and graphite and some kaolinized feldspar. The separation of the graphite from the quartz proved an obstacle. The ore mined in 1905 was reported to carry 6 to 8 per cent of graphite. In 1906 the output averaged 1 ton of graphite daily, separated by the dry method. The footwall of the mine is a fine-grained pre-Cambrian diabase dike; the hanging wall is a coarse-grained, very quartzose gneiss.

6. Prospecting along the strike of the same graphite-bearing beds has been done by the Consolidated Graphite Co. three-fourths of a mile northeast of Anselma, without further development. The T. D. Just Graphite Co. leased a property in this vicinity, erected a mill about 1912, and operated fairly steadily up to the fall of 1919, when operations ceased and the property reverted to the bondholders.

It was subleased by them to Harry Schmehl, who for a year operated a mill, refining ore from this and the neighboring property (No. 7) and recovering graphite from old crucibles. The ore on this property was dug with pick and shovel in the deeply weathered rock of an open cut.

7. The Philadelphia Graphite Co. opened a mine five-eighths of a mile south-southeast of Chester Springs in 1896. In 1901 the mine changed hands, but operations were continued under the same name. In 1903 it again changed hands and the New Philadelphia Graphite Co. was organized. Later the Keystone Graphite Co. took possession and leased the property in 1907 to the Chester Graphite Co., which operated the mine and mill until the fall of 1910, when the lease was given up. The property has been idle since that date, except for two years when it was leased to Harry Schmehl. The graphite-bearing beds are reported to be about 30 feet thick, and the ore carries about 6 to 10 per cent of graphite. The rock is a decomposed gneiss and coarsely crystalline limestone striking N. 25° E. and dipping 35° SE. Pegmatite dikes near the contact with the gneiss contain graphite in large flakes or as amorphous powder in small pockets. Besides the shaft there are two open cuts, in which the ore is soft enough to be worked with pick and shovel.

The Chester Graphite Co., now known as the Paragon Graphite Works, refines crystalline graphite obtained from Alabama, Ceylon, and elsewhere, and manufactures a high-grade product (nearly 100 per cent graphite) suitable for flake graphite and graphite lubricants. The mill and property of this company are just west and across the road from the mine which the company formerly leased. This plant was the only one active in Pickering Valley in 1920 and it still continues to operate.

8. About three-quarters of a mile east of Chester Springs and a quarter of a mile northeast of the Keystone Graphite Co. property the Federal Graphite Co. operated and abandoned a mine before 1900. In 1903 the mill was destroyed by fire and rebuilt. In July, 1909, the company was reorganized as the Federal Carbon Co., and in 1911 the mine was pumped out and put in condition for operating. The Federal Carbon Co. was succeeded by the Standard Carbon Co. The ore beds are the continuation of those formerly mined by the Chester Graphite Co. and strike N. 45° E. and dip 40° SE. The gneiss is decayed and contains 3 to 7 per cent of graphite, with pegmatitic and granitic injections containing graphite in contact with the gneiss. The workings consist of an open cut, a vertical shaft, and a tunnel.

9. Three-quarters of a mile northwest of Chester Springs there is a graphite mine which was opened in September, 1903, by driving a tunnel 400 to 500 feet into the hill. The ore carried an average of 4 to 5 per cent of graphite and yielded 8 tons of finished material daily from 200 tons of raw material. Flake graphite for crucibles was produced. The mill and mine were first operated by Wayne C. P. Parker and subsequently by Charles W. Snyder. In 1904 the property was purchased by the Sterling Graphite Co., which erected a mill in 1906–7 and began operations in the fall of 1907. The mine has been operated intermittently. In 1910 the property was sold to the Rock Graphite Mining & Manufacturing Co., which operated up to November, 1916. Since that time the mine has been idle. The ore is a gneiss which has undergone but little de-

composition and is composed of quartz, feldspar, biotite, graphite, and pyrrhotite. The beds strike nearly north and dip east. The ore is mined in an open pit.

10. Adjoining the Rock Graphite Mining & Manufacturing Co.'s property on the northwest is the mining property of the Crucible Flake Graphite Co., locally known as the Parker Graphite Co. (Wayne C. P. Parker). The company was incorporated in 1905. A mill with expensive machinery and electric power was erected in 1906 and closed in 1907. In 1918 the property was again operated by the Rock Crucible Graphite Co., and new machinery was installed. The mill was shut down in the fall of 1919 and the machinery was removed in the spring of 1920. Since this date the mine has been idle. The graphite-bearing rock is the same as that on the adjoining property (No. 9).

11. The Graphite Mining Co. has owned property at Pikeland, where a little ore has been mined and refined elsewhere. There is no mill on the property.

12. About 2½ miles northeast of the Federal Carbon Co.'s property and 1 mile northwest of Charlestown is the property of the Phoenix Hill Graphite Co., later known as the American Flake Graphite Co. This company started the mine and mill in 1908 and operated intermittently until the spring of 1911. Since that time the mine has been idle and the mill is dismantled. An open cut shows a fine-grained gneiss with numerous pegmatite dikes striking N. 10°–15° E., and dipping 35°–50° SE.

13. Half a mile northwest of Hallman station, on C. C. Walker's farm, a graphite mine was opened and a mill equipped in 1905 by the Husbands Graphite Co. The plant was operated one year, and in 1907 passed into the hands of the Girard Graphite Co., which worked it about a year. In the spring of 1911 the property was sold by the sheriff and the mill dismantled. Since then the plant has been idle. The graphite occurs in a calcareous limonitic gneiss, originally pyritiferous. Large flakes of graphite one-quarter of an inch in diameter have been found here. A limonite ore pit and an outcrop of the Franklin limestone occur just west and north of the graphite mine.

14. In French Creek valley a quarter of a mile southeast of Coventryville on the north side of the creek are the mine and concentrating mill of the Eynon-Just Graphite Co. As owner of this mill the Eynon-Just Co. succeeded the Imperial Graphite Co., which took over the new mill from the United States Graphite Co. and found itself with a mill and no mine. The Eynon-Just Co. bought the property in June, 1911, and in December reported a daily output of 50 tons of hard rock, averaging 15 per cent of graphite. The ore bed is 24 feet thick. The graphite was separated in a mill at the mine and finished in the new mill of the United States Graphite Co. at Byers. This plant was not operating in 1920, and the mill at Byers is in disrepair.

LITERATURE.

The following is a list of important papers on graphite:

1. ALLING, H. L., The Adirondack graphite deposits: New York State Mus. Bull. 199, Albany, 1918.

    In addition to the excellent description of the New York deposits the report contains much of general interest. The method of microscopic analysis developed by the writer is especially valuable. The microscopic analyses check surprisingly well with the chemical analyses where both are given and yield information as to the type of gangue minerals which is of great value to the miner and which is not shown by the chemical analysis.

2. BLEININGER, A. V., Notes on the crucible situation: Metal Industry, vol. 16, pp. 15–16, January, 1918.

    The article contains a short discussion of the adaptability of graphite of different types to crucible manufacture and a detailed study of the properties of crucible clays.

3. DUB, G. D., Preparation of crucible graphite: Bur. Mines War Min. Inv. Ser. 3, December, 1918.

    This paper is one of the most valuable contributions to the subject of graphite technology. A detailed review of mining conditions in Alabama, New York, Pennsylvania, and Texas is given. The various concentration processes are described in detail. The different methods in use are illustrated by flow sheets of typical mills and numerous sketches, and their efficiency is compared. Chemical and mechanical analyses of the finished products are given, and the author makes valuable recommendations for a standard grade of No. 1 flake and improved methods of sampling.

4. FERGUSON, H. G., Graphite in 1918: U. S. Geol. Survey Mineral Resources, 1918, pt. 2, pp. 223–265, 1919.

5. LEIGHOU, R. B., Chemistry of materials of the machine and building industries, New York, 1917.

    Contains notes on the use of graphite in foundry facings, paints, and lubricants.

6. MILLER, B. L., Graphite: Mineral Industry, 1919, pp. 314–328, 1920.

    A short review of the domestic and foreign graphite industry during 1919, with tables of production and imports.

7. MOSES, F. G., Refining Alabama flake graphite for crucible use: Bur. Mines War Min. Inv. Ser. 8, December, 1918.

    Results of experiments in raising low-grade concentrates to a flake of 90 per cent grade. Tests were made with an aspirator, pneumatic jig, pebble mill, electrostatic separator, oil flotation, and burr mill. The processes recommended are a dry process, consisting of treatment in the electrostatic separator followed by grinding in the burr mill and screening, and a wet process, involving crushing in the pebble mill, concentration by oil flotation, drying, and final grinding in the burr mill, followed by screening. The burr mill was found to be a necessity in the finishing process, where a 90 per cent product was required.

8. NEWLAND, D. H., The mining and quarry industry of New York State: New York State Mus. Bull. 196, 1918.

    Graphite, pp. 259–262. Contains description of the mine of the Joseph Dixon Crucible Co. at Graphite, the mines of the Graphite Products Corporation near Saratoga Springs, and the Hooper Brothers' mines near Whitehall.

9. ROWE, R. C., Concentration of graphite ores, past and present: Canadian Min. Jour., vol. 41, No. 33, pp. 676–679, 1920.

10. SEARLE, A. B., Refractory materials, their manufacture and uses, London, 1917.

    Contains notes on the use of graphite in the manufacture of crucibles, fire bricks, and other refractory products.

11. SPEARMAN, CHARLES, The graphite industry: Canadian Min. Jour., vol. 40, pp. 87–88, Feb. 12, 1919.

    Proposes the following flake standards: No. 1 flake should all be above 90-mesh in size, and over half should rest on a 50-mesh screen, and it should contain 85 to 90 per cent graphitic carbon; No. 2 flake should pass through 90-mesh and rest on 120-mesh standard screen. States that experiments showed that 100 grams of Alabama flake, shaken down, occupies 150 cubic centimeters, and the same weight of Canadian flake, 135 cubic centimeters, while 100 grams of Ceylon graphite occupies only 91 cubic centimeters.

12. SPENCE, H. S., Graphite: Canada Dept. Mines, Mines Branch Bull. 511, 202 pp., 1920.

A report on the graphite industry in Canada, with details relating to the occurrence, distribution, refining, and uses of graphite, and a chapter on the world's supply and production.

13. TORONTO UNIVERSITY, DEPARTMENT OF MINING ENGINEERING, Preliminary report of an investigation into the concentration of graphite from some Ontario ores: Canadian Min. Jour., vol. 40, pp. 189–197, 1919.

Describes a series of experiments in a simple wet process of concentration, the final product of which is a flake which is thicker, has a larger proportion of the coarser sizes, and is more brilliant in appearance than flake that is finished by a dry grinding process.

14. WILSON, M. E., Graphite in Port Elmsley district, Lanark County, Ontario: Canada Geol. Survey Summary Report, 1917, pt. E., pp. 29–42, 1918.

Consists chiefly of a geologic description of the Globe mine. The workable graphite ore occurs on the crest of an anticline, in silicified limestone, associated with intrusive pegmatite. This position of the graphite ore and its association with the completely silicified limestone are evidences that the original source of the graphite was the carbonate of the limestone, dissociated by the intrusive pegmatite.

CONCRETE STONE AND CONCRETE BLOCKS.

By G. F. Loughlin and M. E. McCaslin.

INTRODUCTION.

The materials discussed in this report are movable concrete products as distinguished from concrete poured during the construction of buildings and pavements. Compilation of statistics on concrete stone and blocks was begun in 1917, when requests for reports of production were sent to 3,200 persons or firms whose names had been obtained from various sources as supposed manufacturers of these products; replies were received from 1,295. In 1918 requests were sent to 2,830 firms or individuals; 1,962 responded. In 1919 about 4,000 additional names were furnished to the Geological Survey, mostly by cement companies, and 5,754 requests were sent, but only 1,511 reports of actual production were received.

The result of this canvass for three years shows that a large number of people have made concrete products on a small scale and have either moved or gone out of the business at the end of one season. It has been impossible to procure reports from many of them. This report more closely represents the industry than that for 1917 and 1918. According to the replies received, 609 firms were active in 1917, 920 in 1918, and 1,511 in 1919. This increase consists in part of new producers and in part of firms that were not known to the Geological Survey as producers prior to 1919. Many of these firms were apparently unaccustomed to preparing reports of production, and it was necessary for the Survey to write to some of them two or three times in order to get satisfactory statements. This has caused much delay in tabulation, some revised returns for 1919 being received as late as December, 1920.

The producers who reported output in 1919 were distributed among the following groups of States: New England, 24; Middle Atlantic, 96; Southeastern, 36; East Central, 609; West and South Central, 724; Western, 22. Of these 1,511 firms, 61 reported sales of architectural stone, 1,140 of concrete blocks, 76 of concrete brick, and 117 of silo blocks and staves.

This report on concrete products is supplemental to the regular annual reports on natural stone, cement, and sand and gravel, and the figures contained in it are not added to the annual summary of mineral resources of the United States, because that would involve duplication of both aggregate and cement.

DEFINITION OF TERMS.

The term "concrete" as usually understood implies a compact mass of sand and gravel or crushed stone bound together by Portland cement. In this report concrete molded into various shapes is discussed under different heads determined by shape or use of the blocks. These divisions are architectural concrete stone, concrete blocks, bricks, silo blocks and staves, and miscellaneous products.

Architectural concrete stone includes material of various shapes and sizes, which serves the same purpose as natural cut stone and terra cotta in the facings and trimmings of the larger and more elaborate buildings. These blocks are molded and faced so as to imitate cut stone.

Concrete blocks are molded by hand or machine, are solid or hollow, usually rectangular, and are used principally for foundations, partitions, and walls, or as facings and trimmings of dwellings and other small buildings, and serve the same purpose as rubblestone, brick, and monolithic concrete.

Concrete brick are small, rectangular, solid concrete blocks, and serve the same purpose as common clay brick.

Silo blocks are rectangular or slightly curved concrete blocks specially designed for the construction of silos.

Silo staves are long, thin, slightly curved concrete slabs used in the construction of silos.

Miscellaneous products include such articles as tile, fence posts, burial vaults, and lawn decorations.

CONDITION OF THE INDUSTRY.

In 1919, in spite of an apparent increase in the production of architectural stone, concrete blocks, and brick, as shown in the accompanying tables, the concrete industry, in common with many other manufacturing industries, faced very discouraging conditions. The demand for these products was pressing, but, owing to labor troubles, lack of transportation, and high prices, many producers reported that they would discontinue operations until conditions were more favorable. Others continued to operate intermittently. The general state of the industry is illustrated by the comment of one firm, which reported that plants were closing because of shortage of cars and consequent shortage of aggregate, whereas the stock on hand was 25 per cent less than in 1918 and the demand was probably eight times what it was then.

The cost of aggregate was very high during 1919. Cement also was very costly, and at times very difficult to obtain. Furthermore, freight rates were excessive and freight service so poor as greatly to hamper receipt of raw material and delivery of completed product. All these conditions tended to decrease general building throughout the country, and the concrete-block industry therefore was far from prosperous.

PRODUCTION.

The production of architectural concrete stone in 1917 and 1918 was reported in cubic feet, and blocks and brick were combined and reported by numbers. The number of producers using different kinds of aggregate was shown, but no report was given on the quantities of aggregate used. In 1919 figures were obtained in greater detail and it was possible to separate blocks, brick, and silo blocks and staves and to report their quantity in cubic feet, rather than by number, although the number of brick is given also. For miscellaneous products, such as fence posts, burial vaults, lawn ornaments, and tile, only the value is given, because these products were reported in various units and their quantity can not be adequately expressed.

As the list of producers for 1919 is more complete than for 1917 and 1918, no satisfactory comparison can be made with the figures for those years. Such comparison as is warranted is given in the discussion of the different products.

The statistics presented in the tables indicate the quantity sold by the manufacturers during the year. The value for these manufactured products is that received by the producer free on board at point of shipment. The average value per unit was obtained by dividing the total value by the quantity.

According to reports received from 1,511 producers in 1919, there was an apparent increase in the total production and value of all products represented, compared with 1917 and 1918. The total value of all products in 1919 was $7,901,105, as compared with $3,372,277 in 1918. As stated above, however, this represents, in part at least, a more complete canvass of the industry and not the actual increase in the amount of business done. Because the results of the canvass for 1917 and 1918 were incomplete, and therefore not comparable with those for 1919, the tables for these years are not repeated in this report.

Production is shown in these tables in as much detail as possible without disclosing individual output.

Concrete stone produced and sold

State.	Architectural stone. Quantity (cubic feet).	Architectural stone. Value. Total.	Architectural stone. Value. Average per cubic foot.	Concrete blocks. Quantity (cubic feet). Net.	Concrete blocks. Quantity (cubic feet). Gross.	Concrete blocks. Value. Total.	Concrete blocks. Value. Average per gross cubic foot.
New England States:							
Connecticut	(a)	(a)	(a)	(b)	(b)	(b)	(b)
Maine	....	....	....	24,818	31,723	$10,712	$0.34
Massachusetts	a 74,764	a $271,085	a $3.64	b 126,020	b 162,930	b 64,582	b .40
New Hampshire	....	....	....	(b)	(b)	(b)	(b)
Rhode Island	(a)	(a)	(a)	(b)	(b)	(b)	(b)
	74,764	271,085	3.64	150,838	194,653	75,294	.39
Percentage of total	11.9	22.0	....	1.0	1.0	1.4	....
Middle Atlantic States:							
Maryland	....	....	....	49,810	64,753	21,503	.33
New Jersey				298,913	338,587	173,417	.51
New York	151,276	344,553	2.28	608,017	788,772	287,130	.36
Pennsylvania				337,078	432,367	137,990	.32
	151,267	344,553	2.28	1,293,818	1,624,479	620,040	.38
Percentage of total	24.0	27.6	....	10.6	10.4	11.9	....
Southeastern States:							
Florida	9,300	9,210	.99	87,754	112,824	43,922	.39
Georgia	....	....	....				
Kentucky	(a)	(a)	(a)	108,093	140,291	50,988	.36
Mississippi	....	....	....	14,994	19,492	8,580	.44
Tennessee	....	....	....				
Virginia	....	....	....	20,610	26,793	8,880	.33
West Virginia	a 77,160	a 95,215	a 1.23	95,766	124,496	46,261	.37
	86,460	104,425	1.21	327,217	423,896	158,631	.37
Percentage of total	13.6	8.4	....	2.7	3.0	3.0	....
East Central States:							
Illinois	18,767	29,228	1.58	1,314,051	1,703,535	582,738	.34
Indiana				1,145,995	1,487,764	453,561	.30
Michigan	60,941	99,181	1.63	1,237,974	1,592,145	466,841	.29
Ohio	77,550	122,260	1.58	1,805,679	2,435,599	967,281	.40
Wisconsin				781,260	1,010,260	283,767	.28
	157,258	250,669	1.59	6,374,959	8,229,303	2,754,188	.33
Percentage of total	24.9	20.0	....	52.1	52.4	52.9	....
West Central and South Central States:							
Arkansas	....	....	....	58,040	76,667	21,283	.28
Iowa	27,315	45,487	1.67	1,058,434	1,368,689	431,254	.32
Kansas				220,207	284,902	70,888	.25
Louisiana	....	....	....	1,068,517	1,315,050	334,712	.25
Minnesota	23,260	18,260	.79				
Missouri	a 75,525	a 152,460	a 2.00	69,248	88,244	31,290	.35
Nebraska	(a)	(a)	(a)	1,267,380	1,642,490	538,671	.33
North Dakota	....	....	....	(b)	(b)	(b)	(b)
Oklahoma	....	....	....	189,120	245,610	86,762	.35
South Dakota	....	....	....	b 32,662	b 41,992	b 18,220	b .43
Texas	(a)	(a)	(a)	42,680	48,797	32,011	.66
	126,100	216,207	1.71	4,006,288	5,112,441	1,565,091	.36
Percentage of total	20.0	17.0	....	33.0	33.0	30.1	....
Western States:							
Arizona	....	....	....	(b)	(b)	(b)	(b)
California	18,064	19,439	1.08	43,517	56,572	22,375	.40
Colorado				12,679	16,317	5,954	.36
Montana	....	....	....	....	....	....	....
Oregon	(a)	(a)	(a)	(b)	(b)	(b)	(b)
Utah	....	....	....	5,818	7,563	2,943	.39
Washington	a 16,975	a 41,923	a 2.47	b 9,400	b 12,136	b 3,456	b .28
	35,044	61,362	1.75	71,414	92,588	34,728	.36
Percentage of total	5.6	5.0	....	0.6	0.6	0.7	....
	630,893	1,248,301	1.98	12,224,534	15,677,360	5,207,972	.33

[a] Architectural stone for Connecticut and Rhode Island is included under Massachusetts, Kentucky under West Virginia, Nebraska and Texas under Missouri, and Oregon under Washington.

[b] Concrete blocks for Connecticut, New Hampshire, and Rhode Island are included under Massachusetts, North Dakota under South Dakota, and Arizona and Oregon under Washington.

in the United States in 1919.

Concrete brick.				Silo blocks and staves.			Total, excepting miscellaneous products.		Miscellaneous products (value).	Total value.
Quantity.		Value.		Quantity (cubic feet).	Value.		Quantity (cubic feet)	Value.		
Cubic feet.	Number.	Total.	Average per M.		Total.	Average per cubic foot.				
							9,856	$141,950	(c)	$142,113
4,059	102,000	$1,929	$19				35,782	12,641		12,641
68,613	1,715,335	27,537	16				252,898	195,431	c $2,143	197,411
							36,899	18,312		18,312
							6,654	7,511		7,511
72,672	1,817,335	29,466	16				342,089	375,845	2,143	377,988
47.9	48.4	44.2					2.0	5.2	3.0	4.8
							64,753	21,503	12,280	33,783
30,700	767,502	12,280	16				377,387	248,737		248,737
				9,251	$4,495	$0.49	893,940	505,464		505,464
							479,617	205,664	3,819	209,483
30,700	767,502	12,280	16	9,251	4,495	.49	1,815,697	981,368	16,099	997,467
20.0	20.1	18.4		1.2	0.7		10.0	13.7	2.0	12.6
d 6,904	d 172,598	d 2,725	d 16				123,288	52,982	10,080	63,062
							4,836	2,400		2,400
(d)	(d)	(d)	(d)				142,895	52,653		52,653
							3,960	2,250	1,045	3,295
							15,532	6,330		6,330
							26,793	8,880		8,880
							199,956	140,286		140,286
6,904	172,598	2,725	16				517,260	265,781	11,125	276,906
4.6	4.6	4.1					3.0	3.7	1.5	3.5
4,268	67,450	1,782	26	98,934	76,393	.77	1,823,504	688,641	229,308	917,949
2,631	70,800	1,255	18	220,276	258,521	1.17	1,712,671	714,837	38,002	752,839
3,914	125,2'0	1,676	13	66,279	40,532	.61	1,723,279	608,230	40,410	648,640
6,812	168,026	3,696	22	13,493	19,607	1.45	2,530,601	1,108,794	88,167	1,196,961
5,793	153,767	5,108	33	74,405	26,436	.34	1,093,308	319,361	5,259	324,620
23,418	585,283	13,517	23	473,387	421,489	.89	8,883,366	3,439,863	401,146	3,841,009
15.5	15.6	20.3		59.5	65.4		51.0	48.0	54.9	48.6
							76,667	21,283	176,561	25,233
9,655	204,855	4,496	22	136,470	82,898	.61	1,525,619	533,535		706,146
							301,412	101,488	(c)	102,088
(d)	(d)	(d)	(d)				38,195	3,870		3,870
2,531	62,375	1,165	19	140,425	114,265	.81	1,444,191	464,980	c 102,875	567,255
d 2,045	d 53,009	d 848	d 16	e 6,850	e 6,404	e .94	159,938	172,050	4,872	176,922
3,159	78,970	1,809	23	4,475	2,000	.45	1,655,049	544,971	(c)	545,237
							246,056	86,985		87,125
(d)	(d)	(d)	(d)				2,158	680	(c)	680
				13,324	7,091	.53	53,158	24,631	c 3,143	27.368
d 526	d 12,907	d 253	d 20	(e)	(e)	(e)	55,558	48,054		48,054
17,916	412,116	8,571	21	301,544	212,658	.71	5,558,001	2,002,527	287,451	2,289,978
12.0	11.0	13.0		37.9	33.0		32.2	28.0	39.3	29.0
				(e)	(e)	(e)	15,115	4,934		4,934
							68,817	34,901	1,975	35,076
							22,141	12,867		14,667
							12,673	25,817	14,137	29,031
							7,563	2,943		4,693
				e 10,812	e 5,555	e 52	12,135	20,183		29,356
				10,812	5,555	52	138,444	101,645	16,112	117,757
				1.4	0.9		0.8	1.4	2.0	1.5
151,610	3,754,834	66,559	18	794,994	644,197	81	17,254,857	7,167,029	734,076	7,901,105

c Miscellaneous products for Connecticut are included under Massachusetts, Kansas under Minnesota, Nebraska and Oklahoma under South Dakota.

d Concrete brick for Kentucky are included under Florida, Louisiana under Missouri, Oklahoma under Texas.

e Silo blocks and staves for Texas are included under Missouri, and Arizona under Washington.

ARCHITECTURAL CONCRETE STONE.

Architectural concrete stone is used like natural stone and terra cotta in the facing and trimming of buildings. The quantity sold in 1919 increased apparently about 8 per cent. There was also an apparent increase of 16 per cent in value.

The New England States, first in quantity produced in 1918, dropped to fifth place in 1919, showing a decrease of 35 per cent. They produced about 12 per cent of the total quantity and 22 per cent of the total value. The average value per cubic foot was $3.64. There was a marked decrease in the number of manufacturers of this product reporting from these States.

The Middle Atlantic States, which ranked first in value in 1919, were second in quantity, although they showed a decrease of 7 per cent. These States produced about 24 per cent of the total quantity and about 28 per cent of the total value. The average value per cubic foot was $2.28. Fewer producers reported from these States in 1919 than in 1918.

The Southeastern States ranked fourth in quantity in 1919, although they showed an increase of 91 per cent. They represented about 14 per cent of the total quantity and about 8 per cent of the total value of architectural stone. The average value per cubic foot was $1.21.

The East Central States first in quantity in 1917 and fourth in 1918, ranked first again in 1919, showing an increase of 111 per cent. These States furnished about 25 per cent of the total quantity and 20 per cent of the total value of architectural stone. Their rank in value was third. Their average value per cubic foot was $1.59.

The West Central and South Central States ranked third in 1919. They produced about 20 per cent of the total quantity and 17 per cent of the total value, although they showed a decrease of 5 per cent in quantity. The replies from this group of States show that a number of producers have turned from architectural stone to regular building blocks. The average value per cubic foot was $1.71.

The Western States have ranked sixth in quantity since 1917. They showed an increase of 33 per cent in quantity in 1919 as compared with 1918, and their output in 1919 represented about 6 per cent of the entire quantity and 5 per cent of total value. The average value per cubic foot was $1.75.

The average values of architectural stone, highest in Oregon and Washington, were higher in the Middle Atlantic and New England States than in any other group of States, owing in part to the kind of aggregate used. About 92 per cent of the marble and almost 50 per cent of the granite reported as used for facing were reported from these States.

The average value per cubic foot for the entire country increased from $1.12 in 1917 to $1.71 in 1918 and to $1.98 in 1919. The range in price in 1919 was wide. One producer from Connecticut reported it at $1.90 to $5 per cubic foot; another, from New Jersey, reported it at $2 to $3, and stated that it had advanced $1.50 in one year; another, from the same State, reported it at only 25 cents.

Similar varying reports were received from the different States. These low prices, however, may have been prices for concrete blocks erroneously classified. The difference in price was due primarily to differences in the kind of aggregate and molds used and in the cost of labor. It also depended upon whether or not the producer was making a patented product.

CONCRETE BLOCKS.

The principal product in the concrete-stone industry consists of building blocks. The figures here given for these blocks represent for the first time both volume and value. The blocks vary in size; the size most commonly used, however, is 8 by 8 by 16 inches, with about 30 per cent air space or "core." There was a wide range in the value of these products also, owing to difference in aggregates used and to difference in size and finish, whether plain or ornamental. Sand and gravel were the aggregates most commonly used, but a great variety of materials were employed, such as crushed stone, chats, slag, screenings, cinders, coquina (crushed shell rock), crushed clay brick, and plaster.

The entire production of building blocks in the United States in 1919, according to tables shown in this report, was 15,677,360 cubic feet, valued at $5,207,972. As most of the blocks have "core"—which amounts to 30 per cent of the block—the figures show both net cubic feet, or actual quantity of concrete used, and gross cubic feet, or volume of structural material.

No satisfactory comparison of the production of concrete blocks in the three years can be made, because in 1917 and 1918 it was possible to report only the combined number of blocks and brick, whereas in 1919 the blocks are reported in gross and in net cubic feet, and the bricks in cubic feet and in number. The New England States show the highest average value of concrete blocks, 39 cents per cubic foot; the Middle Atlantic and Western States, 38 cents; Southeastern States, 37 cents; West Central and South Central States, 36 cents; East Central States, 33 cents. Blocks of the same size may sell in one city at double the price asked in a neighboring city. The East Central States led in quantity, producing about 52 per cent of the entire output and about 53 per cent of the entire value. The West Central and South Central States took second place, with about 33 per cent of the quantity and 30 per cent of the value. The Middle Atlantic States ranked third, with 11 per cent of the total quantity and 12 per cent of the entire value; the Southeastern States fourth, with 3 per cent; the New England States fifth and the Western States sixth, each with approximately 1 per cent of both quantity and value.

CONCRETE BRICK.

In the report for 1917 and 1918 statistics for concrete brick were not separated from those for concrete blocks. In the canvass of the industry for 1919 figures for brick were obtained separately, and in this report the quantity of brick is given both in cubic feet and in number. In comparison with an annual production prior to 1914 of 7,000,000,000 to nearly 10,000,000,000 common clay brick, the production in 1919 of 3,754,834 concrete brick, valued at $66,559, was a small matter. For a new industry, however, it is a fair showing.

The average value of concrete brick ranged from $13 per thousand in Michigan to $33 per thousand in Wisconsin. The average value for the country was $17.73, as compared with $12.79 per thousand for common clay brick.

Concrete brick are made the same size and used for the same purposes as common clay brick. They are supplied in natural concrete color and also tinted with mineral pigments. Buff and red are popular colors for concrete brick. Colored brick sell for a few dollars a thousand more than plain brick.

SILO BLOCKS AND STAVES.

This report is the first to show separate figures on the quantity and value of the production of concrete silo blocks and staves. These products are manufactured principally in the Central States. The total quantity of the silo blocks and staves sold in 1919 was 794,994 cubic feet, valued at $644,197, or an average of 81 cents a cubic foot.

The East Central States ranked first, their output being about 60 per cent of the total quantity and about 65 per cent of the total value. Indiana was the leading State with a production of 28 per cent of the total output for the United States. The West Central and South Central States ranked second, producing about 38 per cent of the total quantity and about 33 per cent of the total value. The Western States ranked third and the Middle Atlantic States fourth, their production being respectively 1 per cent of the total quantity and 1 per cent of the total value. No one reported making silo blocks in New England in 1919. The average value of silo blocks per cubic foot ranged from $1.45 in Ohio to 34 cents in Wisconsin, but no definite information as to the causes of this wide difference is at hand. Taken by districts, the smaller the output the lower was the average value per cubic foot. In the East Central States, where 60 per cent of the blocks were made, the average value was 89 cents, and in New York and Pennsylvania, credited with 1 per cent of the output, the average value was 49 cents per cubic foot. Curiously there was a great variation in value in adjacent States. The average value in Ohio was $1.45, in Indiana $1.17, and in Michigan 61 cents. If these blocks were of the same size and quality it is apparent that the producers should organize for their common benefit.

MISCELLANEOUS CONCRETE PRODUCTS.

The total value of miscellaneous products reported was $734,076, or approximately 9 per cent of the value of all concrete products. This figure probably is less nearly correct than those for other forms of concrete here reported, because this group includes a variety of products, some of which are made in small number or quantity on many farms or by individuals for home use and not for sale. Under miscellaneous products are included different kinds of roof and floor tile, fence posts, lawn vases and other ornaments, burial vaults, concrete lumber, drain pipes, and culverts. The production of tile was the largest item under miscellaneous products; burial vaults ranked second. This variety of product is suggestive of wider and larger application of concrete.

AGGREGATE.

The aggregates reported as used in concrete products in 1919 comprised sand, gravel, crushed stone, and miscellaneous material. Crushed stone included limestone, basaltic rock (trap rock), granite, and marble. Under miscellaneous material are included chats, slag, cinders, crushed clay brick, plaster, and coquina. The following table shows the quantity of these materials used in making movable concrete products in different sections of the United States. The quantity of aggregate used in 1919 is in part estimated, because some producers kept no record of sand from their own pits or of material used for movable concrete products as distinguished from monolithic concrete in buildings and pavements.

Aggregate and cement used in the production of concrete products in 1919.[a]

District.	Aggregate (short tons).						Portland cement used (barrels).
	Granite.	Marble.	Crushed stone.	Gravel.	Sand.	Miscellaneous.	
New England States	1,512	320	700	5,200	10,000	950	16,325
Middle Atlantic States	28	5,070	14,000	14,400	42,300	10,100	85,500
Southeastern States	1,250		11,050	3,700	23,650	190	28,850
East Central States	15		7,650	207,700	244,750	20,000	484,400
West Central and South Central States	345		4,951	41,900	199,550	5,675	258,100
Western States	10	90		8,424	4,900	525	12,100
	3,160	5,480	38,351	281,324	525,150	37,440	885,275

[a] Estimated in part.

Although in coarse or massive concrete the proportion of sand is only about one-half that of gravel, this table shows that in the concrete products to which this report relates—that is, comparatively small, movable blocks—this proportion is nearly reversed. This difference is, of course, explained by the small size of the products. Limestone and basaltic (trap) rock, which constitute most of the crushed stone recorded, were a poor third in rank by quantity used. Only a few thousand tons each of marble and granite was used, mostly in Massachusetts, New York, New Jersey, Pennsylvania, and Florida. These aggregates were used only in the production of architectural (trim or decorative) stone, producing textural effects imitating marble or granite. The proportion of cement to total aggregate was approximately 1:6.

The quantities of aggregates and cement shown in the foregoing table bear the following ratio to the total quantities sold in the United States in 1919: Crushed stone for concrete, 0.3 per cent; gravel, 1.1 per cent; sand, 2.4 per cent; and Portland cement, 1.1 per cent.

BARYTES AND BARIUM PRODUCTS.[1]

By George W. Stose.

CRUDE BARYTES.

PRODUCTION.

The barytes industry had a prosperous year in 1919. In January the industry, in common with most others, felt the depression that followed the World War, but by June business was about normal, and by August it was very active and advance sales for the output of the rest of the year were not uncommon. The sales of crude barytes in 1919 did not quite equal the sales in 1916, but because of the high price the value of the product marketed exceeded that of 1918 by nearly $700,000. The average price paid was $8.25 a short ton, as compared with $6.73 in 1918, the highest previous average price. Some of the ore brought as much as $9 and $10 a ton, and special lots even more. The following tables show the quantity and price of crude ore mined and marketed:

Crude barytes produced and marketed in the United States, 1880–1919.

	Quantity (short tons).	Value.	Average price per ton.
Annual average for 10 years 1880–1889	21,410		
Annual average for 10 years 1890–1899	27,523		
Annual average for 10 years 1900–1909	58,310		
Annual average for 5 years 1910–1914	43,389		$3.31
1915	108,547	$381,032	3.51
1916	221,952	1,011,232	4.56
1917	206,888	1,171,184	5.66
1918	155,368	1,044,905	6.73
1919	209,330	1,727,822	8.25

Crude barytes produced and marketed in the United States, by States, 1917–1919.

State.	1917			1918			1919		
	Quantity (short tons).	Value.	Average price per ton.	Quantity (short tons).	Value.	Average price per ton.	Quantity (short tons).	Value.	Average price per ton.
Alabama	1,976	$8,868	$4.49	1,794	$9,976	$5.56	(a)	(a)	(a)
Georgia	111,300	601,895	5.41	69,318	418,178	6.03	85,303	$667,521	$7.83
Kentucky	6,720	36,084	5.37	(a)	(a)	(a)	5,435	36,408	6.70
Missouri	59,046	391,363	6.63	49,094	393,738	8.02	73,247	640,398	8.74
North Carolina	1,019	5,080	4.99	(a)	(a)	(a)	(a)	(a)	(a)
Tennessee	16,972	79,058	4.66	22,542	141,844	6.29	34,700	288,622	8.32
Other States [b]	9,855	48,836	4.96	12,620	81,169	6.43	10,645	94,873	8.91
	206,888	1,171,184	5.66	155,368	1,044,905	6.73	209,330	1,727,822	8.25

[a] Included under "Other States."

[b] States having less than three active producers are grouped together to avoid disclosing confidential information. Includes, 1917: California, Nevada, South Carolina, and Virginia; 1918: Kentucky, Nevada, New Mexico, North Carolina, South Carolina, Virginia, and Wisconsin; 1919: Alabama, California, Illinois, Nevada, North Carolina, South Carolina, Virginia, and Wisconsin.

[1] The statistical data in this report were prepared by Mrs. E. R. Phillips.

Georgia led all other States in quantity of barytes marketed in 1919 and surpassed its production of 1918 by approximately 16,000 short tons, but it fell 26,000 tons short of its maximum output, which was made in 1917. Missouri, the second largest producer, on the other hand, gained 24,153 tons over the sales in 1918 and passed its high record of 1917 and 1916. Tennessee, which ranked third in 1919, made the greatest forward stride, marketing about 53 per cent more than in 1918 and over 100 per cent more than in 1917, its lowest recent record, and even surpassed its highest record of 1916. Kentucky, South Carolina, and Virginia were the next States in order of production, together marketing nearly 13,000 tons. California and Illinois were added to the list of States that marketed barytes in 1919, whereas New Mexico, although it produced a little ore, made no shipments. California and Nevada together marketed over 2,500 tons. Alabama, Illinois, North Carolina, and Wisconsin were small producers, marketing together less than 1,000 tons. In the 13 producing States 115 plants were active.

In addition to the barytes sold some ore was produced that was not shipped but was held at the mines, and some plants sold more than they produced, drawing on reserve stocks. Stocks stored at the mines can not be accurately determined, but from the estimates furnished the stocks were increased during the year by more than 4,000 tons. Of the 22,500 tons reported in stock at the mines at the end of the year, more than one-third was held in Missouri, a little less than one-third in Tennessee, and the rest mostly in Georgia and North Carolina.

IMPORTS.

The importation of crude barytes from Europe, which was stopped during the war, was begun again late in 1919; and, although it amounted to only 118 short tons during the year, a resumption of large imports may be expected in the near future. The duty of 15 per cent ad valorem adds 75 cents a ton or less to the price at the Atlantic seaboard, and American mines will have to reduce their price on crude ore materially to compete with the foreign product, especially as most of the foreign ore is of superior quality. A timely report, covering not only the question of tariff on barytes and barium products but also the cost of production of each in 1919, as well as a detailed description of the processes of manufacture and statistics of production and consumption, has recently been published by the Tariff Commission.[2] The following table shows the quantity and price of ore imported into the United States in recent years:

Crude barytes imported for consumption, 1912–1919.

Year.	Quantity (short tons).	Value at mine.[a]	Average price per ton at mine.	Year.	Quantity (short tons).	Value at mine.[a]	Average price per ton at mine.
1912	26,186	$52,467	$2.00	1916	17	$245	$14.41
1913	35,840	61,409	1.71	1917	6	63	10.50
1914	24,423	46,782	1.92	1918	....	....	....
1915	2,504	4,877	1.95	1919	118	594	5.03

[a] Value on which duty is levied. Does not include railroad and ship freight charges to this country or import duty. These amounted to about $3.45 a ton in 1914.

[2] United States Tariff Commission, Tariff Information Series No. 18, Washington, 1920.

MARKETS.

Prior to 1914 the market for crude barytes in the United States centered around St. Louis, Mo., and Philadelphia, Pa. Although four-fifths of the barytes mined in 1919 was marketed or used in these two districts, a growing industry in the Southeastern States utilized the remaining fifth. Of the 202,000 short tons of crude ore used in the manufacture of barium products in 1919, approximately 78,500 tons, or a little less than two-fifths, was used in plants less than 100 miles from Philadelphia (in New Jersey, Pennsylvania, New York, and Delaware), which made chiefly lithopone and some chemicals; about 81,200 tons, or two-fifths, in the plants of the St. Louis district, including Illinois, which made chiefly ground barytes and some lithopone and chemicals; and about 41,000 tons, or a little more than one-fifth, in chemical plants in Tennessee and West Virginia, in ground barytes plants in Georgia, Kentucky, Virginia, and South Carolina, and in a lithopone plant in Maryland. A small quantity of barytes was mined and marketed in California in 1919. The relative quantities used in the three branches of the industry are shown in the following table:

Crude barytes used in the manufacture of barium products, 1915–1919, in short tons.[a]

Year.	Product.			Total.
	Ground barytes.	Lithopone.	Barium chemicals.	
1915	53,903	44,503	10,216	108,622
1916	75,507	71,898	38,283	185,688
1917	60,132	86,065	49,842	196,039
1918	62,440	85,282	38,041	185,763
1919	64,922	103,688	32,976	201,586

[a] Compiled from reports made by the manufacturers of barium products.

PRICES.

The prices obtained for crude barytes f. o. b. at the mines were much higher in 1919 than in any previous year. (See table, p. 335.) The average price received for the total output in the United States was $8.25 a short ton, as compared with $6.73 in 1918 and with $5.66 in 1917. The average price received by 80 operators in Missouri in 1919 was $8.74 a ton, a higher average than in any other State. Many operators reported sales at $9 a ton, a few at $10 a ton, and a little ore mined in California was reported to have brought more than $13 a ton. The prices obtained in States east of the Mississippi are generally lower than those in the West. The average price in Georgia, the State which had the largest production, was $7.83; in Tennessee, $8.32.

CONSUMPTION.

The consumption of barytes in the United States can be computed only approximately from the records available. As there have been no exports of crude barytes, the actual consumption may be fairly determined by adding the imports to the sales of domestic ore by the producers and subtracting or adding the difference between the stocks on hand at the plants of the manufacturers of barium products at the end and at the beginning of the year. As the stocks at the manufacturing plants are not made public, only the apparent consumption (the ore bought by consumers, whether they use it or store it) can be determined and is given in the table below. Comparison of this table with the table showing the crude ore used in manufacturing the various barium products given under the heading "Markets" reveals a considerable discrepancy, which apparently represents the difference in stocks at the factories.

Crude barytes apparently consumed in United States, 1912–1919, in short tons.[a]

Year.	Sales of domestic barytes.	Imports for consumption.	Apparent consumption.
1912	37,478	26,186	63,664
1913	45,298	35,840	81,138
1914	52,747	24,423	77,170
1915	108,547	2,504	111,051
1916	221,952	17	221,969
1917	206,888	6	206,894
1918	155,368	....	155,368
1919	209,330	118	209,448

BARYTES INDUSTRY, BY STATES.

ALABAMA.

Only a few tons of barytes was reported mined and sold in Alabama in 1919. This was produced at the Glidden Barytes Co.'s mine at Jacksonville, Calhoun County, which was taken over late in the year by the Bertha Mineral Co., of Cartersville, Ga. Four other mines in the State were apparently idle.

ALASKA.

Although no barytes was mined in Alaska in 1919, the Walters mine, at Wrangell, was purchased by the Treadwell Gold Mining Co. with the intention of developing the property.

CALIFORNIA.

Considerable ore was apparently mined in the Bardin barium quarries, near Salinas, Monterey County, and on the Maguire property, Liberty Hill, Nevada County, Calif. The product was sold to paint factories in Oakland and San Francisco. The mines at El Portal and San Dimas Canyon were idle in 1919.

GEORGIA.

The barytes mined in Georgia in 1919 came, as usual, from Bartow County, where 11 mines were in operation. A total of 84,576 tons was mined and 85,303 tons, valued at $667,521, was sold. The Paga Mining Co., of Cartersville, operating three mines in the district, was the largest producer. E. I. du Pont de Nemours & Co., of Wilmington, Del., the Bertha Mineral Co. (representing the New Jersey Zinc Co., of New York), and the Nulsen Corporation (formerly the Nulsen, Klein & Krausse Manufacturing Co.), of St. Louis, Mo., all manufacturers of barium products, and the New Riverside Ocher Co., of Cartersville, were also large producers of ore in the Cartersville district. The Big Tom Barytes Co. materially increased its production, whereas the Krebs Mining Co. produced only a small quantity of barytes before the Bertha Mineral Co. took over the operation of the mine for the New Jersey Zinc Co. early in the year. A detailed report on the barytes deposits of the State by J. P. D. Hull was published early in 1920 by the Geological Survey of Georgia.[3]

ILLINOIS.

The Little Jean Mining Co.'s property at Golconda, Ill., was taken over by the Mundy Mineral Sales Co. late in the year; only a small quantity of the ore that had already been mined was sold. The ore is a mixture of 35 per cent fluorspar and 65 per cent barytes and requires careful treatment in jigs to effect satisfactory separation, which has been accomplished and has resulted in a product nearly 96 per cent of which is barium sulphate with a little carbonate. The new owners expect to push production.

KENTUCKY.

Seven barytes mines were operated in Kentucky in 1919. Three of them were in Fayette County and one each in Boyle, Garrard, Mercer, and Woodford counties. Most of them were operated part of the year by J. F. Hughes, of Nicholasville, and the product was sold to the Central Pigment Co., of Nicholasville. The aggregate of shipments from all the mines was about 5,400 tons. Many other small mines in the State were idle, apparently because of labor conditions. A new company, The Chinn Mineral Co., was incorporated late in 1919 to mine barytes deposits near Lexington.

MISSOURI.

The barytes marketed in Missouri in 1919 amounted to 73,247 short tons, valued at $640,398. This exceeded the quantity marketed in each of the two great years of the industry—1917 and 1916—and the value in 1919 far exceeded the value for either of those years as well as the highest value previously recorded, which was $393,738 in 1918. The average price per ton in 1919 was $8.74, as compared with $8.02 in 1918 and $6.63 in 1917.

As usual, the larger part of the output came from Washington County, the Mineral Point region, where 51 mines shipped more than 42,000 tons. The report for the State by counties is as follows:

[3] Georgia Geol. Survey Bull. 36, 1920.

Barytes produced and marketed in Missouri, by counties, 1919.

County.	Number of mines.	Shipments.	
		Quantity (short tons).	Value.
Washington	51	42,677	$377,467
St. Francois	11	3,663	29,217
Jefferson	7	2,929	26,995
Cole	8	2,870	23,058
Miller, Franklin, Benton, and Morgan	5	1,425	11,632
Undistributed [a]		19,683	172,029
	82+	73,247	640,398

[a] Estimate of output of small operators not reporting based on purchases of ore in Missouri by manufacturers of barium products.

The principal buyers from 77 small mines in Missouri were the Nulsen Corporation and the J. C. Finck Mineral Milling Co., both of St. Louis, and the Point Milling & Manufacturing Co., of Mineral Point. The Missouri Baryta Co., affiliated with the J. C. Finck Mineral Milling Co., is reported to have purchased 4,500 acres of barytes land in Washington County in 1919 and expects to double its output.

NEVADA.

The mine at Hawthorne, Mineral County, Nev., apparently produced some barytes in 1919, which was shipped to the West Coast Kalsomine Co., San Francisco, Calif.

NEW MEXICO.

A small quantity of barytes was mined at Las Cruces, N. Mex., in 1919, but none was sold during the year.

NORTH CAROLINA.

Two mines in Madison County, N. C., produced a small quantity of barytes in 1919 and some was sold to Georgia dealers.

SOUTH CAROLINA.

The Cherokee Chemical Co. produced and marketed several thousand tons of ore at its mine at Kings Creek, Cherokee County, S. C., in 1919, about four times as much as was reported sold in 1918. Part of its product was marketed in crude form, but most of it was ground in its plant at the mine.

TENNESSEE.

Six barytes mines were in operation in Tennessee in 1919 and marketed 34,700 tons of crude ore. There has been a steady increase in sales for three years, and the sales in 1919 were considerably more than the previous highest output for the State, 32,416 tons in 1916. Most of the ore was mined in the Sweetwater district, but a little came from the Del Rio district, Cocke County. A large part of the ore was used in the chemical plants of the Durex Chemical Corporation, at Sweetwater, which operated several mines in Loudon, McMinn, and Monroe counties, all in the Sweetwater district. The National Barium Corporation, the largest producer, used much of its output in its lithopone plant (Chemical Pigments Corporation) at St. Helena, near Baltimore, Md., and the product of the Krebs Mining Co. was used in its lithopone plant in Newport, Del. A report on the barite deposits in upper east Tennessee by C. H. Gordon was published early in 1920 by the Tennessee Geological Survey; and a report on the barite deposits of the Sweetwater district, by the same author, was published in 1918.[4]

VIRGINIA.

Considerable ore was taken from the mine at Evington, Campbell County, Va., in 1919, which was operated in the first half of the year by the Clinchfield Products Corporation, of New York, and in the last half by the Rollin Chemical Co., of Charleston, W. Va., which purchased the property. The quantity produced, however, was not as great as in 1918. It was all used in the plants of the two companies at Charleston, W. Va., and Johnson City, Tenn.

WISCONSIN.

A small quantity of barytes was mined at Cuba City, Grant County, Wis., in 1919, and was shipped to Chicago.

BARIUM PRODUCTS.

Under the heading "Barium products" are included not only such chemically manufactured products as barium binoxide and lithopone, but also mechanically prepared barytes, ground and refined by various processes. Only those compounds manufactured directly from crude barytes or from intermediate chemical compounds made from barytes in the same factory are reported here. The total quantity of barium products manufactured and sold in 1919 was considerably greater than in 1918. The quantity of barium chemicals marketed in 1919 was somewhat less than in 1918, but the quantity of lithopone produced and sold was much greater than in 1918.

Marketed barium products which were manufactured in the United States from either domestic or imported crude ore, 1915–1919, in short tons.

Product.	1915	1916	1917	1918	1919 [a]		
					Production.	Value.	Average price.
Ground barytes	51,557	65,440	52,694	55,086	57,985	$1,163,437	$20.06
Lithopone	46,494	51,291	63,713	62,403	79,643	9,911,708	124.45
Barium chemicals [b]	8,823	16,792	22,503	23,186	20,013	1,519,788	75.94
	106,874	133,523	138,910	140,675	157,641	12,594,933	79.90

[a] Figures of production, not sales, are given for 1919. Sales are in general somewhat less (1 to 5 per cent) than figures of production.
[b] Barium chemicals manufactured from secondary barium products bought in open market are not included in table.

[4] Tennessee Geol. Survey Bull. 23, 1920; The resources of Tennessee, vol. 8, No. 1, pp. 48–82, 1918.

GROUND BARYTES.

USES AND PREPARATION.

Barytes, when ground to a very fine powder, is used as a white pigment to be mixed with oil, an inert base in colored oil paints, and a filler in rubber goods, linoleum, oilcloth, paper, and similar articles. It is used to give weight and finish to paper and to give an impervious coating to canvas coverings for hams. It is the basis of artificial ivory, and makes an acid-proof packing for joints in sulphuric acid works. For use in ready-mixed interior white paint it is bleached and ground to a very fine powder of even texture. The opacity of barytes ground in oil is not so great as that of higher-grade pigments, so that the covering power of mixed paint is reduced in proportion to the quantity of ground barytes it contains. Barytes paint has the advantage, however, that it is unaffected by acids or alkalies and so does not turn dark on exposure. The pigment is sometimes made to appear whiter by coloring it bluish white by precipitating on it iron sulphate from solution or by adding Prussian or ultramarine blue. Ground barytes is especially useful as a filler in goods that require a highly calendered surface, such as playing cards, white oilcloth, and enameled paper.

In the preparation of high-grade ground barytes the ore is first ground and bleached with dilute sulphuric acid in lead-lined vats to remove all traces of iron oxide. The German practice of bleaching ore crushed to nut size or larger is not so satisfactory as the American practice of grinding to a meal before bleaching, as it is important to remove all traces of the acid if the product is to be used in colored paint or in paper, and this removal can be more successfully accomplished in the finer form. The crushed and bleached rock is then ground to a fine powder in burr mills or other suitable pulverizers to pass a 200 to 300 mesh screen. The finest grade of ground barytes is obtained by flotation on a stream of water, and this product is called "water floated."

PRODUCTION.

Ground barytes was made and marketed in the United States in 1919 by nine plants, which made 57,985 short tons from 64,922 tons of crude ore, showing a loss in the process of about 11 per cent. This was about 1,500 tons more than was manufactured in 1918. Seventy-five per cent of the output was made in Missouri, at the plants of the Nulsen Corporation and the J. C. Finck Mineral Milling Co., in St. Louis, and of the Point Milling & Manufacturing Co., at Mineral Point. The J. C. Finck Co. has enlarged its plant by the purchase of a fully equipped cooperage works and expects to increase its output from ore from its new mines. Its best grade of floated barytes, known in the trade as "Foam A Barytes," is shipped in barrels. The average price obtained in 1919 for the Missouri product was $20.81 a short ton. Georgia had the next largest production, which was made at Thompson, Weinman & Co.'s plant at Cartersville. Other plants were in operation in South Carolina, Illinois, Kentucky, California, and Virginia. The West Coast Kalsomine Co.'s plant at West Berkeley, Calif., was the only producing plant in the Western

States. The Metals & Chemicals Extraction Corporation, successors of the Barbour Chemical Works, at Oakland, Calif., began manufacture in December, 1919, but reported no sales.

PRICE.

The average price per ton at the plant for the total sales in 1919 was $20.06, as compared with $18.91 in 1918.

Ground barytes, pure white floated domestic, in bags, was quoted [5] in New York from $32 to $34 a short ton, January to February; $30 to $32, March to July; $30 to $31, August to December. Off-color ground barytes in bags in New York was quoted at $24 to $26 a ton in January and dropped to $21 to $24 by December. These prices are $4 to $10 lower than the prices that prevailed in 1918. Foreign ground barytes was not on the market during the year.

LITHOPONE.

Lithopone is a pigment manufactured chemically from barytes and zinc. It contains 68 to 70 per cent of barium sulphate and 30 to 32 per cent of zinc sulphide. A small part of the sulphide is generally changed to oxide in the process of manufacture. Some compounds included under this heading in this report may have a slightly different composition but are essentially barium-zinc compounds of about the composition given above.

Lithopone is used chiefly in paint and as a filler in rubber goods, paper, linoleum, oilcloth, and window shades.

PRODUCTION.

Lithopone was manufactured in 1919 by 15 plants distributed in six States. Eleven of these plants are in the Philadelphia district, of which five are in New Jersey, four in Pennsylvania, one in Delaware, and one in Maryland. Three plants are in Illinois and one in Missouri. Another plant was in course of construction at Kansas City, Mo., by the Sherwin-Williams Co. The total production for the United States in 1919 was 79,643 short tons, as compared with 64,016 tons in 1918. The marked increase was due in part to the general revival of the paint and many other industries after the war, but largely to the increased use of barytes paints in place of higher-priced all-lead and all-zinc paints. The use of 103,688 tons of crude barytes and approximately 22,000 tons of zinc compounds in the production of 79,643 tons of lithopone indicates a large loss in the chemical process of manufacture, probably chiefly of barium sulphide, which is used in excess to insure complete chemical reaction.

About 78 per cent of the total output of lithopone was produced in plants in the Philadelphia district, including Maryland. These include the plants of the Krebs Pigment & Chemical Co., Grasselli Chemical Co., New Jersey Zinc Co., Butterworth-Judson Corporation, Chemical Pigment Corporation, and two plants of E. I. du Pont de Nemours & Co. The large increase occurred chiefly in the output of the Krebs and one of the Du Pont plants. The Butterworth-

[5] Oil, Paint, and Drug Reporter, 1919 Year Book, 1920.

Judson Corporation, which began operations in 1918 with a very small production, made a material addition to the total output in 1919. Besides the two companies that produced lithopone in Illinois in 1918—the Midland Co., at Argo, and the Sherwin-Williams Co., at Chicago—the Consolidated Chemical Products Co., at Alton, began production, and these three plants had a total output in 1919 of 9,694 short tons, a little more than in 1918. The Mineral Refining & Chemical Corporation, the only plant in Missouri that produced barium-zinc paint in 1919, marketed its product under the name of "Marbon white," a compound which it is claimed is not strictly lithopone, but it is included under that heading in this report as a closely related product. This plant has had rapid growth since it began operations in 1917 and produced in 1919 more than three times as much as in 1918.

PRICE.

The lithopone marketed in 1919 brought to the producers an average price of $124.45 a short ton, or 6⅕ cents a pound, which was a little less than the average price in 1918. The highest average price for a single State was $135; the lowest was $120.11. The wholesale price for lithopone in bags in 1919, quoted in New York,[6] began in January at 7¾ cents a pound, dropped to 6½ cents in March, rose to 7 cents in July, and to 7¼ cents in December.

BARIUM CHEMICALS.

PRODUCTION.

Under barium chemicals are included all manufactured chemical compounds that contain barium, including lithopone, but as the manufacture of lithopone is an industry by itself entirely independent of the barium-chemical industry it has here been separately treated. As this report deals with barytes and its immediately derived products, only those chemicals that are made directly from barytes or from primary salts of barium so made in the same plant will be described here. Chemicals that are made from other barium chemicals bought in the open market will therefore not be described and have not been included in the statistical tables in this report. The chemicals here reported include barium binoxide, carbonate, chloride, hydroxide, nitrate, and sulphate.

The manufacture of barium chemicals in the United States, which practically began in 1915 with an output of 8,823 short tons, was nearly doubled in 1916 and nearly trebled in 1917. The output for 1917 was slightly exceeded in 1918, but in 1919 the production dropped slightly, a total of 20,013 short tons, valued at $1,519,788, being reported.

Of the 10 plants in the United States in which barium chemicals were made either directly or indirectly from crude barytes in 1919, 5 are on the Atlantic seaboard in New Jersey, New York, and Pennsylvania, 2 in Illinois, 2 in Tennessee, and 1 in West Virginia.

The Rollin Chemical Corporation, at its plant at Charleston, W. Va., produced the largest quantity of barium chemicals. None were

[6] Oil, Paint, and Drug Reporter, 1919 Year Book, 1920.

produced at the plant at Johnson City, Tenn., after the Rollin Corporation took it over in July. The Durex Chemical Corporation was the next largest producer of chemicals, which were made chiefly at its Sweetwater plant, although some were made at its plant at Long Island City, N. Y. The plants of the Chicago Copper & Chemical Co., at Blue Island, Ill.; Grasselli Chemical Co., at Grasselli, N. J.; Oakland Chemical Co., at New York City; Clinchfield Products Corporation, at Johnson City, Tenn.; E. I. du Pont de Nemours & Co., at Philadelphia, Pa., Carneys Point, N. J., and and Parlin, N. J.; and Consolidated Chemical Co., at Alton, Ill., also produced barium chemicals. Barium chloride was made at six plants, carbonate at five, sulphate (blanc fixe) at four, and other chemicals each at one or two plants.

In the following table are given the quantities of barium chemicals of domestic manufacture sold from 1915 to 1919, and the average price obtained by the producer for each in 1919:

Barium chemicals of domestic manufacture sold, 1915–1919.[a]

Chemical.	1915	1916	1917	1918	1919 [a]	
	Quantity (short tons).	Quantity (short tons).	Quantity (short tons).	Quantity (short tons).	Quantity (short tons).	Average price (per pound).
Barium binoxide	306	1,980	2,555	1,047	858	$0.19
Barium carbonate	2,746	6,844	8,238	7,661	7,135	.02⅘
Barium chloride	2,106	3,643	4,870	4,530	4,509	.03¾
Barium nitrate	971	446	165	137	784	.10
Barium sulphate (blanc fixe)	1,229	3,337	6,314	9,522	5,227	.02½
Barium sulphide	1,220	97	351	269	1,500	.01⅔
Other barium chemicals [b]	245	445	10	20		
	8,823	16,792	22,503	23,186	20,013	.03⅘

[a] Figures of production, not sales, are given for 1919. Sales are in general somewhat less (1 to 5 per cent, than figures of production.

[b] Includes chiefly hydroxide and some other barium chemicals not specified.

PRICES.

In comparison with the prices of barium chemicals received by the producers, given in the preceding table, the range in wholesale market prices in New York in 1919 is given in the following table:

Wholesale market prices per pound of barium chemicals quoted in New York, 1919.[a]

Chemical.	Average, 1918.	Jan. 1, 1919.	Dec. 31, 1919.
Barium chlorate	$0.50 –$0.60	$0.50 –$0.60	$0.50 –$0.60
Barium chloride	.04¼– .05	.03½– .05½	.04 – .04½
Barium dioxide	.25 – .38	.25 – .27	.21½– .22
Barium nitrate	.11 – .14	.11½– .12	.10 – .11
Barium sulphate (blanc fixe), dry, in barrels	.03¾– .06	.05	.04 – .05
Barium sulphate (blanc fixe) pulp (per ton)		50.00 –55.00	35.00 –50.00

[a] Oil, Paint, and Drug Reporter, 1919 Year Book, 1920.

The price of most of the barium chemicals tended downward during 1919. The chlorate, used largely for pharmaceutical purposes, remained the same. The chloride, used largely in industrial chemistry, rose slightly. The dioxide and nitrate, also used largely in pharmaceutics, declined about 5 cents and 1 cent a pound, respectively. The sulphate pigment, blanc fixe, dropped about 1 cent a pound, dry in barrels, and $5 to $15 a ton in pulp. Although the prices are mostly somewhat lower than those for 1918, they have not nearly reached the low level of prices that prevailed in 1914 and 1915.

IMPORTS.

The importation of barium products, which stopped almost entirely in 1918, was revived in 1919. Ground witherite, barium carbonate mineral, which is duty free, was the only barium product imported in 1918. The total value of barium products imported in 1919 was nearly three times that of 1917, but only one-third that of 1916. No ground barytes was imported in 1919. Lithopone was again imported to the value of $122,708, at an average price of 8½ cents a pound, which is considerably more than the average price obtained for the domestic product in 1919. Most of this was imported in the second half of the year, so it may be expected that the next year's imports will be much greater, possibly attaining the previous maximum receipts of 1916. The value of the ground natural barium carbonate (witherite) imported was considerably less than in each of the previous five years, but the value of the chemically precipitated carbonate imported in 1919 was greater than that of 1917 and nearly equal to that of 1915, the last two recorded importations. No barium binoxide has been imported since 1916. The chloride imported in 1919, although received almost entirely in the second half of the year, was of greater value than the receipts for any previous year since 1915. The demand for it may be accounted for in that the price of the imported chemical averaged only 2 cents a pound as compared with 3½ cents for the domestic article. Only $90 worth of blanc fixe was imported in 1919, probably because the price offered was not attractive, as the domestic product sold for 2½ cents a pound. The quantity, value, and average price of each barium chemical imported since 1913 are given in the following table:

Barium compounds imported for consumption in the United States, 1913–1919.[a]

[Values given are those at port of exportation, on which tariff duty is based.]

Year.	Ground barytes.			Lithopone.[b]		
	Quantity (short tons).	Value.	Price per ton.	Quantity (pounds).	Value.	Price per pound.
1913	5,463	$38,155	$6.98	4,725,000	$146,474	$0.03
1914	4,323	30,483	7.05	7,980,000	271,310	.03⅖
1915	1,308	10,736	8.21	4,087,826	137,816	.03⅖
1916	147	2,072	14.10	4,681,560	405,730	.08¾
1917	88	1,743	19.81	448,000	29,199	.06½
1918						
1919				1,477,296	122,708	.08½

[a] Compiled from records of Bureau of Foreign and Domestic Commerce, Department of Commerce.
[b] Prior to October, 1913, imported as zinc sulphide white. Figures for 1913 and 1914 have been adjusted on basis of some lithopone having been listed under that name. Since 1914 no lithopone has apparently been imported as zinc sulphide white.

Barium compounds imported for consumption in the United States, 1913–1919—Continued.

Year.	Barium binoxide.			Blanc fixe (precipitated barium sulphate).		
	Quantity (pounds).	Value.	Price per pound.	Quantity (pounds).	Value.	Price per pound.
1913	4,173,188	$239,000	$0.05¾	4,883,014	$62,785	$0.01¼
1914	5,741,752	332,709	.05⅘	2,847,791	32,619	.01
1915	2,397,359	218,776	.09	1,441,989	18,501	.01¼
1916	106,863	6,590	.06⅕	676,908	17,810	.02⅗
1917	......	......	......	229,040	3,333	.01½
1918	......	......	......	......	......	......
1919	......	......	......	1,285	90	.07

Year.	Artificial barium carbonate (chemically precipitated).			Natural barium carbonate (ground witherite).		
	Quantity (pounds).	Value.	Price per pound.	Quantity (pounds).	Value.	Price per pound.
1913	4,085,878	$38,949	$0.01	1,795,396	$13,116	$0.00¾
1914	3,065,362	28,221	.01	1,187,284	8,084	.00¾
1915	286,504	2,786	.01	1,211,310	12,165	.01
1916	......	......	......	1,607,352	18,169	.01
1917	107,092	1,554	.01½	1,186,260	17,321	.01½
1918	......	......	......	723,676	14,134	.02
1919	8,549	2,666	.31⅕	224,000	4,739	.02

Year.	Barium chloride.			Total.	
	Quantity (pounds).	Value.	Price per pound.	Quantity (short tons).	Value.
1913	3,725,239	$37,620	$0.01	17,159	$576,099
1914	5,921,370	68,866	.01⅕	17,696	772,292
1915	2,561,056	31,295	.01⅕	7,302	432,075
1916	6,614	608	.09⅕	3,686	450,979
1917	......	......	......	1,074	53,150
1918	......	......	......	362	14,134
1919	1,099,686	19,846	.01⅘	1,406	150,049

The barium chemicals imported into the United States in 1914 came from foreign countries in the following proportions:[7]

Barium binoxide: Germany, 95 per cent; England, 4 per cent; Belgium, 1 per cent.

Barium carbonate (chemically precipitated): Germany, 81 per cent; Belgium, 12 per cent; England, 7 per cent.

Barium chloride: Germany, 70 per cent; Austria-Hungary, 30 per cent.

Barium nitrate: Germany, about 99 per cent; Belgium, 1 per cent; England, very small quantity.

[7] U. S. Tariff Commission, Tariff Information Series No. 18, p. 47, 1920.

FLUORSPAR AND CRYOLITE.

By Hubert W. Davis.

FLUORSPAR.

INTRODUCTION.

The result of purchases by steel makers of fluorspar largely in excess of their needs during 1918 and the effect of the decreased output of steel on the fluorspar industry are clearly indicated by the statistics for 1919, which show a decrease of nearly 48 per cent in the shipments as compared with 1918, a year in which fluorspar reached its highest recorded output.

Notwithstanding the decreased demand for fluorspar in 1919, considerable prospecting and development work were done and several new mines were opened. Nevada was added as a producing State.

DOMESTIC FLUORSPAR MINED AND SHIPPED.

The total quantity of domestic fluorspar reported to the Geological Survey as sold (shipped from mines) in 1919 was 138,290 short tons, valued at $3,525,574, or, compared with 1918, a decrease of nearly 48 per cent in quantity and 35 per cent in value. The general average price per ton f. o. b. mines or shipping points for all grades of spar in 1919, according to these figures, was $25.49, compared with $20.72 in 1918, an increase of 23 per cent. The highest average price reported in 1919 was in Utah and the lowest was in Arizona. The average price reported in 1919 was higher than the average quoted price during the year, because a considerable quanity of gravel spar was contracted for in 1918 and paid for on delivery in 1919 at prices between $30 and $35 a ton. On the other hand, the average price reported in 1918 was lower than the average price quoted during that year, because a considerable quantity of gravel spar was being delivered in 1918 on old contracts at prices between $5 and $10 a ton. Kentucky and Illinois fluorspar was quoted during practically the whole of 1919 at $25 a ton f. o. b. mines for 85 per cent washed gravel spar and at $22.50 for 80 per cent similar material.

The shipments of fluorspar in 1919 represent the quantity sold direct to consumers and therefore exclude spar sold by one operator to another, and also the crude spar that, on account of impurities which render it unmerchantable when mined, is sold to operators of custom mills, who clean the material and sell it to the consumer. This is particularly true of the so-called " lump " spar mined in the

Jamestown district, Colo., where, according to Aurand,[1] the simpler washing processes in vogue in Illinois-Kentucky fields are not well adapted to most of the ores and if used would entail the installation of an elaborate system of screens and jigs, the cost of which would without doubt prove too expensive for the individual properties, which are not only small but are worked on a very small margin of profit. In 1917 several lots of crude fluorspar were shipped from this district to eastern steel manufacturers, but on account of the high content of silica the spar was rejected. After this a series of systematic jigging and table concentrations was begun, and it was found that the fluorspar could be raised in grade to a product averaging about 85 per cent of calcium fluoride and not more than 7 per cent of silica.[2] Several mills are now equipped to handle the crude spar from this district. This cleaned spar is included in the tables instead of the original lump.

Similar difficulties are experienced by some of the smaller operators in the western Kentucky district, but they were remedied to some extent in 1919 through the operation of custom mills by the Roberts Milling Co. and the Standard Spar Mining Co., both of which reported that a small quantity of spar was treated in 1919. The crude spar was taken to these mills by the producer, who paid a small fee for having the spar turned into a merchantable product and then shipped it to the consumer. In this way the small operator was generally enabled to obtain a higher price than if he sold to local dealers. Some crude spar in this district, however, is sold to local operators, who prepare it for the market. Much merchantable fluorspar is also sold by one producer to another in this district.

The total quantity of fluorspar sold in 1919 in the United States by one operator to another or by producers to operators of custom mills, who in turn sold it direct to consumers amounted to 7,202 short tons, valued at $97,858, or $13.59 a ton, which was $11.90 a ton less than the average price of the spar sold direct to consumers.

As usual, gravel spar, the grade used principally for flux in the manufacture of open-hearth steel, constituted the bulk of the output in 1919. The shipments of gravel spar amounted to 122,584 short tons, valued at $2,917,359, compared with 236,121 tons, valued at $4,735,260, in 1918, a decrease of 48 per cent in quantity and of 38 per cent in total value. The shipments of lump spar in 1919 were 5,333 short tons, valued at $161,991, compared with 18,944 tons, valued at $457,018, in 1918, a decrease in quantity of 72 per cent and in value of nearly 65 per cent. Ground spar was the only grade to show an increase in 1919, being marketed to the extent of 10,373 short tons, valued at $446,224, compared with 8,752 tons, valued at $273,203, in 1918, an increase in quantity of nearly 19 per cent and in value of 63 per cent.

The total quantity of crude fluorspar mined can not be ascertained exactly, because at most of the smaller mines only the cleaned spar is weighed. From such figures as are available, however, it is apparent that the crude spar mined in 1919 amounted to approximately 192,000 short tons, compared with 326,000 tons in 1918, a decrease of 41 per

[1] Aurand, H. A., Fluorspar deposits of Colorado: Colorado Geol. Survey Bull. 18, pp. 17–18, 1920.
[2] Hibbs, J. G., Boulder County fluorspar: Eng. and Min. Jour., Feb. 21, 1920, p. 494.

cent. The quantity of merchantable spar recovered in 1919 amounted to 153,182 short tons, compared with 270,412 tons in 1918—a decrease of 43 per cent.

FLUORSPAR MINED AND SHIPPED, BY STATES.

Fluorspar was shipped in 1919 from Illinois, Kentucky, Colorado, New Mexico, New Hampshire, Nevada, Utah, and Arizona in quantities ranking in the order in which the States are named. Nevada is a new producing State, and of the other States Utah is the only one to report an increase in 1919. Illinois shipped 92,729 tons of fluorspar, valued at $2,430,361, and Kentucky shipped direct to consumers 32,386 tons, valued at $883,171. These States together therefore furnished 90 per cent of the total fluorspar shipped in 1919, Illinois supplying 67 per cent and Kentucky 23 per cent. The fluorspar shipped direct to consumers from Colorado amounted to 9,687 tons, valued at $150,739, and from New Mexico to 2,346 tons, valued at $37,643. New Hampshire, Nevada, Utah, and Arizona together shipped 1,142 tons, valued at $23,660.

Such details of the fluorspar shipments by States as may be published by the Geological Survey without revealing statistics of individual producers, except by permission, are given in the following table for the years 1915 to 1919:

Domestic fluorspar sold, 1915-1919.

State.	Gravel.			Lump.			Ground.			Total.		
	Quantity (short tons).	Value.	Average price per ton.	Quantity (short tons).	Value.	Average price per ton.	Quantity (short tons).	Value.	Average price per ton.	Quantity (short tons).	Value.	Average price per ton.
1915.												
Illinois	112,769	$547,415	$4.85	12,033	$90,337	$7.51	10,757	$116,161	$10.80	135,559	$753,913	$5.56
Kentucky												
Other States a	b 1,382	b 10,562	7.64	(b)	(b)					1,382	10,562	7.64
	b 114,151	b 557,977	4.89	b 12,033	b 90,337	7.51	10,757	116,161	10.80	136,941	764,475	5.58
1916.												
Illinois	123,983	660,714	5.33	14,489	114,993	7.94	7,595	94,039	12.38	146,067	869,746	5.95
Kentucky												
Other States a	b 9,668	b 52,908	5.47	(b)	(b)					9,668	52,908	5.47
	b 133,651	b 713,622	5.34	b 14,489	b 114,993	7.94	7,595	94,039	12.38	155,735	922,654	5.92
1917.												
Colorado	11,140	94,365	8.47	5,964	102,268	17.15				17,104	196,633	11.50
Illinois	136,954	1,111,348	8.11	19,584	247,192	12.62	10,136	178,342	17.59	156,676	1,373,333	8.77
Kentucky	33,641	534,017	15.87							43,639	697,566	15.98
Other States a	b 1,409	b 20,190	14.33	(b)	(b)					1,409	20,190	14.33
	b 183,144	b 1,759,920	9.61	b 25,548	b 349,460	13.68	10,136	178,342	17.59	218,828	2,287,722	10.45
1918.												
Arizona				364	5,537	15.21				364	5,537	15.21
Colorado	32,680	287,620	8.80	5,795	129,160	22.29				38,475	416,780	10.83
Illinois	122,721	2,565,394	20.90	9,518	260,948	27.42	8,752	273,203	31.22	132,798	2,887,099	21.74
Kentucky	79,411	1,856,739	23.38							87,604	2,069,185	23.62
New Mexico	b 1,309	b 25,507	19.49	b 3,267	b 61,373	18.79				3,437	64,348	18.72
Other States a										1,139	22,532	19.78
	b 236,121	b 4,735,260	20.05	b 18,944	b 457,018	24.12	8,752	273,203	31.22	263,817	5,465,481	20.72
1919.												
Illinois	81,026	1,962,934	24.23	4,246	133,993	31.56	10,373	446,224	43.02	92,729	2,430,361	26.21
Kentucky	29,470	770,381	26.14							32,386	883,171	27.27
Colorado	b 12,088	b 184,044	15.23	b 1,087	b 27,998	25.76				9,687	150,739	15.56
New Mexico										2,346	37,643	16.05
Other States a										1,142	23,660	20.72
	b 122,584	b 2,917,359	23.80	b 5,333	b 161,991	30.38	10,373	446,224	43.02	138,290	3,525,574	25.49

a 1915: Colorado, New Hampshire, and New Mexico; 1916: Arizona, Colorado, and New Hampshire; 1917: Arizona and New Hampshire; 1918: New Hampshire, Utah, and Washington; 1919: Arizona, Nevada, New Hampshire, and Utah.

b Some lump spar is included with gravel.

In 1919 there were 63 operators who produced fluorspar, compared with 119 in 1918.

Merchantable fluorspar mined and number of producers in 1918 and 1919, by States.

State.	1918			1919		
	Number of producers.	Quantity (short tons).	Percentage of total.	Number of producers.	Quantity (short tons).	Percentage of total.
Illinois	13	134,039	49.57	11	103,113	67.31
Kentucky	54	90,900	33.61	31	32,548	21.25
Colorado	37	39,099	14.46	8	12,484	8.15
New Mexico	7	4,736	1.75	9	3,645	2.38
New Hampshire	2	[a] 1,029	[a] .38	1	531	.35
Arizona	4	539	.20	1	45	.10
Utah	1	70	.03	1	116	
Washington	1	([a])	([a])			
Nevada				1	700	.46
	119	270,412	100.00	63	153,182	100.00

[a] Output of Washington included with New Hampshire.

In the following table, summarizing the annual output of domestic fluorspar from 1883 to 1919, the quantities from 1883 to 1905 represent quantity mined; beginning with 1906 they represent quantity shipped from mines. Subnormal conditions are shown in the pre-war year 1914 and the post-war year 1919, and more or less abnormal conditions in 1917 and 1918.

Fluorspar produced in the United States, 1883–1919.

Year.	Quantity (short tons).	Value.	Year.	Quantity (short tons).	Value.	Year.	Quantity (short tons).	Value.
1883	4,000	$20,000	1896	6,500	$52,000	1909	50,742	$291,747
1884	4,000	20,000	1897	5,062	37,159	1910	69,427	430,196
1885	5,000	22,500	1898	7,675	63,050	1911	87,048	611,447
1886	5,000	22,000	1899	15,900	96,650	1912	116,545	769,163
1887	5,000	20,000	1900	18,450	94,500	1913	115,580	736,286
1888	6,000	30,000	1901	19,586	113,803	1914	95,116	570,041
1889	9,500	45,835	1902	48,018	271,832	1915	136,941	764,475
1890	8,250	55,328	1903	42,523	213,617	1916	155,735	922,654
1891	10,044	78,330	1904	36,452	234,755	1917	218,828	2,287,722
1892	12,250	89,000	1905	57,385	362,488	1918	263,817	5,465,481
1893	12,400	84,000	1906	40,796	244,025	1919	138,290	3,525,574
1894	7,500	47,500	1907	49,486	287,342			
1895	4,000	24,000	1908	38,785	225,998		1,927,631	19,230,498

Figure 16 shows graphically the course of the production of fluorspar in the United States from 1883 to 1919. The quantities beginning in 1906 represent shipments from mines. Two periods of fluctuation in output, between 1889 and 1898 and between 1902 and 1908, are in strong contrast with the large and steady increase in production in the periods 1898 to 1902 and 1908 to 1912. The decline from 1912 to 1914, although greater in tons than that from 1905 to 1906, is not so great in proportion to the current production, and the increase from 1914 to 1918 and the decrease from 1918 to 1919 are clearly the largest in any similar periods. For convenience of comparison, the imports, beginning with the first full year for which records are available, 1910, are shown on the same diagram.

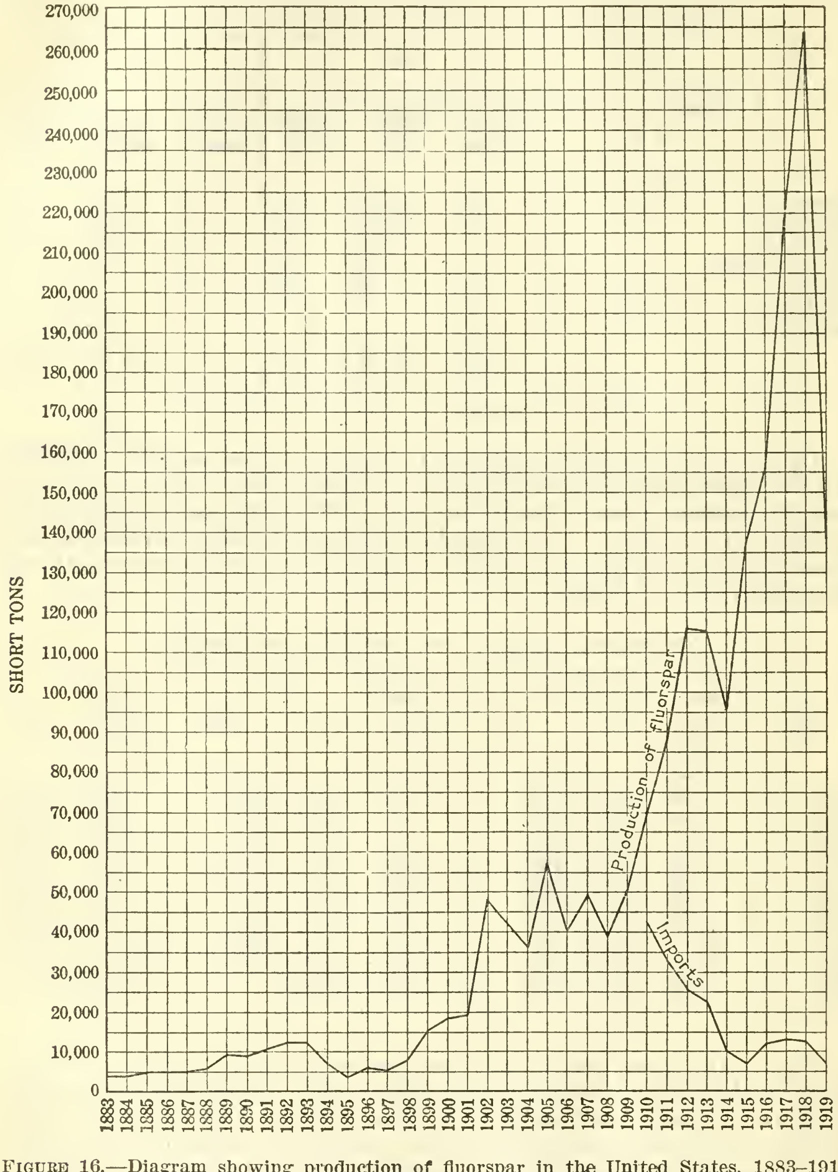

FIGURE 16.—Diagram showing production of fluorspar in the United States, 1883–1919, and imports, 1910–1919.

Figure 17 shows the course of the average prices of domestic fluorspar from 1883 to 1919.

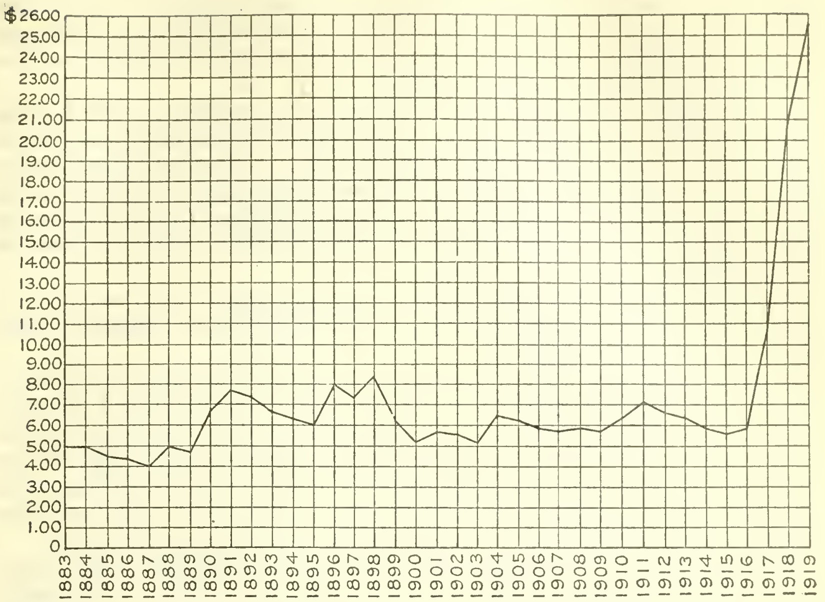

FIGURE 17.—Curve showing average prices per ton of fluorspar at the mines in the United States, 1883–1919.

STOCKS OF FLUORSPAR.

According to the reports of producers, the total quantity of fluorspar in stock at the mines or at shipping points at the end of 1919 amounted to 31,953 short tons, compared with 22,779 tons in 1918, an increase of about 40 per cent. As the quantity of spar in stock piles is necessarily partly estimated, there are variations in the mine reports from year to year which prevent an absolute balance between the quantity mined and the quantity shipped and stocks on hand. Data on consumers' stocks are not available, but it is probable that large supplies were on hand at the end of 1919.

Stocks of fluorspar at mines or shipping points in 1918 and 1919, by States, in short tons.

State.	1918	1919	State.	1918	1919
Arizona	255	255	New Mexico	1,299	1,880
Colorado	4,745	5,870	Utah	50	....
Illinois	5,288	16,044	Washington	200	200
Kentucky	10,942	7,404			
Nevada	....	300		22,779	31,953

IMPORTS.[3]

The imports of fluorspar into the United States in 1919 again showed a decrease, which was probably due in part to the decreased demand, but it is understood that shipments from England were cur-

[3] The statistics of imports were compiled by J. A. Dorsey, of the United States Geological Survey, from records of the Bureau of Foreign and Domestic Commerce.

tailed on account of labor conditions in that country. It is also understood that on account of the low ocean freight rates fluorspar is not a profitable cargo and is carried only in such quantities as are required to ballast a vessel properly.

The imports of fluorspar entered for consumption in the United States in 1919 were 6,943 short tons, valued at $107,631, compared with 12,572 tons, valued at $169,364, in 1918. This represents a decrease in quantity of 45 per cent and in total value of 36 per cent. The value at the foreign ports of shipment assigned to the imports in 1919 averaged $15.50 a ton compared with $13.47 in 1918, an increase of 15 per cent.

The imports of fluorspar in 1919 were equivalent to about 5.7 per cent of the domestic production of gravel spar as compared with about 5.3 per cent in 1918.

According to the values reported, including the duty of $1.34 a short ton ($1.50 a long ton) and the ocean freight, figured roughly at $5 a ton, the average cost of imported spar at the docks in the United States was $21.84 a ton in 1919, compared with $23.80 for domestic gravel spar at the mine or mill; in 1918 the cost of imported material, including the duty of $1.34, was $14.81 a ton plus the ocean freight charges, compared with $20.05 for domestic gravel spar.

The distances that domestic spar must be transported from mines to steel plants in the Lehigh and Susquehanna valleys of Pennsylvania are generally much greater than the distances that English spar must be carried from the docks to these points, so that a slight advantage in price on account of a saving in railway freight charges may be enjoyed by users of the imported material.

According to a consumer in the Lehigh Valley who uses a large quantity of fluorspar imported from England, the foreign spar purchased in 1919 averaged 75 per cent of calcium fluoride and 4 per cent of silica and its cost delivered at the works was about $18 a ton, compared with a cost of about $25 a ton for domestic spar which averaged 85 per cent of calcium fluoride and 6 per cent of silica. Thus the cost of domestic spar was $0.294 per unit of CaF_2, as against $0.24 per unit for the imported material. This consumer states that the better grades of domestic fluorspar are more efficient than the imported spar; that some of the foreign material, especially that received during the war, and some grades of domestic material were unsatisfactory; and that on a fairly even price basis the better grades of domestic fluorspar are to be preferred.

A consumer in southeastern Pennsylvania who uses considerable quantities of English fluorspar states that the material imported in 1919 averaged 83 to 87 per cent of calcium fluoride and 8 to 10 per cent of silica, and that it cost delivered at his steel plant about $21 a ton, or about 25 cents per unit of CaF_2.

Of the imports in 1919 England furnished 6,041 short tons, valued at $94,099, or $15.58 a ton, at the British port of shipment, and Canada supplied 902 tons, valued at $13,532, or $15 a ton.

Fluorspar imported and entered for consumption in the United States in 1918 and 1919, by source and port of entry.

Source.	Port of entry.	1918		1919	
		Quantity (short tons).	Value.	Quantity (short tons).	Value.
England	Massachusetts	273	$3,617	43	$680
	New York	1,235	19,824	648	9,449
	Philadelphia	3,626	47,251	1,616	23,291
	Maryland	6,525	76,699	3,734	60,679
		11,659	147,391	6,041	94,099
Canada	St. Lawrence	67	1,750		
	Buffalo	446	10,033	82	1,909
	Dakota	39	637	746	9,785
	Michigan	361	9,553	74	1,838
		913	21,973	902	13,532
		12,572	169,364	6,943	107,631

Fluorspar imported and entered for consumption, 1909–1919.

Year.	Quantity (short tons).	Value.	Average price per ton.
1909	6,971	$26,377	$3.78
1910	42,488	135,152	3.18
1911	32,764	80,592	2.46
1912	26,176	71,616	2.74
1913	22,682	71,463	3.15
1914	10,205	38,943	3.82
1915	7,167	22,878	3.19
1916	12,323	54,000	4.38
1917	13,616	114,598	8.42
1918	12,572	169,364	13.47
1919	6,943	107,631	15.50

CONSUMPTION.

The market for the bulk of the fluorspar sold in the United States depends on the condition of the steel industry, and the demand fluctuates with the rise and fall in the production of basic open-hearth steel. Most of the domestic gravel and some of the lump spar, together with probably most of the imported spar, are consumed as flux in basic open-hearth steel furnaces and to a smaller extent in other metallurgic operations. From 1915 to 1919 the sales of gravel spar have constituted between 83 and 89 per cent of the total marketed output of domestic fluorspar. Fluorspar is used also as a flux in iron blast furnaces, iron foundries, and gold, silver, copper, and lead smelters; in the manufacture of glass, of enameled and sanitary ware, and of hydrofluoric acid; in the electrolytic refining of antimony and lead; in the production of aluminum: as a bond for constituents of emery wheels; for carbon electrodes; in the extraction of potash from feldspar; and in the recovery of potash in the manufacture of Portland cement.

The following extract from an article on fluorspar as an economizer of fuel was published in the trade journal Concrete, issue of May, 1920, page 82:

In these days, when fuel shortage and high prices make economy a very important factor in manufacture, cement producers are utilizing every means to "cut the coal bill." This has led to the closer investigation of the value of the rotary kiln, methods of utilizing powdered fuel and of feeding the raw mixture, and other ways.

In a recent letter to Concrete A. W. Robertson, Grand Forks, B. C., Canada, has suggested the use of fluorspar with the raw mixture, which has proven a successful means. Mr. Robertson remarks as follows:

"In a plant in which the writer was interested, the fuel item was always our nightmare in the cost sheets, the question becoming so acute that it was either quit or find a remedy. After many experiments it was found that fluorspar or calcium fluoride filled the bill, its use affecting a marked economy in fuel consumption. The calcium and the silica of the spar were recovered and gave a slight addition to our tonnage. The fluorspar available varied slightly in its contents, but on an average a slight departure from the use of ¾ per cent of spar to the weight of raw materials was made with most beneficial results. The quality of the cement was in no way affected."

If any economy in fuel is effected by the use of fluorspar in the rotary kiln it is perhaps due to the lowering of the fusing point of the mixture of raw materials through the addition of an efficient flux.

Much interest has been shown by producers of fluorspar in the use of fluorspar as a wood preservative, as is indicated by a recent article.[4] In spite of the proved value of sodium fluoride as a wood preservative, it is not being used to any extent for that purpose, except by a large coal-mining company, which has been using it since 1915 for the treatment of its mine timbers in preference to zinc chloride or coal-tar creosote. Other companies have expressed an interest in sodium fluoride, but they have never used it in quantity because at present sodium fluoride is selling at 15 cents a pound while zinc chloride can be purchased at 8 cents a pound. During the six years 1913–1918 an average of 28,540,174 pounds of zinc chloride has been used in preserving wood; thus it can be seen that a new field might be opened to sodium fluoride if it could be sold on a fairly even price basis with zinc chloride. However, should sodium fluoride begin to compete sharply with zinc chloride, the price of the latter could probably be reduced. Such a reduction in price would, no doubt, encourage the use of these mineral solutions and thus cause a larger volume of timber to be treated.

Sodium fluoride possesses several minor advantages over zinc chloride, such as less solubility, greater toxic efficiency, and less corrosive action, and it is said not to be injurious to paint applied to timber treated with it. Its superiority for general use as a wood preservative is, however, not sufficient to justify the consumer in paying a much greater price for it.

A close estimate of the annual consumption of fluorspar in the United States can not be made without a knowledge of the stocks maintained by consumers. These stocks are variable; but, as the value of fluorspar as a flux in the manufacture of open-hearth steel and in other metallurgic operations has become generally appreciated and also on account of the difficulties and uncertainty in procuring supplies, consumers have made efforts to keep large stocks in reserve.

Data furnished by steel manufacturers who produced about 50 per cent of the output of basic open-hearth steel in 1919 show that the consumption of fluorspar ranged from 7.25 to 11.8 pounds to each ton of steel. It is believed that if data from all the plants were available

[4] Hunt, G. M., Will sodium fluoride come into general use for preserving wood?: Chem. and Met. Eng., Dec. 8, 1920, pp. 1123–1124.

they would show an average of about 10 pounds of fluorspar to 1 ton of steel. In 1919 a total of 25,719,312 tons of basic open-hearth steel was manufactured, which, on the assumption that 10 pounds of fluorspar was used to each ton of steel made, would indicate a consumption of about 128,600 tons of fluorspar. The quantity of fluorspar reported as shipped to steel manufacturers in 1919 amounted to 120,199 short tons. Adding the imports of 6,943 tons and the stocks estimated to be held by steel manufacturers at the end of 1918, amounting, according to Burchard,[5] to about 57,500 tons, indicates 184,642 tons available for consumption in 1919. It is thus apparent that a surplus of about 56,000 tons of fluorspar was in the hands of steel consumers at the end of 1919, or nearly as much as at the end of 1918.

The shipments of domestic spar plus the imports—as there are no considerable exports at present, and the figures of export are not listed separately by the Bureau of Foreign and Domestic Commerce—should give from year to year an index to the quantity consumed and should indicate the relative increase or decrease in consumption. The total quantity of all grades of spar apparently consumed in 1919 was 145,233 short tons, as compared with 276,389 tons in 1918, a decrease of 47 per cent.

The general relation between the total consumption of fluorspar and the output of open-hearth steel may be noted by comparison of the two following tables:

Fluorspar available for consumption, 1910–1919, in short tons.

Year.	Sales of domestic spar	Imports for consumption.	Apparent consumption.
1910	69,427	42,488	111,915
1911	87,048	32,764	119,812
1912	116,545	26,176	142,721
1913	115,580	22,682	138,262
1914	95,116	10,205	105,321
1915	136,941	7,167	144,108
1916	155,735	12,323	168,058
1917	218,828	13,616	232,444
1918	263,817	12,572	276,389
1919	138,290	6,943	145,233

Open-hearth steel produced, 1910–1919, in long tons.[a]

Year.	Basic.	Acid.	Total.
1910	15,292,329	1,212,180	16,504,509
1911	14,685,932	912,718	15,598,650
1912	19,641,502	1,139,221	20,780,723
1913	20,344,626	1,255,305	21,599,931
1914	16,271,129	903,555	17,174,684
1915	22,308,725	1,370,377	23,679,102
1916	29,616,658	1,798,769	31,415,427
1917	32,087,507	2,061,386	34,148,893
1918	32,476,571	1,982,820	34,459,391
1919	25,719,312	1,229,382	26,948,694

[a] Statistics for 1910 and 1911 according to annual reports of the American Iron and Steel Association and since 1911 from reports of American Iron and Steel Institute.

[5] Burchard, E. F., Fluorspar and cryolite in 1918: U. S. Geol. Survey, Mineral Resources, 1918, p. 325, 1919.

FLUORSPAR SHIPPED, BY USES.

It is possible for the first time, owing to the cooperation of the fluorspar producers, to present in the following table data on the shipments and value of fluorspar sold for use in the various industries in 1919. The dependence of the fluorspar industry on the steel industry is clearly shown by the fact that nearly 87 per cent of the total fluorspar shipped in 1919 was taken by steel manufacturers. There is considerable variation in the average price per ton, as shown in the following table. The high price of spar for glass and enamel ware and hydrofluoric acid is due to the high quality demanded.

Fluorspar shipped in 1919, by uses.

Use for which shipped.	Quantity.		Value.	Average price per ton.
	Percentage of total.	Short tons.		
Open-hearth steel	86.92	120,199	$2,841,462	$23.64
Glass and enamel ware	7.47	10,338	444,696	43.02
Hydrofluoric acid	2.63	3,643	134,641	36.96
Aluminum	1.10	1,516	37,169	24.52
Foundry	.84	1,156	67,606 (Foundry and Other)	26.06 (Foundry and Other)
Other [a]	1.04	1,438		
	100.00	138,290	3,525,574	25.49

[a] Includes fluorspar shipped for use in lead refining, compounding with brass steel, cement and chemical manufacture, and unspecified.

FLUORSPAR IN FOREIGN COUNTRIES.

ARGENTINA.[6]

At San Roque, in Cordoba, Argentina, veins of fluorite occur in biotite gneiss east of the contact of the gneisses with the granite massif of the Andes and in association with numerous pegmatites. The veins have a northwesterly strike, can be traced for several hundred yards, and range from fissure veins 8 to 12 inches wide to lodes several yards wide. The fluorspar occurs in bands that are colorless, light green, yellow, violet, blue, or almost black. Pyrite is the only metallic mineral in the veins, and there is some chalcedony which is white with a light violet tinge due to the inclusion of microscopic fluorite.

AUSTRALIA.

NEW SOUTH WALES.

At the old Woolgarlo silver-lead mine, in the Yass division, New South Wales, which carries more or less fluorspar, mining operations were commenced in October, 1915, and up to the end of 1917 about 2,356 long tons of fluorspar had been recovered. This, together with 731 tons obtained from Carboona, in the Tumbarumba district, was shipped to the steel works of the Broken Hill Proprietary Co., at

[6] Miller, B. L., and Singewald, J. T., Mineral deposits of South America, p. 54, 1919.

Newcastle, where the fluorspar was used chiefly in connection with the manufacture of steel. The quantity mined in 1919 amounted to 2,014 long tons, as compared with 2,278 tons in 1918.[7]

From time to time small deposits of fluorspar associated with tungsten and copper ores have been found in the neighborhood of The Gulf.[8] The fluorspar is generally very clean and pure, the only inclusions seen being traces of native bismuth and a small quantity of metallic sulphide (iron?). It would not be difficult to obtain the mineral in bulk practically free from these impurities. The deposits are most commonly associated with tungsten, which is not, however, mixed with the fluorspar to any extent. No defined body has yet been found, and consequently no estimate of quantities likely to be available can be given. The largest deposit known was associated with a pipelike formation of copper ore inclosed in granite, as indeed are all the known deposits in this district. The fluorspar in this deposit entirely surrounded the copper, but how far it extended beyond was not proved, as only the center of the formation—the copper ore—was taken out. Judged by what was seen in the shaft, it was estimated that the thickness of this inclosing layer of fluorite is from 1 to 3 feet. The copper was in the form of the yellow sulphide, partly altered to the black sulphide; its value in bulk was estimated at 23 per cent of copper. The diameter was irregular and would average 3 or 4 feet; the depth attained at the time of inspection was about 50 feet.

There are several localities in which the fluorite found is of the same quality. Some of it is roughly crystallized and very translucent, and it is all of a rich green color, except that associated with the copper ore, whose color is less distinct.

The localities in which it is found are about three-quarters of a mile west to 3 miles northwest of The Gulf. As expensive cartage of 30 miles or more to the nearest railway station at Deepwater is necessary, the mineral can not be used for ordinary industrial purposes, such as smelting, in which great purity might not be essential.

Several inquiries were recently made for pure fluorite for purposes for which inferior material would be unsuitable, and, as samples had been forwarded for analyses, the inquirers were readily satisfied as to quality. This has resulted in the mining of more than 100 tons and the establishment of the enameling industry in Sydney. Other inquiries have been made about fluorite for fluxing, including one recently in connection with the smelting of nickel ores in New Caledonia. The cost of transit to the railway may, however, prove too high to admit of its use for this purpose.

Fluorspar has never been mined in this district for itself, except as mentioned above, and no attempts have been made to develop it. It will prove to be patchy in its occurrence, and only comparatively small deposits may be found; but it is believed that appreciable quantities could be obtained by systematic prospecting for it. It is regarded as a good indication of the proximity of more valuable minerals, such as tungsten, of which it is a common associate. Therefore, in opening any deposits of fluorite there would always be a possibility of finding other minerals whose presence might not otherwise become known.

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[7] New South Wales Dept. Mines Ann. Rept., 1919, p. 4, 1920.

[8] Smith, George, Occurrence of pure fluorspar in New South Wales: Dept. Mines Ann. Rept., 1918, p. 76, 1919.

QUEENSLAND.

In the Herbertson district, Queensland, 71 long tons of fluorspar was mined for export in 1917, but none was reported to have been mined in 1918 and 1919.[9]

Many inquiries for fluorspar have been made by merchants in Sydney, but little business has resulted.[10]

CANADA.

The greatly increased use of fluorspar as a flux in the manufacture of open-hearth steel has led to the development and opening of deposits of fluorspar in Canada. The principal producing area is at Madoc, Ontario, where the fluorspar occurs in veins associated with much calcite and a little quartz; these veins are reported to cut all the rock formations from the older crystalline rocks to the later Paleozoic limestones.[11] In the Matachewan area fluorspar has been found in small quantity in a number of quartz veins in Cairo and Alma townships. It has also been found in a barite vein. All the veins are reported to occur in syenite.[12]

The greater part of the output in Ontario is shipped to Hamilton, Welland, Toronto, and other points in Ontario, but a portion is exported to the United States.[13]

The Rock Candy mine, on Kennedy Creek near Grand Forks, British Columbia, owned by the Consolidated Mining & Smelting Co., was opened during 1918. The mine has been developed by tunnels, crosscuts, and a raise.[14] The deposit is about 140 feet wide at the lowest point developed. The entire 140 feet is not commercial fluorite, the greater portion being a vein material of chert, barite, and quartz, with small inclusions of limonite, chalcopyrite, galena, chalcocite, pyrite, and covellite. The surrounding rocks appear to belong to the alkali-syenite group. A mill having a capacity of 100 tons a day has been built on Lynch Creek, in the Similkameen district. A good many problems in regard to concentration of fluorite by decrepitation have been overcome by the company's chemists, and the results are satisfactory.[15] The mine is about 2 miles from the mill and is connected with it by an aerial tramway. A considerable quantity of the fluorspar is shipped to the company's smelter at Trail, where it is used for making hydrofluoric acid, which is used in the lead refinery. Shipments are also made to other points in Canada and to the United States.

The quantity of fluorspar shipped from mines in Canada amounted to less than 100 short tons prior to 1916, when 1,284 tons was mined and shipped. The shipments increased to 7,362 tons, valued at $135,-712, or $18.43 a ton, in 1918, but coincident with the depressed condition of the steel industry in 1919 the shipments declined to 5,063 tons, valued at $97,837, or $19.32 a ton.[16]

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[9] Queensland Under Secretary for Mines Ann. Rept., 1920.
[10] Queensland Govt. Min. Jour., April, 1920, p. 143.
[11] Eng. and Min. Jour., July 20, 1918, p. 104.
[12] Canadian Min. Jour., June 15, 1918, p. 201.
[13] Ontario Bur. Mines Twenty-eighth Ann. Rept., 1919.
[14] British Columbia Dept. Mines Bull. 1, 1920.
[15] British Columbia Minister of Mines Ann. Rept., 1919.
[16] Preliminary report of the mineral production of Canada during the calendar year 1919, Canada Dept. Mines, Mines Branch, 1919.

The consumption of fluorspar by Canadian steel works has shown an increase from 7,461 tons in 1910 to 12,796 tons in 1919. The largest consumption was in 1918, when 17,307 tons was consumed.

Although the production of fluorspar in Canada has been increased, the output is not equal to the demand and it is necessary to import considerable quantities from England and the United States. No data are available showing the quantities imported, but the consumption of fluorspar plus the exports minus the shipments should give an index to the quantity imported, and these data, together with the production of open-hearth steel, are shown in the following table:

Statistics of fluorspar in Canada, 1913–1919, in short tons.

Year.	Production of open-hearth steel.[a]	Fluorspar.			
		Consumed.[a]	Shipped.[a]	Exported to United States.[b]	Apparent imports.
1913	864,035	10,687	....	....	10,687
1914	623,698	7,845	....	....	7,845
1915	990,795	13,520	....	....	13,520
1916	1,400,883	13,213	1,284	556	12,485
1917	1,685,715	17,084	4,249	93	12,928
1918	1,746,334	17,307	7,362	913	10,858
1919	1,008,540	12,796	5,063	902	8,635

[a] Data compiled from reports of Canada Dept. Mines, Mines Branch.
[b] Data compiled from Bur. Foreign and Domestic Commerce.

GERMANY.[17]

The largest fluorspar deposits in Germany are in the Harz Mountains, Upper Palatinate, Thuringian Forest, and Black Forest. The best material, generally containing 95 to 98 per cent of calcium fluoride and relatively little silica, is produced in the Upper Palatinate. Many mines were forced to close before the war because mining was profitable only in particularly rich veins, but during the war profits increased so greatly that nearly all the mines that had closed were able to resume work.

Most of the fluorspar produced in Germany is consumed by the iron industry, which, it is estimated, uses between 79 and 84 per cent. The glass industry is estimated to consume between 10 and 15 per cent, and the remainder is used in the chemical, enamel, and optical industries.

By reason of the cheapness of mining and milling and of the unfavorable rate of German exchange it is believed that fluorspar can, despite the enormous wages, freights, and cost of packing, be profitably exported at present, and advantage is largely taken of this opportunity. Austria and Hungary, in which currency conditions are worse than in Germany, are said to be able to offer fluorspar only at higher prices, so that Germany, being able to offer cheaper prices on the world market than any other country, seems to be in a favorable position for the export of this mineral.

[17] Information furnished by Beer, Sondheimer & Co., Frankfort on the Main, Germany.

GREAT BRITAIN.

Fluorspar occurs in abundance in the lead and zinc veins of Derbyshire and Durham and in smaller quantities elsewhere in England. It is commonly associated with calc-spar, quartz, and barytes in the gangue of the veins, but it is noticeable that in Derbyshire, where the country rock is chiefly limestone, the associated minerals are calc-spar and barytes, and in Durham, where much of the country rock is arenaceous, the associated minerals are calc-spar and quartz.[18]

Fluorspar is a by-product in some lead mines, but in certain mines it now forms the chief product, veins which are poor in lead ore or from which the lead ore had been extracted before fluorspar became a valuable material being now reworked for fluorspar.[19] During the last 20 years a considerable quantity of fluorspar has been recovered by picking over surface dumps and from the waste stowed in the mines. Very little dressing is required, except to remove lead ore where it is present in remunerative quantities. In fact, a considerable proportion of the fluorspar of commerce is actually the tailing from lead-dressing plants. For these various reasons the cost of production is low—at Ashover it has varied from 3s. 6d. (85 cents) a ton in 1911 to 13s. 6d. ($3.28) in 1916.

Prior to 1901 the production of fluorspar in England amounted to less than 1,500 long tons annually, after which a general rise set in, the output reaching 64,874 tons in 1917. About 1905 it was found that fluorspar suitable for basic open-hearth steel furnaces could be obtained at small cost through the working of the old lead-mine dumps, and in that year the output amounted to 39,446 tons, compared with 18,160 tons in 1904. From 1905 to 1913 large quantities of fluorspar were shipped to the United States and competed to a considerable extent with domestic fluorspar, but during the last seven years the exports to the United States have shown a large decrease, averaging about 11,800 long tons annually.

No data are available showing the quantities of fluorspar consumed in the industries in the United Kingdom, but it is reported[20] that the annual home requirements amount to about 35,000 long tons and that about 10,000 tons is exported to Canada.

The production of fluorspar in Great Britain[21] in 1919 amounted to 36,860 long tons, valued at £36,252,[22] as compared with 53,498 tons, valued at £41,310, in 1918.

The output of fluorspar in Great Britain is reported under three headings—metalliferous mines, quarries more than 20 feet deep, and certain workings not included under metalliferous mines or quarries. It is probable that the output recorded under certain workings is from old waste dumps. In the following table is given the production of fluorspar under the above-mentioned classification:

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[18] Carruthers, R. G., Pocock, R. W., and Wray, D. A., Fluorspar: Special report on the mineral resources of Great Britain, vol. 4 (Geol. Survey Mem.), 38 pp., 1916.

[19] Report of the department committee appointed by the Board of Trade (Great Britain) to investigate and report upon the nonferrous mining industry, 1920.

[20] Report of the controller of the department for the development of the mineral resources in the United Kingdom, 1918.

[21] Mines and Quarries, general report for 1919, pt. 3, 1920.

[22] The value of the pure metal content of the pound sterling, as declared by the United States Treasury, is $4.8665; but exchange rates fluctuated so greatly in the years under discussion that no attempt has been made to convert the values given above to United States money.

Fluorspar produced in Great Britain, 1913–1919, in long tons.

Year.	Metalliferous mines.	Quarries (more than 20 feet deep).	Other.	Total.
1913	33,833	4,963	14,867	53,663
1914	24,688	2,513	6,615	33,816
1915	25,577	1,734	5,812	33,123
1916	34,547	139	20,045	54,731
1917	43,934	8	20,932	64,874
1918	43,066	1,051	9,381	53,498
1919	32,725	....	4,135	36,860

MEXICO.

In Mexico, according to Wittich,[23] fluorspar is one of the nonmetalliferous minerals which has been exploited on a large scale during the last few years and the mining of which can be still further expanded. It is found associated with local metalliferous minerals and with other gangue minerals, such as quartz and calcite.

One of the richest deposits and the only one from which the mineral has been mined commercially is in Mount Realejo, near Guadalcazar, in the State of San Luis Potosi, where brilliantly colored fluorite occurs with other minerals on the contact between the granite and the Cenomanian limestone. The fluorite is found in masses or in irregular veins associated with quartz, pyrite, and a little antimony.

Statistics on the production of fluorite in Guadalcazar are not available, but it is reported that shipments amounting to many tons are sent monthly from the station of Villar, the nearest to Guadalcazar. The product is consumed in the iron and steel works of Monterrey and also in the chemical industry for the production of hydrofluoric acid.

About three-fifths of a mile west of Guadalcazar fluorspar, associated with pyrite, tetrahedrite, arsenopyrite, and stibnite, forms a single mass in the contact deposits. About 3 miles from these deposits fluorspar is found in deposits of cinnabar, in the limestone. The cinnabar deposits contain also nodules of barite (barium sulphate) and anhydrite, with small cubes of fluorite. Near the mine La Luz, in the eastern slope of Mount Realejo, fluorite is found with various contact minerals, such as iron garnets and grossularite, and with black and white tourmalines, calcite, and pyrite; these minerals form an extensive contact zone, massive and very compact.

Several other deposits of fluorite in Mexico give promise of becoming profitable. One of these is in the Magdalena district, State of Sonora.[24] A deposit of green fluorite in the town of Chalchihuites, in Zacatecas, has been temporarily exploited. Fluorspar with bismuth minerals and pyrite is encountered in the rhyolite of Santa Rosa Mountain, north of Guanajuato. Fluorspar is found in the Garandiay mine, near Saxco, Guerrero.

The geologic catalogue of the minerals of Mexico, published in 1901, contains a list of the places where fluorspar is found, but only

[23] Wittich, Ernesto, La fluorita en los criaderos de contacto y de cinabrio de Guadalcazar, San Luis Potosí: Petróleo. vol. 13, No. 197, p. 10, Apr. 17, 1920.
[24] Peña, Marcelo, Los criaderos de fluorita en Santa Cruz, Sonora: Bol. minero, vol. 5, No. 546, p. 577, 1918.

at the few localities mentioned above is it recognized in commercial quantity.

SPAIN.

Small quantities of fluorspar are mined annually at a lead mine in the province of Guipuzcoa, Spain. The quantity mined in 1919 was 280 metric tons, as compared with 350 tons in 1918.

PRODUCTION IN PRINCIPAL COUNTRIES.

The principal sources of the world's present supply of fluorspar are the United States, Great Britain, Germany, France, Canada, Australia, Italy, Spain, Mexico, Norway, and the territory that was Austria-Hungary. The bulk of the world's supply comes from the United States and Great Britain, and the United States is also the largest consumer. In the following table is given the production of fluorspar in those of the above-mentioned countries for which statistics are available. No statistics are available for Mexico, Germany, and the former Austria-Hungary, but the annual pre-war output of Germany and Austria-Hungary was about 8,000 and 20,000 tons, respectively.

Fluorspar produced in some principal countries, 1913–1919, in metric tons.

Country.	1913	1914	1915	1916	1917	1918	1919
United States	104,853	86,289	124,230	141,282	198,519	239,333	125,454
Canada				1,165	3,855	6,679	4,593
Great Britain	54,522	34,357	33,653	55,607	65,912	54,357	37,452
Spain	351	79	370	277	250	350	280
France	7,524	(a)	(a)	(a)	(a)	(a)	4,894
Australia:							
New South Wales			424	1,407	1,631	2,315	2,046
Queensland					72		
Norway			180	140	(a)	(a)	(a)
Italy				800	800	876	900

a Statistics not available.

OPTICAL FLUORSPAR.

Fluorspar suitable for optical purposes has occasionally been found in mines in southern Illinois, western Kentucky, and some Western States. In 1918, 371 ounces of optical fluorspar were produced from material mined in Riverside County, Calif., and Crittenden County, Ky.; none was reported in 1919.

Notes on the properties, uses, quality, and value of optical fluorspar and suggestions as to developments were given in the chapter on fluorspar in Mineral Resources for 1917, Part II, pages 301–302; in the chapter on gems and precious stones in Mineral Resources for 1918, Part II, page 13; and in Bulletin 38 of the Illinois Geological Survey, 1918.

CRYOLITE.[25]

All the natural cryolite—sodium-aluminum fluoride (Na_3AlF_6)—used in the United States is imported from Greenland. Some artificial cryolite is understood to be produced in the manufacture of

[25] For data on the character, source, mining, and use of cryolite see Bernard, C. P., The cryolite mine at Ivigtut, Greenland: Min. Mag. (London), April, 1916, pp. 202–203; also U. S. Geol. Survey Mineral Resources, 1916, pt. 2, pp. 322–323, 1919.

aluminum, but it is not reported as marketed commercially, and no statistics are available as to its output.

The quantity of cryolite imported for consumption in the United States in 1919 was 2,131 long tons, valued at $106,956, compared with 1,950 tons, valued at $97,500, in 1918. The average price per ton, computed from declared values at the Greenland port of shipment, was $50.19 in 1919, compared with $50 in 1918. Cryolite is imported free of duty.

The annual imports of cryolite, beginning in 1894, as compiled from the records of the Bureau of Foreign and Domestic Commerce, are shown in the following table:

Cryolite imported and entered for consumption in the United States, 1894–1919.

Year.	Quantity (long tons).	Value.	Average price per ton.	Year.	Quantity (long tons).	Value.	Average price per ton.
1894 [a]	12,756	$170,215	$13.34	1907	1,438	$28,902	$20.10
1895	8,685	116,273	13.39	1908	1,124	16,445	14.63
1896	7,024	93,198	13.27	1909	1,278	18,427	14.42
1897	3,009	40,056	13.31	1910	36	2,343	65.08
1898	10,788	114,178	10.58	1911	2,007	47,093	23.46
1899	5,529	79,455	14.37	1912	2,126	48,293	22.72
1900	5,878	78,658	13.38	1913	2,559	52,557	20.54
1901	6,167	82,533	13.38	1914	4,612	94,424	20.47
1902	4,653	61,116	13.13	1915	3,940	82,750	21.00
1903 [b]	7,708	102,879	13.34	1916	3,857	165,222	42.84
1904	959	13,708	14.29	1917	4,383	218,500	49.86
1905	1,600	22,482	14.05	1918	1,950	97,500	50.00
1906	1,505	29,583	19.66	1919	2,131	106,956	50.19

[a] Fiscal years, 1894–1902. [b] Calendar years, 1903–1919.

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SLATE.

By G. F. Loughlin and A. T. Coons.

CONDITIONS OF SLATE INDUSTRY.

The slate industry, like all other industries connected with the building trades, was affected by industrial conditions in 1919. Labor in all sections was reported as very scarce and hard to hold in spite of continued increase in wages. Lack of cars for transportation and difficulty in obtaining coal were, however, considered more serious drawbacks than labor conditions.

The demand for all products was very light during the first part of the year, but during the last half and especially during the last three months the demand exceeded the supply. The prices for all classes of slate were somewhat increased, but only enough, it was stated, to cover the increased cost of production. The demand for electrical slate, which fell off so abruptly with the signing of the armistice in November, 1918, did not recover until the end of 1919, but the prospects for 1920 were then good.

Completion of the tables that follow has been greatly delayed because of the cooperative agreement with the Bureau of the Census, through which all returns from producers were received. Returns for 1920, collected from producers direct, are now complete, and a review of the industry for both 1919 and 1920 will be given in the report for 1920.

GENERAL STATISTICS.

The sales of slate in 1919 were marked by an increase of 19.6 per cent in the quantity of roofing slate and a decrease of 18 per cent in the quantity of millstock for structural and electrical work. The increase in the production of roofing slate does not denote any marked prosperity, as the output of this product has decreased more than 63 per cent within the last 10 years. The increase in value of roofing slate in 1919 amounted to 39 per cent, compared with 1918, and was due largely to an increase of 95 cents in the average value per square, which was $2.95 more than in 1910.

Slate sold in the United States, 1910–1919.

Year.	Roofing slate.			Millstock.			Other uses (value).	Total value.
	Number of squares (100 sq. ft.).	Value.	Average price per square.	Quantity (square feet).	Value.	Average price per square foot.		
1910	1,260,621	$4,844,664	$3.84	5,181,498	$999,098	$0.192	$392,997	$6,236,759
1911	1,124,677	4,348,571	3.87	5,744,577	1,027,605	.178	351,843	5,728,019
1912	1,197,288	4,636,185	3.87	5,765,273	1,013,220	.176	393,913	6,043,318
1913	1,113,944	4,461,062	4.00	6,312,011	1,233,838	.195	480,576	6,175,476
1914	1,019,553	4,160,832	4.08	5,361,925	977,930	.182	568,025	5,706,787
1915	967,880	3,746,334	3.87	4,576,112	819,672	.179	392,909	4,958,915
1916	835,873	3,408,934	4.08	5,782,842	1,177,260	.20	[a] 752,643	5,338,837
1917	703,667	3,411,740	4.85	5,478,151	1,277,249	.23	[a] 1,060,977	5,749,966
1918	379,817	2,219,131	5.84	4,841,133	1,498,164	.31	[b] 321,475	[c] 4,038,770
1919	454,337	3,085,957	6.79	3,965,281	1,316,436	.33	[ab] 1,628,255	6,030,648
Percentage of increase or decrease	+19.6	+39.1	+16.3	−18.1	−12.1	+6.5	(d)	(d)

[a] Includes value of slate granules. Prior to 1916 no record of this product was obtained.
[b] Includes in 1918: 1,244,740 school slates, valued at $17,016, 1,607,849 square feet of blackboard material, valued at $264,921, and 89,074 square feet of billiard-table material, valued at $33,502, and excludes value of slate granules; in 1919: 2,445,435 school slates, valued at $54,635, 1,845,687 square feet of blackboard and bulletin-board material, valued at $304,251, 349,018 square feet of billiard-table material, valued at $107,471, and 202,611 short tons of slate granules, valued at $1,155,140.
[c] Excludes value of slate granules.
[d] Not comparable on account of exclusion of value of slate granules in 1918.

Colored slates [a] sold in New York and Vermont in 1909 and 1914–1919.

Year.	Red.	Green.			Purple.	Purple and green, mottled, variegated	Total.
		Sea-green.	Unfading green.	Green.			
1909	$37,789	$758,372	$183,135	$246,612	$145,041	$443,430	$1,814,379
1914	36,256	789,055	81,884	190,265	121,935	307,628	1,527,023
1915	28,223	672,917	71,765	191,573	88,987	303,199	1,356,664
1916	16,039	529,875	51,328	122,487	265,523	328,154	1,313,406
1917	[b] 18,796	350,762	77,805	232,469	216,454	474,055	1,370,341
1918	[b] 11,383	343,309	42,574	237,182	175,656	430,709	1,240,813
1919	[b] 30,138	466,029	107,271	154,978	252,912	430,320	1,441,648

[a] Exclusive of value of granules.
[b] Value of 1,719 squares of roofing slate in 1917, 852 squares in 1918, and 3,036 squares in 1919.

Slate sold in United States, 1915–1919, by States.

State.	1915	1916	1917	1918	1919
California	....	(a)	(a)	(a)	....
Maine	$243,312	$342,474	$322,685	$287,891	$279,274
Maryland	91,277	71,737	67,938	42,113	71,593
New Jersey	(a)	(a)	(a)	(a)	....
New York	127,603	21,345	55,207	[b] 11,383	450,379
Pennsylvania	3,044,269	3,124,743	3,306,704	2,304,647	2,885,072
Tennessee	....	....	(a)	(a)	....
Utah	(a)	(a)	(a)	(c)	400
Vermont	1,234,891	1,607,901	1,858,307	[b] 1,279,987	2,143,648
Virginia	210,612	165,483	135,380	109,723	200,282
Undistributed [d]	6,951	5,154	3,745	3,026	....
	4,958,915	5,338,837	5,749,966	[b] 4,038,770	6,030,648

[a] Included under "Undistributed."
[b] Exclusive of value of slate granules.
[c] Slate granules only produced and figures excluded from total for United States in 1918.
[d] 1915: New Jersey and Utah; 1916: California, New Jersey, and Utah; 1917: California, New Jersey, Tennessee, and Utah; 1918: California, New Jersey, and Tennessee.

Slate sold in the United States in 1918 and 1919, by States and uses.

State.	Number of operators.	Roofing slate.			Mill stock.						Other.	Total value.
		Number of squares (100 square feet).	Value.	Average price per square.	Structural and sanitary.		Electrical.		Total.			
					Quantity (square feet).	Value.	Quantity (square feet).	Value.	Quantity (square feet).	Value.		
1918.												
California	1			$8.00								(a)
Maine	3	2,699	$26,417	9.79			436,171	$260,059	436,171	$260,059	$1,415	$287,891
Maryland	4	4,680	40,869	8.73							1,244	42,113
New Jersey	2			4.80								(a)
New York	8	852	11,383	13.36								b 11,383
Pennsylvania	49	211,196	1,161,545	5.50	2,824,795	$686,999	406,514	171,880	3,231,309	858,879	c 284,223	2,304,647
Tennessee	1			5.00								
Vermont	36	144,338	866,168	6.00	134,367	40,162	1,039,286	339,064	1,173,653	379,226	34,593	b 1,279,987
Virginia	4	15,590	109,723	7.04								109,723
Undistributed d		462	3,026									3,026
	108	379,817	2,219,131	5.84	2,959,162	727,161	1,881,971	771,003	4,841,133	1,498,164	321,475	b 4,038,770
1919.												
Maine	3	4,476	42,851	9.57	2,454	1,535	387,767	234,888	390,221	236,423		279,274
Maryland	4	6,483	70,336	10.85	1,388	1,257			1,388	1,257		71,593
New York	6	3,386	35,138	10.38							415,241	450,379
Pennsylvania	43	269,580	1,679,519	6.23	2,604,784	676,301	302,879	114,933	2,907,663	791,234	414,319	2,885,072
Utah	1										400	400
Vermont	31	148,522	1,057,831	7.12	54,621	29,547	611,388	257,975	666,009	287,522	798,295	2,143,648
Virginia	4	21,890	200,282	9.15								200,282
	92	454,337	3,085,957	6.79	2,663,247	708,640	1,302,034	607,796	3,965,281	1,316,436	e 1,628,255	6,030,648

a Included under "Undistributed."
b Exclusive of value of slate granules.
c Composed of 1,244,740 school slates, valued at $17,016; 1,592,849 square feet of blackboard material, valued at $262,221; 14,916 square feet of billiard-table material, valued at $3,252; and slate for other uses, valued at $1,734.
d Includes California, New Jersey, and Tennessee.
e Includes 2,445,435 school slates, valued at $54,635; 1,845,687 square feet of blackboard and bulletin-board material, valued at $304,251; 349,018 square feet of billiard-table material, valued at $107,471; and 202,611 short tons of slate granules, valued at $1,155,140.

Slate sold in Pennsylvania in 1918 and 1919.

County.	Number of operators.	Roofing slate.			Mill stock.								Other (value).[a]	Total value.
		Number of squares (100 square feet).	Value.	Price per square.	Structural. Quantity (square feet).	Structural. Value.	Electrical. Quantity (square feet).	Electrical. Value.	Blackboards. Quantity (square feet).	Blackboards. Value.	School slates. Number.	School slates. Value.		
1918.														
Lehigh	13	21,548	$118,826	$5.53	64,378	$15,518	214,145	$83,774	298,690	$39,977	514,033	$6,953	....	$265,048
Northampton	36	189,648	1,042,719	5.50	2,760,417	671,481	192,369	88,106	1,294,159	222,244	730,707	10,063	$4,986	2,039,599
	49	211,196	1,161,545	5.50	2,824,795	686,999	406,514	171,880	1,592,849	262,221	1,244,740	17,016	4,986	2,304,647
1919.														
Lehigh and Lancaster	14	22,287	135,769	6.09	74,199	21,670	113,661	64,823	223,466	44,932	1,898,872	31,992	7,861	307,047
Northampton	29	247,293	1,543,750	6.24	2,530,585	654,631	189,218	50,110	1,622,221	259,319	546,563	22,643	47,572	2,578,025
	43	269,580	1,679,519	6.23	2,604,784	676,301	302,879	114,933	1,845,687	304,251	2,445,435	54,635	55,433	2,885,072

[a] In 1918, includes 14,916 square feet of billiard-table material, valued at $3,252; in 1919, 167,488 square feet of billiard-table material, valued at $45,417.

Roofing slate exported from the United States, 1914–1919.

1914	$139,125	1916	$27,630	1918	$65,224
1915	46,137	1917	27,113	1919	55,164

The following table of exports was furnished by the Bureau of Foreign and Domestic Commerce, United States Department of Commerce:

Roofing slate exported from the United States, 1918 and 1919.

1918.

Canada	$54,478	Hongkong	$94
Mexico	50	Philippine Islands	673
Panama	20	Dutch East Indies	49
South America:		French Oceania	1
British Guiana	290	Australia	4,371
Peru	4,000		
Chile	220		65,224
West Indies:			
Haiti	150		
Trinidad and Tobago	828		

1919.

Canada	$43,774	Panama	$1,745
Newfoundland and Labrador	34	Colombia	545
Mexico	1,934	England	15
Honduras	8	Greece	39
West Indies:		British South Africa	79
Bermuda	1,060	Australia	3,766
Cuba	1,116		
Dominican Republic	51		55,164
Trinidad and Tobago	998		

Slate, other than roofing, exported in 1918 and 1919.

Country.	Electrical.		Structural.		Blackboards.		Billiard tables.		School slates.		Slate pencils.		Total value.
	Quantity (square feet).	Value.	Quantity (square feet).	Value.	Quantity (square feet).	Value.	Quantity (square feet).	Value.	Quantity (cases).[a]	Value.	Quantity (cases).[a]	Value.	
1918.													
Canada	10,883	$7,215			8,025	$1,605	39	$12	2,804	$20,473			$29,305
Mexico	1,900	2,147					433	130	146	507			2,784
Central America	80	91					632	190	1,762	12,526	300	$3,081	15,888
West Indies	2,520	2,848	1,285	$525	4,262	985	1,989	597	435	2,447			7,402
South America	7,400	8,374					1,150	345	3,124	24,154	300	3,081	35,954
Europe	3,340	3,774					235	71	470	1,784			5,629
Africa	360	407							1,535	11,325	750	7,703	19,435
Oceania	2,820	3,186							3,115	15,296	800	8,216	26,698
Asia	6,580	7,436							3,130	23,168	1,300	13,864	44,468
	35,883	35,478	1,285	525	12,287	2,590	4,478	1,345	16,521	111,680	3,450	35,945	187,563
1919.													
Canada	12,646	7,555	(b)	(b)	33,401	7,259	b2,001	b 1,031					15,845
Mexico	2,280	1,527					1,145	343	28	286			2,156
Central America	140	93					468	140					233
West Indies	3,760	2,525					2,529	759	1,000	9,980			13,264
South America	6,200	4,153					5,171	1,551	4,405	44,035			49,739
Europe	2,659	1,896			1,440	346	62	19					2,261
Africa	620	415							2,509	25,039			25,454
Oceania	2,240	1,500					39	12	4,821	48,091			49,603
Asia	10,940	7,327					97	29	1,000	9,980			17,336
	41,485	26,991	(b)	(b)	34,841	7,605	b11,512	b3,884	13,763	137,411			175,891

a Cases weigh from 130 to 165 pounds each; average is 135 pounds.
b Structural slate included under slate for billiard tables.

Slate imported into Canada in 1916-1919.[a]

	1916	1917	1918	1919
Roofing slate	[b] $21,335	[b] $20,785	[b] $47,975	[b] $27,623
School writing slate	35,887	40,603	41,122	46,342
Slate pencils	11,309	8,717	10,361	10,059
Slate of all kinds and manufactures of	28,245	36,788	33,596	58,953
	96,776	106,893	133,054	142,977

[a] McLeish, John, Preliminary report of the mineral production of Canada during the calendar year 1919, Canada Dept. Mines.

[b] Represents 4,412 squares in 1916; 3,909 squares in 1917; 8,296 squares in 1918; and 4,036 squares in 1919.

FELDSPAR.

By L. M. Beach.

PRODUCTION.

The feldspar sold in 1919 was 28 per cent less in quantity and 13 per cent less in value than in 1918. The average price for spar sold crude in 1919 was $5.36 per long ton, as compared with $4.65 in 1918. The average price of ground spar was $14.64 per short ton, as compared with $12.33 in 1918.

In the following tables are shown the classified data of the production of feldspar in recent years.

Feldspar sold in 1918 and 1919, and value at price for crude feldspar.

State.	1918		1919	
	Quantity (long tons).	Value.	Quantity (long tons).	Value.
California	1,296	$8,839	(a)	(a)
Connecticut	5,305	29,419	9,715	$84,050
Maine	22,656	105,430	12,845	59,602
Maryland	7,843	40,299	6,982	39,610
New York	11,277	58,076	(a)	(a)
North Carolina	35,732	160,275	22,495	116,826
Pennsylvania	4,389	27,651	(a)	(a)
Undistributed			11,404	47,904
	88,498	429,989	63,441	347,992

a Included under "Undistributed."

Many feldspar miners grind their spar and market it in ground form and by the short ton; hence the following table is given in short tons. The values for each State include both crude and ground spar sold and represent the money paid for the spar when first marketed.

Crude and ground feldspar sold in 1918 and 1919.

State.	1918		1919	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.
California	1,451	$8,839	(a)	(a)
Connecticut	5,942	52,117	10,880	$133,113
Maine	25,376	283,957	14,387	206,659
Maryland	8,784	40,299	7,820	39,610
New York	12,631	71,590	(a)	(a)
North Carolina	40,020	160,275	25,195	116,826
Pennsylvania	4,916	57,269	(a)	(a)
Undistributed			12,772	88,992
	99,120	674,346	71,054	585,200

a Included under "Undistributed."

Crude and ground feldspar sold in 1915–1919.

Year.	Quantity (short tons).	Value.
1915	105,118	$489,223
1916	132,681	702,278
1917	141,924	728,838
1918	99,120	674,346
1919	71,054	585,200

Feldspar sold in Canada, 1915–1919.[a]

Year.	Quantity (short tons).	Value.
1915	15,455	$59,124
1916	19,488	71,407
1917	11,493	54,555
1918	18,782	112,728
1919	14,679	86,231

[a] Statistics taken from reports on the mineral production of Canada, Canada Dept. Mines.

SILICA (QUARTZ).

By L. M. Beach.

PRODUCTION.

Silica of the kinds considered in this report is used in the manufacture of wood filler, pottery, paints, and scouring soaps, as a polisher, as foundry mold wash, in metallurgic and chemical processes, and for cosmetics and dentifrices.

The following table summarizes the data available to show the silica of these forms marketed in the United States from 1917 to 1919, inclusive.

Silica sold for pottery, paints, fillers, polishers, abrasives, and other uses in the United States, 1917–1919.

Material.	1917		1918		1919	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
Quartz (vein quartz, pegmatite, and quartzite)	142,673	$318,069	71,740	$259,330	63,332	$373,571
Sand and sandstone [a]	532,454	1,195,142	98,956	620,584	47,277	288,890
Tripoli (ground and otherwise prepared)	26,069	338,188	19,982	199,854	24,292	181,541
Diatomaceous earth	[b] 3,033	[b] 31,368	[b] 2,965	[b] 24,947	42,642	531,960
	[b] 704,229	[b] 1,882,767	[b] 193,643	[b] 1,104,715	177,543	1,375,962

[a] Includes only finely ground material. Figures probably incomplete.
[b] Excludes California product used for filters and as insulating and fireproofing material, which the Survey is not at liberty to publish.

IMPORTS.

The Bureau of Foreign and Domestic Commerce records imports of "flint, flints, and flint stones, unground," from several countries. These imports are partly flint pebbles for use in grinding mills and partly material for uses such as are listed in this report. The figures can not be accurately separated.

Value of pebbles and flint imported for consumption in the United States, 1915–1919.

1915	$274,904
1916	313,120
1917	197,156
1918	$127,808
1919	250,096

QUARTZ.

Vein and pegmatite quartz and quartzite amounting to 63,332 short tons, valued at $373,571, were sold in 1919. This was a decrease of 12 per cent in quantity and an increase of 44 per cent in value.

Quartz sold in the United States, 1915–1919.

Year.	Crude.		Ground.		Total.	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
1915	94,299	$80,630	18,276	$192,923	112,575	$273,553
1916	70,417	78,283	18,097	164,503	88,514	242,786
1917	126,575	120,856	16,098	197,213	142,673	318,069
1918	61,008	121,888	10,732	137,442	71,740	259,330
1919	51,774	135,187	11,558	238,384	63,332	373,571

Vein and pegmatite quartz and quartzite sold in the United States, 1918-1919, by States.

State.	Crude.		Ground.		Total.	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
1918.						
Arizona, California, Colorado, Michigan, and Wisconsin	8,088	$37,211	1,269	$17,212	9,357	$54,423
Connecticut, Maine, Massachusetts, New York, and Pennsylvania	6,686	16,045	7,274	95,403	13,960	111,448
Alabama, Maryland, North Carolina, and Tennessee	46,234	68,632	2,189	24,827	48,423	93,459
	61,008	121,888	10,732	137,442	71,740	259,330
1919.						
Arizona, California, Colorado, Michigan, and Montana	16,578	27,339	....	....	16,578	27,339
Connecticut, Maine, Massachusetts, New York, Pennsylvania, Tennessee, and Wisconsin	30,788	91,487	7,436	161,994	38,224	253,481
Maryland and North Carolina	4,408	16,361	4,122	76,390	8,530	92,751
	51,774	135,187	11,558	238,384	63,332	373,571

ABRASIVE MATERIALS.

By L. M. Beach and A. T. Coons.

INTRODUCTION.

This chapter is concerned with natural and artificial abrasives composed of one or more minerals and used for grinding, polishing, and other abrasive operations. Quartz and feldspar are excluded because the precise separation according to their uses can not be made, their principal uses being for purposes other than abrasives, and therefore they are considered in other chapters. The total value of all abrasive materials consumed in the United States during the years 1915–1919 is given in the first of the following tables, and the value of different abrasive materials imported into the United States for consumption in the same years is given in the second table.

CONSUMPTION.

Value of all abrasive materials[a] consumed in the United States, 1915–1919.

	1915	1916	1917	1918	1919
Natural abrasives	$1,218,508	$1,664,339	$2,385,165	$2,864,332	$2,887,902
Artificial abrasives	2,248,778	2,935,909	8,137,242	[b] 6,940,000	[c] 5,019,779
Imports	540,783	555,850	812,303	1,187,632	2,237,077
	4,008,069	5,156,098	11,334,710	10,991,964	[c] 10,144,758

[a] Exclusive of feldspar and various forms of quartz. See chapters on feldspar and silica (quartz).
[b] Estimated and not including entire production during second half of 1918.
[c] Not including prodution of one large company.

Value of abrasive materials imported for consumption in the United States, 1915–1919.

Material.	1915	1916	1917	1918	1919
Millstones and burrstones	$17,027	$19,816	$18,227	$20,017	$26,356
Grindstones and pulpstones	68,892	63,277	57,950	27,361	50,551
Hones, oilstones, and whetstones	14,247	10,614	10,636	6,075	12,199
Emery and corundum	271,649	240,737	210,602	614,167	595,203
Diatomaceous earth, tripoli, and rottenstone	27,333	37,573	17,864	11,128	12,545
Pumice	65,691	116,543	147,278	33,014	119,781
Diamond dust and bort	75,944	67,290	349,746	475,870	1,420,442
	540,783	555,850	812,303	1,187,632	2,237,077

NATURAL ABRASIVES.

Natural abrasives were produced in 1919 in 26 States, which are listed below:

Alabama............Millstones.
Arkansas...........Oilstones.
California...........Diatomaceous (infusorial) earth, grinding pebbles, and pumice.
Connecticut.........Diatomaceous (infusorial) earth.
Idaho...............Diatomaceous (infusorial) earth.
Illinois.............Tripoli.
Indiana............Oilstones and rubbing stones.
Kansas.............Pumice.
Kentucky..........Hones.
Michigan...........Grindstones.
Minnesota..........Grinding pebbles and tube-mill lining.
Missouri............Tripoli.
Nebraska...........Pumice.
Nevada.............Diatomaceous (infusorial) earth and grinding pebbles.
New Hampshire.....Garnet and scythestones.
New York..........Diatomaceous (infusorial) earth, emery, garnet, and millstones.
North Carolina.......Garnet and millstones.
Ohio................Grindstones, pulpstones, oilstones, and scythestones.
Oklahoma..........Tripoli.
Oregon.............Diatomaceous (infusorial) earth.
Pennsylvania........Millstones and rottenstone.
Utah................Diatomaceous (infusorial) earth.
Vermont............Scythestones.
Virginia............Emery and millstones.
Washington.........Diatomaceous (infusorial) earth.
West Virginia.......Grindstones and pulpstones.

Value of natural abrasives produced and sold in the United States, 1915–1919.

Abrasive.	1915	1916	1917	1918	1919
Millstones	$53,480	$44,559	$43,489	$92,514	$66,972
Grindstones and pulpstones	648,479	766,140	1,147,784	1,776,282	1,336,015
Oilstones and scythestones	115,175	154,573	168,704	189,033	235,943
Emery (also corundum in 1917 and 1918)	31,131	123,901	241,050	112,878	23,203
Garnet	139,584	208,850	198,327	248,161	310,131
Abrasive quartz and feldspar	(a)	(a)	(a)	(a)	(a)
Diatomaceous (infusorial) earth and tripoli	b 167,474	b 241,553	b 369,556	b 224,801	713,501
Pumice	63,185	82,263	84,814	91,178	116,835
Grinding pebbles	....	42,500	72,191	82,851	85,302 (Grinding pebbles and tube-mill lining)
Tube-mill lining	....	....	59,250	46,634	
	1,218,508	1,664,339	2,385,165	2,864,332	2,887,902

a See chapters on feldspar and silica (quartz).
b Exclusive of considerable production for special uses upon which the Geological Survey is not at liberty to report.

Value of millstones produced and sold in the United States, 1914–1919.

State.	1914	1915	1916	1917	1918	1919
Alabama	(a)	....	(a)	(a)	....	(a)
Maryland	....	....	....	....	(a)	....
New York	$16,748	$16,883	$10,287	$22,103	$25,488	$10,155
North Carolina	5,164	(a)	(a)	(a)	39,224	29,025
Pennsylvania	(a)	(a)	(a)	(a)	(a)	(a)
Virginia	20,100	23,170	25,752	18,980	(a)	(a)
Undistributed	1,304	13,427	8,520	2,406	27,802	27,792
	43,316	53,480	44,559	43,489	92,514	66,972

a Included in "Undistributed."

Value of burrstones and millstones imported for consumption in the United States, 1915–1919.

Year.	Rough.	Made into millstones.	Total.	Year.	Rough.	Made into millstones.	Total.
1915	$16,045	$982	$17,027	1918	$17,570	$2,447	$20,017
1916	15,495	4,321	19,816	1919	8,996	17,360	26,356
1917	17,048	1,179	18,227				

Grindstones and pulpstones produced and sold in the United States, 1915–1919.

Year.	State.	Grindstones.		Pulpstones.	
		Quantity (short tons).	Value.	Quantity (pieces).	Value.
1915	Michigan, Ohio, and West Virginia	42,623	$564,340		
	Ohio			696	$84,139
1916	Michigan, Ohio, and West Virginia	50,839	631,497		
	Ohio			1,066	134,643
1917	Michigan, Ohio, and West Virginia	54,432	806,896		
	Ohio and West Virginia			2,325	340,888
1918	Michigan, Ohio, and West Virginia	56,554	1,262,602		
	Ohio and West Virginia			2,921	513,680
1919	Michigan, Ohio, and West Virginia	40,755	993,959		
	Ohio and West Virginia			2,450	342,056

Value of grindstones and pulpstones produced and sold in the United States, 1915–1919.

1915	$648,479	1918	$1,776,282
1916	766,140	1919	1,336,015
1917	1,147,784		

Value of grindstones and pulpstones imported for consumption in the United States, 1915–1919.

1915	$68,892	1918	$27,361
1916	63,277	1919	50,551
1917	57,950		

Grindstones, pulpstones, and scythestones produced in Canada, 1915–1919.[a]

Year.	Quantity (short tons).	Value.	Year.	Quantity (short tons).	Value.
1915	2,508	$35,768	1918	3,072	$83,005
1916	3,478	52,782	1919	2,020	60,516
1917	2,523	45,754			

[a] Figures taken from the annual reports on mineral production of Canada, Canada Dept. Mines.

Value of oilstones and scythestones produced and sold in the United States, 1915–1919.

1915	[1] $115,175	1918	[4] $189,033
1916	[2] 154,573	1919	[4] 235,943
1917	[3] 168,704		

[1] Includes a quantity of honestone quarried in Kentucky and Ohio and "rubbing stone" quarried in Indiana and Ohio.
[2] Includes a quantity of honestone quarried in Kentucky and Pennsylvania and "rubbing stone" quarried in Indiana.
[3] Includes a quantity of honestone quarried in Kentucky and "rubbing stone" quarried in Indiana and Kentucky.
[4] Includes a quantity of honestone quarried in Kentucky and "rubbing stone" quarried in Indiana.

Value of hones, oilstones, and whetstones imported for consumption in the United States, 1915–1919.

1915	$14,247	1918	$6,075
1916	10,614	1919	12,199
1917	10,636		

Emery produced and sold in the United States, 1910–1919.

Year.	Quantity (short tons).	Value.	Year.	Quantity (short tons).	Value.
1910	1,028	$15,077	1915	[a] 3,063	[a] $31,131
1911	659	6,778	1916	15,282	123,901
1912	992	6,652	1917	[b] 17,135	[b] 241,050
1913	[a] 957	[a] 4,785	1918	[c] 10,422	[c] 112,878
1914	[a] 485	[a] 2,425	1919	2,601	23,203

[a] Estimated. [b] Includes 820 short tons of corundum, valued at $67,461. [c] Includes corundum.

Emery and corundum imported for consumption in the United States, 1915–1919.

Year.	Grains.		Ore and rock.		Other manufactures.	Total value.
	Quantity.	Value.	Quantity.	Value.	Value.	
	Pounds.		*Long tons.*			
1915	1,277,673	$56,254	8,462	$197,303	$18,092	$271,649
1916	1,689,689	90,646	7,623	113,176	36,915	240,737
1917	2,207,912	119,033	1,056	50,087	41,482	210,602
1918	4,138,587	231,908	6,677	322,610	59,649	614,167
1919	547,349	32,128	11,401	522,036	41,039	595,203

Canadian corundum shipped, 1915–1919.[a]

Year.	Quantity (short tons).	Value.	Year.	Quantity (short tons).	Value.
1915	339	$37,798	1918	137	$26,112
1916	67	10,307	1919	....	....
1917	188	32,153			

[a] Figures taken from the annual reports on mineral production of Canada, Canada Dept. Mines.

Abrasive garnet produced and sold in the United States, 1915–1919.

Year.	Quantity (short tons).	Value.	Year.	Quantity (short tons).	Value.
1915	4,301	$139,584	1918	4,696	$248,161
1916	6,171	208,850	1919	4,944	310,131
1917	4,995	198,327			

Diatomaceous earth and tripoli produced and sold in the United States, 1915–1919.

Year.	Quantity (short tons).	Value.	Year.	Quantity (short tons).	Value.
1915 [a]	35,304	$167,474	1918[a]	22,947	$224,801
1916 [a]	45,978	241,553	1919	66,934	713,501
1917 [a]	29,102	369,556			

[a] Exclusive of considerable production for special uses upon which the Survey is not at liberty to report

Tripoli produced and sold in the United States, 1918–19.

State.	1918			1919		
	Quantity (short tons).	Value.		Quantity (short tons).	Value.	
		Estimated (crude).	As sold (crude and finished).		Estimated (crude).	As sold (crude and finished).
Illinois	12,004	$18,902	$100,126	13,014	$32,961	$116,492
Missouri, Oklahoma, and Pennsylvania	7,978	34,913	99,728	11,278	65,049	65,049
	19,982	53,815	199,854	24,292	98,010	181,541

Diatomaceous earth produced and sold in the United States, 1918–19.

State.	1918[a]		1919	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.
Western States[b]	2,847	$18,525	42,642	$531,960
Eastern States[c]	118	6,422		
	2,965	24,947	42,642	531,960

[a] Exclusive of considerable production for special uses upon which the Survey is not at liberty to report.
[b] 1918: California, Idaho, Nevada, Utah, and Washington; 1919: California, Idaho, Nevada, Oregon, Utah, and Washington.
[c] 1918: Connecticut, New York, and Virginia; 1919: Connecticut and New York.

Value of tripoli, diatomaceous earth, and rottenstone imported for consumption in the United States, 1915–1919.

1915	$27,333	1918	$11,128
1916	37,573	1919	12,545
1917	17,864		

Pumice produced and sold in the United States, 1915–1919.

Year.	Quantity (short tons).	Value.	Price per ton.	Year.	Quantity (short tons).	Value.	Price per ton.
1915	27,708	$63,185	$2.28	1918	30,637	$91,178	$2.98
1916	33,320	82,263	2.47	1919	36,051	116,835	3.24
1917	35,293	84,814	2.40				

Value of pumice imported for consumption in the United States, 1915–1919.

1915	$65,691	1918	$33,014
1916	116,543	1919	119,781
1917	147,278		

Pebbles, cubes, and artificially rounded blocks for grinding produced and sold in the United States, 1917–1919.

Year.	Quantity (short tons).	Value.	Year.	Quantity (short tons).	Value.
1917	12,000	$72,191	1919[a]	9,448	$85,302
1918	9,934	82,851			

[a] Includes tube mill lining.

Value of general imports of pebbles and flint into the United States, 1915–1919.

Country.	1915	1916	1917	1918	1919
Belgium					$34,783
British India		$2,440			
Canada	$1,128			$700	1,742
Denmark	152,129	175,916	$122,883	86,664	95,254
England	1,303				
France	91,024	117,649	65,311	38,519	117,691
Italy			39		
Japan	97	7,924			
Norway		1,780			
Portugal		214			
Sweden	28,088	7,197	7,744	1,925	626
	273,769	313,120	195,977	127,808	250,096

Value of pebbles and flint imported for consumption in the United States, 1915–1919.

1915	$274,904	1918	$127,808
1916	313,120	1919	250,096
1917	197,156		

ARTIFICIAL ABRASIVES.

The artificial abrasives here considered are of three kinds—(1) metallic abrasives, manufactured by the Pittsburgh Crushed Steel Co., Pittsburgh, Pa., and including "diamond crushed steel" (crushed crucible steel), "angular grit" (crushed chilled iron), and "crushed cast iron"; (2) silicon carbides, including carborundum, manufactured by the Carborundum Co., at Niagara Falls, N. Y.; crystolon, manufactured by the Norton Co., at Chippewa, Ontario; and carbolon, manufactured by the Exolon Co., at Thorold, Ontario, and Blasdell, N. Y.; (3) aluminum oxides, including alundum, manufactured by the Norton Co., at Niagara Falls, N. Y., and Chippewa, Ontario; aloxite, manufactured by the Carborundum Co., at Niagara Falls, N. Y., Niagara Falls, Ontario, and Shawinigan, Quebec; exolon, manufactured by the Exolon Co., at Blasdell, N. Y., and Thorold, Ontario; lionite, manufactured by the General Abrasives Co. (Inc.), at Niagara Falls, N. Y.; coralox, manufactured by the D. A. Brebner Co. (Ltd.), at Hamilton, Ontario; and natite, manufactured by the National Abrasive Co., at Hamilton, Ontario.

So far as known to the Geological Survey, these are the only artificial abrasives manufactured in North America. Artificial abrasives sold under other names are merely the above-named products marketed under special trade names or are imported products.

In the following table the quantity and value reported for 1918 and 1919 are incomplete, as certain figures on production have not been obtained from one producing company.

Artificial abrasives produced in the United States and Canada, 1915–1919.

Year.	Quantity (pounds).	Value.	Year.	Quantity (pounds).	Value.
1915	37,684,000	$2,248,778	1918 [a]	87,600,000	$6,940,000
1916	77,612,000	2,935,909	1919 [a]	56,562,000	5,019,779
1917	115,822,000	8,137,242			

[a] Not including entire production.

CEMENT.[1]

By Ernest F. Burchard.

INTRODUCTION.

After marked declines in output of hydraulic cement during the war years 1917 and 1918, production and shipments of this essential structural material showed satisfactory gains during 1919 (13.7 per cent and 20.7 per cent, respectively, over 1918), and the cement industry in general made progress toward better conditions. After the armistice was declared the expectation of lower prices deterred building operations until about the middle of 1919, when the under-built conditions of the country forced building in spite of high prices, thus causing a heavy demand for Portland cement, which resulted in a shortage and in higher prices than had been expected. Stocks of cement at the end of 1919 were lower than at any time for many years, but with the seasonal lull in building operations in the winter of 1919–20 many mills were closed because manufacturing costs were so high that producers were unwilling to accumulate stocks in view of the uncertainty as to future demand and prices.

An estimate of the output of Portland cement in 1919 was published by the United States Geological Survey early in February, 1920, and, as usual, the annual estimate was close enough for practical purposes, as the estimated production and shipments of Portland cement proved to be, respectively, within 0.6 per cent and 0.15 per cent of the final figures for 1919. The lateness in completion of the final figures presented herewith must be ascribed to delays in receiving returns from the Bureau of the Census, through which the canvass of the mineral industry for the year 1919 was made. The last plant schedule to be received from the Census did not reach the Geological Survey until March, 1921.

PRODUCTION OF HYDRAULIC CEMENTS.

The total quantity of Portland, natural, and puzzolan cements marketed or shipped from the mills in the United States in 1919, as shown below, increased 20.7 per cent in quantity and 29.5 per cent in value.

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[1] The statistical tables were prepared by Mrs. E. R. Phillips except those of imports and exports, which were prepared by J. A. Dorsey, from the records of the Bureau of Foreign and Domestic Commerce, Department of Commerce.

Principal hydraulic cements shipped from factories in the United States in 1917, 1918 and 1919.

Class.	1917		1918		1919	
	Quantity (barrels).	Value.	Quantity (barrels).	Value.	Quantity (barrels).	Value.
Portland	90,703,474	$122,775,088	70,915,508	[a]$113,316,275	85,612,899	$146,734,844
Natural, Puzzolan	639,456	435,370	432,966	401,341	528,589	583,554
	91,342,930	123,210,458	71,348,474	[a]113,717,616	86,141,488	147,318,398

[a] Revised figures.

Principal hydraulic cements produced in the United States, 1818–1919.[a]

Year.	Natural cement.		Portland cement.	
	Quantity (barrels).	Value.	Quantity (barrels).	Value.
1818–1912	232,076,611	$148,123,758	[b] 590,190,930	[b] $562,242,149
1913	744,658	345,889	92,097,131	92,557,617
1914	751,285	351,370	88,230,170	81,789,368
1915	750,863	358,627	85,914,907	73,886,820
1916	[c] 842,137	[c] 430,874	91,521,198	100,947,881
1917	[c] 639,456	[c] 435,370	92,814,202	125,670,430
1918	[c] 432,966	[c] 401,341	71,081,663	[d] 113,730,661
1919	[c] 528,589	[c] 583,554	80,777,935	138,130,269
	[c] 236,766,565	[c] 151,030,783	1,192,628,136	1,288,955,195

Year.	Puzzolan cement.		Total.	
	Quantity (barrels).	Value.	Quantity (barrels).	Value.
1818–1912	[e] 4,588,455	[e] $3,736,873	826,855,996	$714,102,780
1913	107,313	97,663	92,949,102	93,001,169
1914	68,311	63,358	89,049,766	82,204,096
1915	42,678	39,801	86,708,448	74,285,248
1916	(c)	(c)	92,363,335	101,378,755
1917	(c)	(c)	93,453,658	126,105,800
1918	(c)	(c)	71,514,629	[d] 114,132,002
1919	(c)	(c)	81,306,524	138,713,823
	[c] 4,806,757	[c] 3,937,695	1,434,201,458	1,443,923,673

[a] Statistics by years or decades between 1818 and 1912 have been published in the chapters on cement in Mineral Resources for 1915 and 1916.
[b] First recorded output in 1870.
[c] Figures for puzzolan cement, 1916–1919, are included with natural cement.
[d] Revised figures.
[e] First recorded output in 1896.

PORTLAND CEMENT.

PRODUCTION, SHIPMENTS, AND STOCKS.

The total production of Portland cement in the United States in 1919, as reported to the United States Geological Survey, increased 14 per cent in quantity and nearly 21.5 per cent in value.

The shipments of Portland cement from the mills in the United States in 1919 exceeded production and increased 20.7 per cent in quantity and about 29.5 per cent in value as compared with 1918.

The average price for the whole country in 1919 increased 11 cents a barrel, or 6.9 per cent. This was the selling price of cement in bulk at the mills and included cost of labor and packing but not the value of the sacks or barrels. The quantity of Portland cement made in 1919 was approximately equivalent to 13,559,153 long tons, and the price per ton was about $10.19.

At the beginning of 1919 Portland cement was being produced at the rate of a little more than 3,000,000 barrels a month, and the rate steadily increased to more than 7,500,000 barrels in May, after which the upward curve was gentler until the peak, above 9,000,000 barrels, was reached in October. The last two months showed a steady decline to less than 5,000,000 barrels in December. Shipments were low in January and February, a little more than 2,000,000 barrels a month, but during the next seven months they increased at a rapid rate from about 4,250,000 barrels in March to more than 12,000,000 barrels in September; in October, November, and December the rate decreased so that less than 5,000,000 barrels were shipped in the last month of the year. The average monthly production and shipments in 1919 were, respectively, about 6,731,500 and 7,134,400 barrels, compared with about 5,923,000 and 5,910,000 barrels in 1918. The course of stocks at mills during 1919 did not at all parallel that of production and shipments. The year began with a normal supply of about 10,500,000 barrels on hand. This quantity was increased to more than 12,275,000 barrels in February and remained at nearly the same figure until May, when there was on hand nearly 13,000,000 barrels, the largest quantity since early in 1917. From June to October the volume of stocks fell off rapidly, and in November and December gradually, shipments having exceeded production in these months. The year 1919 closed with less than 6,000,000 barrels of Portland cement in stock, the lowest quantity reported to the Survey at the close of any year.

PRODUCTION, SHIPMENTS, AND STOCKS, BY STATES.

In the following table the production and shipments and the corresponding values of Portland cement for 1918 and 1919 are arranged by States, provided there are three or more producers or shippers in a single State, or permission is given to publish figures where there are less than three. By the term "producer" is meant a Portland-cement manufacturing company, whether the company operates one or more plants. In the table the term "producing plant" is applied to a mill or group of mills located at one place and operated by one company, but each establishment at a different place is counted as a plant. There were producing plants in 26 States in 1918 and 27 States in 1919, but as a number of these States did not contain three or more plants it has been necessary to group together in this table several States that are not closely related geographically. In the table "Portland cement produced and shipped by districts," however, statistics are given for groups of States (generally not more than three) that are geographically related.

In all the States in which Portland cement was manufactured in 1919, there were increases in production, except in Alabama, Georgia, Iowa, Montana, Oregon, Virginia, and West Virginia; and also in shipments, except in Alabama, Kentucky, and Virginia, as compared with the output in 1918, and in all the States the average factory price per barrel showed an increase. The net change for the whole country was an increase in production of 9,696,272 barrels, and in shipments of 14,697,391 barrels. In 1919 shipments exceeded production by 4,834,964 barrels.

Portland cement produced, shipped, and in stock in the United States, 1918 and 1919, by States.

State.	Production.					Stock (barrels).		
	Active plants.		Quantity (barrels).		Percentage of change.	1918 (revised).	1919	Percentage of decrease.
	1918	1919	1918	1919				
California	9	8	4,354,074	4,612,679	+ 7	528,026	431,335	18
Illinois	4	4	3,594,038	4,206,918	+17	646,255	18,125	97
Indiana	5	5	5,291,851	7,262,454	+37	822,888	435,985	47
Iowa	4	4	3,626,455	3,573,278	− 1	1,055,540	126,162	88
Kansas	7	7	2,499,723	2,927,270	+17	323,008	220,994	32
Michigan	10	11	3,554,872	4,675,244	+32	635,447	207,965	67
Missouri	5	5	4,738,596	5,216,347	+10	626,552	160,123	74
New York	8	8	4,095,588	4,383,579	+ 7	832,271	711,504	15
Ohio	5	5	1,440,859	1,637,418	+14	262,142	82,614	68
Oklahoma	3	3	1,246,515	1,362,687	+ 9	89,188	81,225	9
Oregon and Washington	7	5	1,196,474	1,561,951	+31	287,242	220,906	23
Pennsylvania	21	21	22,628,901	25,325,173	+12	2,839,018	1,811,551	36
Texas	5	5	1,971,867	2,249,735	+14	289,779	205,918	29
Utah	3	3	570,310	819,861	+44	147,293	34,295	77
Other States [a]	18	17	10,271,540	10,933,341	+ 6	1,066,395	476,646	55
	114	111	71,081,663	80,777,935	+14	10,451,044	5,225,348	50

State.	Shipments.					Average factory price per barrel.	
	1918		1919			1918	1919
	Quantity (barrels).	Value.	Quantity (barrels).	Value.	Percentage of increase in quantity.		
California	4,238,424	$7,091,789	4,743,336	$8,860,196	12	$1.67	$1.87
Illinois	3,703,471	5,695,186	4,873,831	7,901,689	32	1.54	1.62
Indiana	6,205,326	9,580,563	7,667,976	12,527,770	24	1.54	1.63
Iowa	3,188,669	5,423,926	4,569,110	7,798,347	43	1.70	1.71
Kansas	2,586,834	4,219,203	3,023,901	5,467,284	17	1.63	1.81
Michigan	3,618,088	6,078,167	4,990,308	8,468,196	38	1.68	1.70
Missouri	4,515,695	7,132,470	5,496,164	9,264,017	22	1.58	1.69
New York	4,074,159	6,568,716	4,441,250	7,700,406	9	1.61	1.73
Ohio	1,289,887	2,208,119	1,821,597	3,311,179	41	1.71	1.82
Oklahoma	1,218,841	2,203,041	1,366,884	2,657,339	12	1.81	1.94
Oregon and Washington	1,327,252	2,535,855	1,615,890	3,359,056	22	1.91	2.08
Pennsylvania	22,238,689	33,600,956	26,250,077	43,126,528	18	1.51	1.64
Texas	1,918,919	3,297,977	2,318,747	4,226,222	21	1.72	1.82
Utah	549,593	[b] 1,085,917	935,305	1,906,816	70	1.98	2.04
Other States [a]	10,241,661	16,594,360	11,498,523	20,159,799	12	1.62	1.75
	70,915,508	[b] 113,316,275	85,612,899	146,734,844	21	1.60	1.71

[a] 1918: Alabama, Colorado, Georgia, Kentucky, Maryland, Minnesota, Montana, New Jersey, Tennessee, Virginia, West Virginia. 1919: Same States, with Nebraska included.
[b] Revised figures.

PRODUCTION, SHIPMENTS, AND STOCKS, BY COMMERCIAL DISTRICTS.

The division of the cement-producing territory into 12 geographic units, termed "commercial districts," is based to some extent on the relations of the Portland-cement plants to their trade territory, and in forming the districts it has been found advisable to divide Pennsylvania, Indiana, and Texas in order to group the plants commercially.

As shown in the accompanying table there were increases in both production and shipments in all districts except Tennessee–Alabama–Georgia in 1919 as compared with the output of each in 1918, and the average factory price per barrel showed a general increase.

Portland cement produced, shipped, and in stock in the United States, 1918 and 1919, by districts.

Commercial district.	Production.							
	Active plants.		Quantity (barrels).		Percentage of change.	Stock (barrels).		Percentage of decrease.
	1918	1919	1918	1919		1918 (revised).	1919	
Lehigh district (eastern Pennsylvania and western New Jersey)	20	20	19,701,820	22,747,956	+15	2,510,331	1,655,428	34
New York	8	8	4,095,588	4,383,579	+ 7	832,271	711,504	15
Ohio and western Pennsylvania	8	8	6,439,179	6,599,820	+ 2	845,373	347,438	59
Michigan and northeastern Indiana	12	12	4,106,467	5,047,395	+23	790,495	261,965	67
Kentucky and southern Indiana	3	3	1,609,475	2,490,497	+55	246,242	99,626	60
Illinois and western Indiana	5	6	7,169,038	9,088,081	+27	1,088,775	302,724	72
Maryland, Virginia, and West Virginia	5	4	2,281,629	2,469,768	+ 8	268,384	100,193	63
Tennessee, Alabama, and Georgia	5	4	2,990,734	2,744,646	− 8	125,501	37,235	70
Iowa, Minnesota, and Missouri	10	10	9,478,051	10,038,625	+ 6	1,887,902	366,193	81
Nebraska,[a] Kansas, Oklahoma, and central Texas	14	15	5,370,181	6,151,095	+15	651,611	469,682	28
Rocky Mountain States, (Colorado, Utah, Montana, and western Texas)	8	8	2,288,953	2,811,843	+23	388,891	221,119	43
Pacific Coast States (California, Oregon, and Washington)	16	13	5,550,548	6,204,630	+12	815,268	652,241	20
	114	111	71,081,663	80,777,935	+14	10,451,044	5,225,348	50

[a] No output in 1918.

Portland cement produced, shipped, and in stock in the United States, 1918 and 1919, by States—Continued.

Commercial district.	Shipments.					Average factory price per barrel.	
	1918		1919		Percentage of change in quantity.	1918	1919
	Quantity (barrels).	Value.	Quantity (barrels).	Value.			
Lehigh district (eastern Pennsylvania and western New Jersey	19,351,123	$29,399,457	23,501,560	$38,511,273	+22	$1.52	$1.64
New York	4,074,159	6,568,746	4,441,250	7,700,406	+ 9	1.61	1.73
Ohio and western Pennsylvania	6,231,702	9,598,241	7,102,442	12,144,272	+14	1.54	1.71
Michigan and northeastern Indiana	4,183,260	6,986,903	5,459,439	9,274,025	+31	1.67	1.70
Kentucky and southern Indiana	1,960,109	3,171,616	2,640,556	4,405,939	+35	1.62	1.67
Illinois and western Indiana	7,894,542	12,038,589	9,932,158	16,092,758	+26	1.53	1.62
Maryland, Virginia, and West Virginia	2,308,193	3,745,757	2,613,963	4,517,591	+13	1.62	1.73
Tennessee, Alabama, and Georgia	3,092,425	4,711,835	2,830,588	4,952,245	− 8	1.52	1.75
Iowa, Minnesota, and Missouri	8,712,597	14,211,139	11,440,645	19,314,646	+31	1.63	1.69
Nebraska,[a] Kansas, Oklahoma, and central Texas	5,365,848	9,067,729	6,309,024	11,662,504	+18	1.69	1.85
Rocky Mountain States, (Colorado, Utah, Montana, and western Texas)	2,175,874	[b]4,188,619	2,982,048	5,939,933	+37	1.93	1.99
Pacific Coast States (California, Oregon, and Washington)	5,565,676	9,627,614	6,359,226	12,219,252	+14	1.73	1.92
	70,915,508	[b]113,316,275	85,612,899	146,734,844	+21	1.60	1.71

[a] No output in 1918. [b] Revised figures.

Portland cement shipped from mills in the United States, 1911–1919.

Year.	Quantity (barrels).	Value.	Year.	Quantity. (barrels).	Value.
1911	75,547,829	$63,762,368	1916	94,552,296	$104,258,216
1912	85,012,556	69,109,800	1917	90,703,474	122,775,088
1913	88,689,377	89,106,975	1918	70,915,508	[a] 113,316,275
1914	86,437,956	80,118,475	1919	85,612,899	146,734,844
1915	86,891,681	74,756,674			

[a] Revised figures.

LEHIGH DISTRICT.

The production of Portland cement in the Lehigh district, in eastern Pennsylvania and western New Jersey, in 1919 increased 15.5 per cent, and the shipments from mills in this district increased 21.4 per cent. The production of white Portland cement from two plants in this district is included in the figures for 1919. As the average price reported for the white cement was considerably higher than that reported for ordinary gray cement, the average price for the district is slightly higher than if it represented gray Portland cement alone.

The Lehigh district produced 28.2 per cent of the total output of Portland cement in the United States in 1919, compared with 27.7 per cent in 1918. In 1897 this district produced 75 per cent and in 1907 50 per cent of the total for the United States.

Portland cement produced in the Lehigh district and in the United States, 1911–1919.

Year.	Lehigh district (barrels).	United States (barrels).	Percentage made in Lehigh district.	Year.	Lehigh district (barrels).	United States (barrels).	Percentage made in Lehigh district.
1911	25,972,108	78,528,637	33.1	1916	24,105,381	91,521,198	26.3
1912	24,762,083	82,438,096	30.0	1917	24,423,507	92,814,202	26.3
1913	27,139,601	92,097,131	29.5	1918	19,701,820	71,081,663	27.7
1914	24,614,933	88,230,170	27.9	1919	22,747,956	80,777,935	28.2
1915	24,876,442	85,914,907	29.0				

STOCKS AT MILLS.

The stock of Portland cement reported on hand at the mill at the end of 1919 as shown in the tables on pages 390–391 represented an unusually large decrease and was smaller than has been reported to the Survey at the end of any previous year. The reports of stocks at a few mills in 1918 were revised by the producers at the end of 1919 by request of the Geological Survey, but the stock reported for 1919 does not check very closely with the stock calculated by balancing the shipments for 1919 against the production of 1919 plus the stock at the end of 1918. Close agreement is not always to be expected, considering that the volume of stocks can not be measured with accuracy.

Portland cement in stock in the United States Dec. 31, 1911 to 1919

Year	Barrels.	Year	Barrels.
1911	10,385,789	1916	8,360,552
1912	7,811,329	1917	10,353,838
1913	11,220,328	1918	10,451,044
1914	12,773,463	1919	5,225,348
1915	11,462,523		

DOMESTIC CONSUMPTION OF PORTLAND CEMENT.

An estimate of the total consumption of Portland cement in the United States may be made by adding the imports to the shipments and subtracting the exports from the sum. Of course, a variable but considerable stock of cement is at all times in transit, in warehouses at distributing points, and awaiting use on the ground at large jobs, so that the estimate thus made is at best approximate. Still another uncertain element in this estimate is the fact that as imports and exports are classed as hydraulic cement (including hydraulic lime, gypsum, magnesium chloride, and other cements), the records do not discriminate between Portland and other cements. Portland cement,however, constitutes by far the greater part of the exports, and, as the tables show, the imports are small. The apparent domestic consumption in 1919, 83,158,257 barrels, increased about 21 per cent, compared with 1918.

The following table gives the figures necessary for estimates of consumption so far as available, as prior to 1911 no records were at hand for shipments:

Apparent domestic consumption of Portland cement, 1911–1919, in barrels.

Year.	Shipments.	Imports.	Exports.	Apparent consumption.
1911	75,547,829	164,670	3,135,409	72,577,090
1912	85,012,556	68,503	4,215,532	80,865,527
1913	88,689,377	85,470	2,964,358	85,810,489
1914	86,437,956	120,906	2,140,197	84,418,665
1915	86,891,681	42,218	2,565,031	84,368,868
1916	94,552,296	1,836	2,563,976	91,990,156
1917	90,703,474	2,323	2,586,215	88,119,582
1918	70,915,508	305	2,252,446	68,663,367
1919	85,612,899	8,931	2,463,573	83,158,257

PORTLAND CEMENT CONSUMED PER CAPITA.

The estimates of consumption of Portland cement in the States and the dependencies of the United States according to political divisions are of course only approximate, as they represent only the records of shipments by manufacturers into the several States. Also, the shipments of cement into a State may not equal the consumption in that State during the same period, but if taken for a long period they should afford a very fair index to the consumption.[2] The estimates of consumption in the outlying possessions of the United States, except the Philippine Islands, are based on the official statistics of exports to those countries from the United States and do not include small imports that may have come from foreign countries. The table of exports to other countries on page 402 shows the shipments of cement from the United States to the Philippines, but there are no data available as to the imports of cement to the islands from foreign countries, and these imports figure largely in their per capita consumption. The simplest available common index is the estimated consumption per capita in barrels, which is obtained by comparing the shipments into States and certain possessions with the population for the States and those possessions in 1918 and 1919, as estimated by the Bureau of the Census.

There is a discrepancy between the official figures of the Bureau of Foreign and Domestic Commerce for exports of cement, as given on page 402, and the exports reported by manufacturers, as given in the following table, owing to the fact that cement shipped from mills destined for foreign countries is reported by the shipper as exported, whether or not it leaves the country during that calendar year, but the Bureau of Foreign and Domestic Commerce bases its export figures on the cement that actually leaves the country, according to its records. The exports given by that bureau include all other hydraulic cement exported, whereas the table of per capita consumption relates only to Portland cement. Another source of apparent disagreement is the fact that the lump figure for unspecified exports reported by manufacturers does not include the exports to Alaska, Hawaii, and Porto Rico, statistics for which are given separately in the same table.

[2] Data on per capita consumption of Portland cement by States beginning with the year 1914 are available in preceding volumes of Mineral Resources.

Estimated per capita consumption of Portland cement in the United States and certain outlying possessions in 1918 and 1919.

State.	1918			1919		
	Population (estimated).	Consumption (shipments to States).	Estimated consumption per capita.	Population (estimated as of Dec. 31, 1919).	Consumption (shipments to States).	Estimated consumption per capita.
		Barrels.	*Bbls.*		*Barrels.*	*Bbls.*
Alabama	2,395,270	839,891	0.35	2,348,174	571,222	0.24
Alaska	64,990	7,008	.11	54,899	4,002	.07
Arizona	272,034	297,849	1.09	334,162	409,781	1.23
Arkansas	1,792,965	303,304	.17	1,752,204	418,093	.24
California	3,119,412	3,606,286	1.16	3,426,861	3,900,436	1.14
Colorado	1,014,581	584,760	.58	939,629	680,802	.72
Connecticut	1,286,268	930,420	.72	1,380,631	1,311,829	.95
Delaware	216,941	269,249	1.24	223,003	296,798	1.33
District of Columbia	374,581	602,666	1.61	437,571	410,305	.94
Florida	938,877	388,241	.41	968,470	513,125	.53
Georgia	2,935,617	717,800	.24	2,895,832	1,072,732	.37
Hawaii	223,419	112,230	.50	255,912	73,451	.29
Idaho	461,766	212,022	.46	431,866	380,929	.88
Illinois	6,317,734	4,925,736	.78	6,485,280	6,154,227	.95
Indiana	2,854,167	2,406,617	.84	2,930,390	3,135,162	1.07
Iowa	2,224,771	2,298,157	1.03	2,404,021	3,362,263	1.40
Kansas	1,874,195	1,422,877	.76	1,769,257	1,900,921	1.07
Kentucky	2,408,547	633,642	.26	2,416,630	773,011	.32
Louisiana	1,884,778	587,208	.31	1,798,509	593,459	.33
Maine	782,191	247,345	.32	768,014	330,448	.43
Maryland	1,384,539	1,449,446	1.05	1,449,661	1,367,836	.94
Massachusetts	3,832,790	2,225,422	.58	3,852,356	2,377,677	.62
Michigan	3,133,678	3,266,393	1.04	3,668,412	5,097,575	1.39
Minnesota	2,345,287	2,164,947	.92	2,387,125	2,979,549	1.25
Mississippi	2,001,466	165,061	.08	1,790,618	261,512	.15
Missouri	3,448,498	1,652,454	.48	3,404,055	1,932,119	.57
Montana	486,376	369,206	.76	548,889	376,690	.69
Nebraska	1,296,877	1,101,593	.85	1,296,372	1,472,603	1.14
Nevada	114,742	37,765	.33	77,407	54,017	.70
New Hampshire	446,352	225,774	.51	443,083	341,013	.77
New Jersey	3,080,371	2,869,894	.93	3,155,900	3,179,174	1.01
New Mexico	437,015	132,756	.30	360,350	139,328	.39
New York	10,646,989	6,319,045	.59	10,385,227	7,078,888	.68
North Carolina	2,466,025	648,403	.26	2,559,123	790,020	.31
North Dakota	791,437	291,248	.37	646,872	358,675	.55
Ohio	5,273,814	5,010,482	.95	5,759,394	6,258,862	1.09
Oklahoma	2,377,629	1,118,595	.47	2,028,283	1,302,870	.64
Oregon	888,243	324,764	.37	783,389	585,927	.75
Pennsylvania	8,798,067	6,611,108	.75	8,720,017	7,571,085	.87
Porto Rico	1,247,677	188,728	.15	1,299,809	201,385	.15
Rhode Island	637,415	343,182	.54	604,397	468,539	.78
South Carolina	1,660,934	715,483	.43	1,683,724	527,652	.31
South Dakota	735,434	435,485	.59	636,547	727,958	1.14
Tennessee	2,321,253	943,349	.41	2,337,885	778,232	.33
Texas	4,601,279	1,509,318	.33	4,663,228	1,981,500	.42
Utah	453,648	350,603	.77	449,396	548,377	1.22
Vermont	366,192	122,477	.33	352,428	175,797	.50
Virginia	2,234,030	2,073,385	.93	2,309,187	1,785,908	.77
Washington	1,660,578	1,044,898	.63	1,356,621	1,278,499	.94
West Virginia	1,439,165	1,257,954	.87	1,463,701	764,135	.52
Wisconsin	2,553,983	2,230,895	.87	2,632,067	3,261,135	1.24
Wyoming	190,380	193,922	1.02	194,402	308,178	1.59
Unspecified		2,904			118,508	
	106,795,270	68,790,247	.64	107,321,240	82,744,219	.77
Exports reported by manufacturers but not included above		2,125,261			2,868,680	
Total shipped from cement plants		70,915,508			85,612,899	

The per capita consumption shown by the table necessarily falls short of the total apparent consumption by the quantity of the imports. These, however, are small—only 305 barrels in 1918, and 8,931 barrels in 1919.

The highest per capita consumption in 1919 was that of Wyoming, 1.59 barrels, and this State also showed the largest increase, 0.57

barrel. There were 15 States in 1919 in which the per capita consumption was more than 1 barrel, 6 of them east and 9 of them west of the Mississippi River; none of them were in the South. The District of Columbia, which held the record, 1.61 barrels in 1918, dropped to 0.94 barrel in 1919. There were changes in all the States but only 11 decreases were recorded. Decreases in Maryland, Virginia, and West Virginia were probably due to cessation of construction of factory buildings for war work, and the general increases elsewhere reflected revival of building activity and of the use of cement on farms. The general average of consumption rose from 0.64 barrel in 1918 to 0.77 barrel in 1919.

It will be noted that there were decreases in population in 25 States and increases in all the others, which possibly indicate shifting in industrial population after the war. The net change in population appears to have been a gain of 525,970 at the end of 1919.

LOCAL SUPPLIES OF PORTLAND CEMENT.

In connection with the study of consumption of cement it is of interest to compare the shipments from the mills within a State or group of States with the estimated consumption of that area and thus to ascertain the extent of the surplus or deficiency in the supply of cement locally available. The following table has therefore been arranged with that in view. Data for 1916 and 1917 will be found in the chapters on cement in Mineral Resources for 1917 and 1918. The second table shows how much of the surplus product was consumed by each of the non cement-producing States and dependencies.

Among the cement-producing States there are, of course, fewer deficiencies than surpluses, and certain of the deficiencies indicated are due to local conditions. For instance, in 1919 Illinois showed a deficiency of more than 1,280,000 barrels, while Indiana showed a surplus of more than 4,500,000 barrels. This was equalized in large part by the flow of cement from northern Indiana into the adjacent populous Chicago district in Illinois. Ohio showed a deficiency of more than 4,400,000 barrels, which was largely supplied from Pennsylvania's surplus of nearly 18,700,000 barrels and from Indiana. New York State, though a large producer, had a deficiency equal to over 59 per cent of shipments, which was mostly supplied from the Lehigh district. The Iowa-Minnesota-Nebraska group showed a deficiency of more than 1,750,000 barrels in 1919, and in Maryland, New Jersey, Virginia, and West Virginia there was indicated a shortage of nearly 2,000,000 barrels, probably supplied in large part from the Lehigh district in Pennsylvania. The quantities consumed in the nonproducing States and dependencies are of interest in comparison with the other data. More than 500,000 barrels were consumed in 1919 in each of the States of Florida, Louisiana, North Carolina, South Carolina, and South Dakota; Connecticut consumed more than 1,300,000 barrels, Massachusetts more than 2,370,000 barrels, and Wisconsin more than 3,260,000 barrels; but the per capita consumption in all these States is a better index to the relative consumption than the total figures. The quantity consumed in the nonproducing States plus the unspecified quantities and the exports amounted in 1919 to 17,722,294 barrels, compared with 14,042,308 barrels in 1918, and in 1919 this total represented 20.7 per cent of the total shipments from mills in the United States.

Estimated surplus or deficiency in local supply of Portland cement in cement-producing States, 1918–19, in barrels.

State or division.	1918			1919		
	Shipments from mills.	Estimated consumption.	Surplus or deficiency.	Shipments from mills.	Estimated consumption.	Surplus or deficiency.
California	4,238,424	3,606,286	+ 632,138	4,743,336	3,900,436	+ 842,900
Illinois	3,703,471	4,925,736	− 1,222,265	4,873,831	6,154,227	− 1,280,396
Indiana	6,205,326	2,406,617	+ 3,798,709	7,667,976	3,135,162	+ 4,532,814
Kansas	2,586,834	1,422,877	+ 1,163,957	3,023,901	1,900,921	+ 1,122,980
Michigan	3,618,088	3,266,393	+ 351,695	4,990,308	5,097,575	− 107,267
Missouri	4,515,695	1,652,454	+ 2,863,241	5,496,164	1,932,119	+ 3,564,045
New York	4,074,159	6,319,045	− 2,244,886	4,441,250	7,078,888	− 2,637,638
Ohio	1,289,887	5,010,482	− 3,720,595	1,821,597	6,258,862	− 4,437,265
Oklahoma	1,218,841	1,118,595	+ 100,246	1,366,884	1,302,870	+ 64,014
Pennsylvania	22,238,689	6,611,108	+15,627,581	26,250,077	7,571,085	+18,678,992
Texas	1,918,919	1,509,318	+ 409,601	2,318,747	1,981,500	+ 337,247
Utah	549,593	350,603	+ 198,990	935,305	548,377	+ 386,928
Washington	1,116,754	1,044,898	+ 71,856	1,402,616	1,278,499	+ 124,117
Alabama, Georgia, Kentucky, and Tennessee	3,603,451	3,134,682	+ 468,769	3,330,626	3,195,197	+ 135,429
Colorado, Montana, and Oregon	1,478,033	1,278,730	+ 199,303	1,743,674	1,643,419	+ 100,255
Iowa, Minnesota, and Nebraska [a]	4,196,902	5,564,697	− 1,367,795	6,060,316	7,814,415	− 1,754,099
Maryland, New Jersey, Virginia, and West Virginia	4,362,442	7,650,679	− 3,288,237	5,146,291	7,097,053	− 1,950,762
	70,915,508	56,873,200	+14,042,308	85,612,899	67,890,605	+17,722,294

[a] Nebraska had no output in 1918.

Estimated consumption of Portland cement in non cement-producing States, 1918–19, in barrels.

State.	1918	1919
Alaska	7,008	4,002
Arizona	297,849	409,781
Arkansas	303,304	418,093
Connecticut	930,420	1,311,829
Delaware	269,249	296,798
District of Columbia	602,666	410,305
Florida	388,241	513,125
Hawaii	112,230	73,451
Idaho	212,022	380,929
Louisiana	587,208	593,459
Maine	247,345	330,448
Massachusetts	2,225,422	2,377,677
Mississippi	165,061	261,512
Nevada	37,765	54,017
New Hampshire	225,774	341,013
New Mexico	132,756	139,328
North Carolina	648,403	790,020
North Dakota	291,248	358,675
Porto Rico	188,728	201,385
Rhode Island	343,182	468,539
South Carolina	715,483	527,652
South Dakota	435,485	727,958
Vermont	122,477	175,797
Wisconsin	2,230,895	3,261,135
Wyoming	193,922	308,178
Unspecified	2,904	118,508
	11,917,047	14,853,614
Exports to foreign countries	2,125,261	2,868,680
Surplus from cement-producing States	14,042,308	17,722,294
Consumption in cement-producing States	56,873,200	67,890,605
Total shipments	70,915,508	85,612,899

PRICES.

AT FACTORIES.

Average prices of Portland cement sold in bulk at the factories, as reported to the Geological Survey, are shown in the tables of shipments by States and districts during 1918 and 1919 (pp. 390–392). According to these figures the average prices in 1919 ranged between $1.62 a barrel in Illinois and $2.08 a barrel in Oregon–Washington, as compared with $1.51 in Pennsylvania and $1.98 in Utah in 1918. The general average price for the whole country was $1.71 in 1919, compared with $1.60 in 1918, an increase of 6.9 per cent. This is the highest average price that has been realized since 1894. All the districts, as well as nearly every State, showed an increase in average price. The district average prices are a little nearer the general average than the State average prices.

Average factory price per barrel in bulk of Portland cement, 1870–1919.

1870–1880	$3.00	1896	$1.57	1909	$0.813
1881	2.50	1897	1.61	1910	.891
1882	2.25	1898	1.62	1911	.844
1883	2.15	1899	1.43	1912	.813
1884	2.10	1900	1.09	1913	1.005
1885–1888	1.95	1901	.99	1914	.927
1889	1.67	1902	1.21	1915	.860
1890	2.09	1903	1.24	1916	1.103
1891	2.13	1904	.88	1917	1.354
1892	2.11	1905	.94	1918	1.598
1893	1.96	1906	1.13	1919	1.71
1894	1.73	1907	1.11		
1895	1.60	1908	.85		

AT MARKETS.

In comparison with factory prices the wholesale prices of Portland cement per barrel in bulk in carload lots at Chicago, Denver, Dallas, and San Francisco, quoted[3] by months during 1919, are of interest and seem to bear out contentions by manufacturers that market prices were proportionately higher than factory prices. The sudden drop of 60 cents to $1 a barrel in April indicates that notable reductions in price must have been made about the beginning of the building season.

Wholesale prices of Portland cement per barrel in bulk in carload lots in 1919, by months.

	January.	February.	March.	April.	May.	June.
Chicago, Ill	$3.05	$3.05	$3.05	$2.05	$2.00	$2.00
Denver, Colo	3.67	3.67	3.67	2.67	2.67	2.67
Dallas, Tex	2.93	2.93	2.93	2.03	2.03	2.03
San Francisco, Calif	3.48	3.03	3.60	3.00	2.40	2.40

	July.	August.	September.	October.	November.	December.
Chicago, Ill	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00
Denver, Colo	2.67	2.67	2.67	2.67	2.67	3.12
Dallas, Tex	2.03	2.03	2.03	2.03	2.03	2.03
San Francisco, Calif	2.40	2.43	2.43	2.43	2.43	2.43

[3]Engineering News-Record.

MANUFACTURING CONDITIONS.

PLANTS.

Portland cement was manufactured at 111 plants in 1919, as compared with 114 plants in 1918, a decrease of 3 producing plants. Five established plants manufactured no cement during the year—one each in Alabama, California, Indiana, Oregon, and Virginia—but some of the idle plants shipped cement from stock. One plant each in Michigan and Nebraska, idle in 1918, produced cement in 1919. One new plant produced Portland cement in 1919, that of the Indiana Portland Cement Co., at Greencastle, Ind., which was equipped as follows: Wet process; limestone, clay, and shale; clinker burned with coal; one 10 by 240 foot kiln; daily clinker capacity, 1,500 barrels.

KILNS.

The total number of rotary kilns reported in plants that operated in 1919 was 720, compared with 749 in 1918, a net decrease of 29 kilns. The number of active small kilns, 40 to 60 feet long, was decreased by 6; kilns between 60 and 100 feet long decreased by 3; 100-foot kilns decreased by 7; 110-foot kilns decreased by 10; kilns 120 feet long increased by 7; kilns 125 feet long decreased by 17; kilns 125 to 150 feet long remained the same in number; kilns 150 to 200 feet in length and kilns more than 200 feet in length increased by 4. According to these reports the increase of 14 kilns 120 feet or more in length in 1919 must have not only offset the loss in operation of 43 kilns, 17 of which were larger, the rest smaller, but resulted in the production of nearly 10,000,000 barrels more cement—an obviously impossible achievement.

Lengths of rotary cement kilns in active plants in the United States, 1916–1919.

Length (feet).	Number of kilns.				Length (feet).	Number of kilns.			
	1916	1917	1918	1919		1916	1917	1818	1919
40 to 60	128	108	77	71	126 to 149	62	65	63	63
61 to 99	119	94	90	87	150 to 199	69	73	63	66
100 to 109	81	84	105	98	200 to 260			15	19
110	89	83	65	55					
120	109	88	88	95		807	789	749	720
125	150	194	183	166					

KILN FUELS.

A summary of kiln fuels reported in 1919 shows that 90 plants, employing 596 kilns, burned powdered coal; 14 plants, employing 73 kilns, burned crude oil; and 1 plant burned natural gas. At certain plants more than one fuel is used. For instance, three plants reported coal and oil, two plants coal and gas, and one plant oil, coal, and gas. The percentage of cement burned by coal decreased from 82.4 in 1918 to 81.6 in 1919.

Portland cement burned by different fuels in 1918 and 1919.

Fuel.	1918				1919			
	Number of plants.	Number of kilns.	Barrels of cement.	Percentage of total.	Number of plants.	Number of kilns.	Barrels of cement.	Percentage of total.
Coal	93	605	58,605,244	82.4	90	596	65,877,185	81.6
Coal and crude oil	2	28	5,188,915	7.3	3	32	6,985,271	8.6
Coal and gas	1	4			2	9		
Crude oil	16	99	6,442,165	9.1	14	73	6,634,775	8.2
Crude oil, coal and gas	2	13	845,339	1.2	1	5	1,280,704	1.6
Natural gas	......	......	......	......	1	5		
	114	749	71,081,663	100.0	111	720	80,777,935	100.0

CAPACITY.

The total annual capacity for the manufacture of finished Portland cement in 1919 of all the plants in the United States, either active or only temporarily closed, according to manufacturers' reports, was 134,092,700 barrels, compared with 137,601,200 barrels in 1918, a decrease of 3,508,500 barrels. The figures originally published for 1918 have been revised slightly in view of later information. The total production of cement in 1919 (80,777,935 barrels) was thus about 60 per cent of the total capacity, whereas the production in 1918 represented about 52 per cent of the apparent total capacity in that year. No explanation is at hand for this apparent shrinkage in the cement-manufacturing capacity, which, as will be seen in the following table, was reported in 7 out of the 12 districts, but it seems more than likely to be due partly to the writing off of capacity formerly estimated for old and obsolete equipment.

Portland cement manufacturing capacity of the United States, by commercial districts, 1918 and 1919.

District	Estimated capacity (barrels).		Percentage of capacity utilized.	
	1918 (revised).	1919	1918	1919
Lehigh district (eastern Pennsylvania and western New Jersey)	40,049,000	38,340,000	49.2	59.3
New York	8,311,400	8,450,000	49.2	51.9
Ohio and western Pennsylvania	9,338,000	8,850,000	68.9	74.6
Michigan and northeastern Indiana	7,770,000	7,923,000	52.9	63.7
Southern Indiana and Kentucky	4,550,000	4,450,000	35.4	56.0
Illinois and western Indiana	14,060,000	14,162,000	51.0	64.2
Maryland, Virginia, and West Virginia	4,322,200	4,700,000	52.7	52.5
Tennessee, Alabama, and Georgia	4,500,000	4,300,000	66.5	63.8
Iowa, Missouri, and Minnesota	13,840,000	13,975,000	68.5	71.8
Nebraska,[a] Kansas, Oklahoma, and central Texas	10,579,500	10,390,000	50.8	59.2
Rocky Mountain States (Colorado, Utah, Montana, and western Texas)	4,498,000	4,285,000	50.9	65.6
Pacific Coast States (California, Washington, and Oregon)	15,783,100	14,267,700	35.2	43.5
	137,601,200	134,092,700	51.7	60.2

[a] Nebraska had no output in 1918.

RECOVERY OF POTASH.

The production of potash salts as a by-product of the manufacture of Portland cement continued during 1919 to be a subject of interest to the cement industry but not so much so as in 1917 and 1918. In 1919 the production of potash salts was reported by 14 cement plants, 4 of them in California, 1 in Indiana, 1 in Maryland, 1 in Missouri, 1 in New York, 1 in Ohio, 3 in Pennsylvania, 1 in Tennessee, and 1 in Utah. In 1918 there were 12 plants producing potash salts. In 1919 the quantity of potash (K_2O) produced by cement plants was 1,258 short tons, valued at $270,505—a slight decrease in quantity as compared with 1,549 short tons, valued at $603,617, in 1918.[4]

NATURAL AND PUZZOLAN CEMENTS.

For several years only one manufacturer has reported an output of puzzolan or slag-lime cement, and in order that this quantity may be included in the cement totals for the United States without revealing confidential information it is added to the output of natural cement. The puzzolan cement plant is at Birmingham, Ala.

The natural cement and puzzolan cement shipped from mills in the United States during 1919 amounted to 528,589 barrels, valued at $583,554, as compared with an output of 432,966 barrels, valued at $401,341, in 1918, an increase in 1919 of 22.1 per cent in quantity and of 45.4 per cent in value. The average price of these cements per barrel at the mills in 1919 was $1.10, as compared with 92.7 cents in 1918, both prices well below those of Portland cement in the same years.

Natural cement was produced in 1919 in seven plants, distributed in six States—at Siegfried, Pa.; Lisbon, Ohio; Speeds, Ind.; Utica, Ill.; Fort Scott, Kans.; and Austin and Mankato, Minn. In 1918 the same plants with an additional one at Binnewater, N. Y., were in operation. The Binnewater or Rosendale locality has long been famous for the manufacture of natural cement, and the closing of its plants is noteworthy.

Natural and puzzolan cement shipped, 1918 and 1919.

State.	1918			1919		
	Producing plants.	Quantity (barrels).	Value.	Producing plants.	Quantity (barrels).	Value.
Alabama [a]	1			1		
Illinois	1	184,066	$208,746	1	226,671	$294,463
Indiana	1			1		
Kansas	1	193,296	149,818	1		
Minnesota	2			2	301,918	289,091
Ohio	1			1		
Pennsylvania	1	55,604	42,777	1		
New York	1			(b)		
	9	432,966	401,341	8	528,589	583,554

[a] Puzzolan only. [b] New York had no production in 1919.

[4] For production of potash salts see the chapter on potash in Mineral Resources for 1919 and former years

FOREIGN TRADE IN CEMENT.

EXPORTS.

In 1919 the hydraulic cement exported to foreign countries, including the Philippine Islands and the Canal Zone, was 2,463,573 barrels, most of it Portland cement, valued at the United States ports of shipment at an average of approximately $3.05 a barrel, as compared with about $2.62 a barrel in 1918. The total quantity increased about 9.4 per cent and the value 27.1 per cent. The quantity exported in 1919 was less than 3 per cent of the total shipments of hydraulic cement in that year.

The exports, as shown in the following table, go mainly to South America, which received about 1,335,000 barrels; the West Indies, which received about 715,000 barrels; and Central America, including Mexico, which received about 331,000 barrels, leaving less than 83,000 barrels for Europe, Africa, Asia, and Oceania. The export trade fluctuates from year to year. The noteworthy increases in 1919 were shown in exports to Argentina, Brazil, and Colombia, and the principal decreases in exports to British Guiana, Chile, Cuba, and Panama.

Hydraulic cement exported from the United States in 1919, by countries.

Country.	Quantity (barrels).	Value.	Country.	Quantity (barrels).	Value.
Argentina	382,181	$1,139,984	French Africa	7,355	$24,420
Belgian Kongo	2,251	7,153	French Guiana	3,182	9,728
Belgium	226	784	French Oceania	162	591
Bermuda	580	1,812	French West Indies	11,879	38,333
Bolivia	9,921	31,470	German Africa	90	275
Brazil	579,863	1,757,723	Greece	179	819
British East Indies:			Guatemala	24,659	86,699
British India	764	2,403	Haiti	27,924	84,956
Straits Settlements	82	321	Honduras	11,231	34,435
British Guiana	15,544	45,358	Hongkong	74	288
British Honduras	1,219	3,850	Iceland and Faroe Islands	1	4
British Oceania:			Italy	100	407
Australia	296	1,276	Japan	575	2,228
New Zealand	107	576	Liberia	559	1,914
Other	240	586	Madagascar	11,568	39,300
British South Africa	703	1,906	Mexico	135,056	433,417
British West Africa	18,235	55,955	Miquelon, Langley, and St. Pierre islands	164	589
British West Indies:					
Barbados	1,419	4,405	Netherlands	30	153
Jamaica	18,279	54,334	Newfoundland and Labrador	5,563	15,557
Trinidad and Tobago	17,965	56,239	Nicaragua	10,593	37,014
Other	7,623	23,671	Norway	51	288
Canada	12,415	42,969	Panama	117,445	288,678
Canary Islands	1,600	4,500	Paraguay	7,650	22,735
Chile	59,700	198,303	Peru	120,335	368,370
China	60	290	Philippine Islands	346	1,422
Colombia	75,266	242,115	Portuguese Africa	5,705	17,741
Costa Rica	9,371	31,732	Salvador	21,540	75,296
Cuba	561,671	1,675,022	Spain	343	1,298
Dominican Republic	58,273	196,087	Turkey in Europe	25	96
Dutch East Indies	2,299	11,434	Uruguay	24,374	94,252
Dutch Guiana	3,242	10,303	Venezuela	35,401	109,526
Dutch West Indies	6,145	20,995	Virgin Islands of the United States	3,199	11,057
Ecuador	17,816	54,604			
England	4,192	12,252			
France	6,667	21,091		2,463,573	7,513,389

Hydraulic cement exported from the United States, 1913–1919.[a]

Year.	Quantity (barrels).	Value.	Percentage of total shipments.	Year.	Quantity (barrels).	Value.	Percentage of total shipments.
1913	2,964,358	$4,270,666	3.3	1917	2,586,215	$5,328,536	2.8
1914	2,140,197	3,088,809	2.5	1918	2,252,446	5,912,166	3.2
1915	2,565,031	3,361,451	2.9	1919	2,463,573	7,513,389	2.9
1916	2,563,976	3,828,231	2.7				

[a] Export statistics compiled from records of Bureau of Foreign and Domestic Commerce ,Department of Commerce.

IMPORTS.

The quantity of foreign hydraulic cement imported for consumption into the United States in 1919 was approximately 8,931 barrels of 380 pounds, valued at $52,636, or about $5.89 a barrel, as compared with 305 barrels, valued at $1,200, or about $3.93 a barrel, in 1918.

From 1887 to 1907 imports were with few exceptions more than 1,000,000 barrels each year, but since 1910 they have been unimportant and during the World War, owing to the cessation of imports from Belgium, Germany, and France, they were very small. It is not expected that imports will again become large, because of the wide distribution of domestic Portland cement plants and the general excellence of their product.

Roman, Portland, and other hydraulic cement imported into the United States in 1919, by countries.

Country.	Quantity (barrels).	Value.
Austria-Hungary	7,074	$48,000
Canada	1,428	3,333
Panama	4	25
Japan	1	5
Country not given	[a] 424	[a] 1,273
	8,931	52,636

[a] White, nonstaining cement.

Foreign cement imported for consumption, 1913–1919, in barrels of 380 pounds.[5]

1913	85,470	1917	2,323
1914	120,906	1918	305
1915	42,218	1919	8,931
1916	1,836		

PORTLAND CEMENT IN CANADA.

The following statement is quoted from the annual report on the mineral production of Canada in 1919, issued by the Canada Department of Mines, Mines Branch, November, 1920:

The total quantity of cement sold from Canadian cement mills in 1919 was 4,995,257 barrels, valued at $9,802,433, or an average of $1.96 per barrel—an increase in quantity sold of 1,403,776 barrels, or 39 per cent, and an increase in total value of $2,725,930, or 38½ per cent.

[5] Statistics compiled from records of Bureau of Foreign and Domestic Commerce, Department of Commerce.

Sales of cement from mills in Quebec in 1919 were 2,260,422 barrels, valued at $4,340,010; in Ontario, 2,023,280 barrels, valued at $3,650,585; and in Manitoba, Alberta, and British Columbia, 711,555 barrels, valued at $1,811,838.

The total quantity of cement made in 1919 was 4,613,588 barrels, as compared with 3,417,600 barrels in 1918, an increase of 1,195,928 barrels, or 35 per cent.

Stocks of cement on hand January 1, 1919, were 1,471,865 and at the end of December had been reduced to 1,089,970 barrels.

The total imports of cement in 1919 were 49,232 hundredweight, equivalent to 14,066 barrels of 350 pounds each, valued at $51,314, or an average of $3.65 per barrel.

The total consumption of cement, therefore, was 4,831,817 barrels, an increase of 1,234,423 barrels, or 34.3 per cent.

LIME.

By G. F. Loughlin and A. T. Coons.

PRODUCTION.

The lime sold in the United States in 1919 showed an increase in quantity of 4 per cent and in value of 10 per cent, compared with 1918. The greatest quantity of lime sold in any one year was recorded in 1916; the highest mark in value was reached in 1919. The average value per ton of lime increased nearly 6 per cent over 1918 and 122 per cent over 1915.

In the following tables are given figures showing the details of the production of lime for 1919. The usual discussion of the figures, some of the supplementary tables, and all the graphs are omitted on account of the lateness of the publication of the report.

Lime sold in the United States in 1915–1919.

Year.	Quantity (short tons).	Value.[a]	Average value per ton.	Number of plants in operation.
1915	3,622,810	$14,424,036	$3.98	906
1916	4,073,433	18,509,305	4.54	778
1917	3,786,364	23,807,877	6.29	595
1918	3,206,016	26,808,909	8.36	496
1919	3,330,347	29,448,553	8.84	539

[a] The value given represents the value of bulk lime f. o. b. at point of shipment and does not include cost of barrel or package.

Lime sold in the United States in 1918, by States.

State or Territory.	Rank of State by quantity.	Quantity (short tons).	Percentage of total quantity.	Value.	Rank of State by value.	Average value per ton.	Number of plants in operation.
Alabama	17	49,209	1.54	$439,366	16	$8.93	9
Arizona	21	11,212	.35	126,390	20	11.27	3
Arkansas	24	8,320	.26	62,250	25	7.48	3
California	15	55,588	1.73	558,058	14	10.04	11
Colorado	26	6,077	.19	61,476	26	10.12	4
Connecticut	16	(a)	(a)	(a)	22	7.90	6
Florida	31	(a)	(a)	(a)	27	13.58	1
Hawaii	34	(a)	(a)	(a)	32	11.25	1
Idaho	39	(a)	(a)	(a)	36	10.72	2
Illinois	14	64,672	2.02	535,090	15	8.27	11
Indiana	8	116,321	3.63	865,597	10	7.44	8
Iowa	23	(a)	(a)	(a)	24	7.65	2
Kansas	40	(a)	(a)	(a)	40	7.00	1
Kentucky	38	1,884	.06	14,925	38	7.92	3
Maine	13	83,034	2.59	906,179	9	10.91	4
Maryland	10	106,737	3.33	808,766	11	7.58	19
Massachusetts	7	123,697	3.86	1,030,929	7	8.33	11
Michigan	6	134,813	4.21	1,186,007	6	8.80	7
Minnesota	22	10,792	.34	86,882	21	8.05	5
Missouri	4	201,737	6.29	1,721,800	3	8.53	20
Montana	29	(a)	(a)	(a)	33	5.32	2
Nevada	28	(a)	(a)	(a)	30	7.51	1
New Jersey	37	2,208	.07	12,268	39	5.56	3
New Mexico	35	(a)	(a)	(a)	37	7.67	2
New York	12	87,127	2.71	913,366	8	10.48	15
North Carolina	27	(a)	(a)	(a)	28	9.75	1
Ohio	2	489,893	15.28	4,640,536	2	9.47	32
Oklahoma	33	(a)	(a)	(a)	35	9.00	2
Oregon	36	2,257	.07	26,884	34	11.91	4
Pennsylvania	1	801,834	25.01	6,654,407	1	8.30	162
Porto Rico	32	3,973	.12	44,047	29	11.09	27
Rhode Island	41	(a)	(a)	(a)	41	12.30	1
South Dakota	30	4,772	.15	40,490	31	8.48	4
Tennessee	11	106,527	3.32	682,450	13	6.41	17
Texas	18	45,206	1.41	363,022	18	8.03	8
Utah	25	7,844	.24	67,642	23	8.62	8
Vermont	19	35,728	1.11	382,363	17	10.70	7
Virginia	3	249,990	7.80	1,629,567	4	6.52	27
Washington	20	22,118	.69	226,104	19	10.22	6
West Virginia	5	167,901	5.24	1,194,610	5	7.11	10
Wisconsin	9	109,303	3.41	740,700	12	6.78	25
Wyoming	42	(a)	(a)	(a)	42	18.75	1
Undistributed	....	95,242	2.97	786,738	....	....	....
	....	3,206,016	100.00	26,808,909	....	8.36	496

a Included under "Undistributed."

Lime sold in the United States in 1919, by States.

State or Territory.	Rank of State by quantity.	Quantity (short tons).	Percentage of total quantity.	Value.	Rank of State by value.	Average value per ton.	Number of plants in operation.
Alabama	7	135,095	4.1	$1,062,542	11	$7.87	10
Arizona	22	10,905	.3	138,062	22	12.66	3
Arkansas	23	10,794	.3	115,019	23	10.66	4
California	18	39,307	1.2	466,905	17	11.88	8
Colorado	36	2,136	.1	26,102	36	12.22	3
Connecticut	16	(a)	(a)	(a)	16	10.27	5
Florida	24	(a)	(a)	(a)	24	12.64	2
Hawaii	34	(a)	(a)	(a)	26	23.36	1
Idaho	38	(a)	(a)	(a)	37	14.76	2
Illinois	15	65,060	2.0	580,041	15	8.92	11
Indiana	12	107,460	3.2	902,469	13	8.40	6
Iowa	27	(a)	(a)	(a)	29	9.79	2
Kansas	41	(a)	(a)	(a)	42	15.04	1
Kentucky	40	988	(a)	9,275	40	9.39	3
Maine	14	96,582	2.9	1,207,508	8	12.50	4
Maryland	13	103,563	3.1	860,187	14	8.30	29
Massachusetts	8	131,762	4.0	1,339,464	6	10.17	11
Michigan	6	145,783	4.4	1,381,534	5	9.48	7
Minnesota	20	23,005	.7	294,313	20	12.79	6
Missouri	4	180,749	5.4	1,735,705	4	9.60	19
Montana	32	3,340	.1	35,834	32	10.73	3
Nevada	35	(a)	(a)	(a)	34	10.67	1
New Jersey	29	4,828	.1	29,098	35	6.03	7
New Mexico	37	1,758	.1	17,615	39	10.02	4
New York	9	126,404	3.8	1,131,860	9	8.95	16
North Carolina	26	(a)	(a)	(a)	27	9.59	2
Ohio	2	512,614	15.4	4,477,987	2	8.74	33
Oklahoma	33	(a)	(a)	(a)	33	11.03	2
Oregon	31	(a)	(a)	(a)	28	17.01	1
Pennsylvania	1	779,608	23.4	6,181,710	1	7.93	187
Porto Rico	28	5,407	.2	54,803	31	10.14	23
Rhode Island	39	(a)	(a)	(a)	38	15.91	1
South Dakota	30	4,205	.1	56,540	30	13.45	3
Tennessee	11	116,346	3.5	958,816	12	8.24	18
Texas	17	49,831	1.5	459,279	18	9.22	7
Utah	25	6,982	.2	94,027	25	13.47	12
Vermont	19	37,850	1.1	436,000	19	11.52	8
Virginia	3	223,768	6.7	1,805,627	3	8.07	36
Washington	21	19,534	.6	232,723	21	11.91	5
West Virginia	5	174,167	5.2	1,274,294	7	7.32	8
Wisconsin	10	123,620	3.7	1,094,725	10	8.86	23
Wyoming	42	(a)	(a)	(a)	41	24.61	2
Undistributed	....	86,896	2.6	988,489	....	....	....
	....	3,330,347	100.0	29,448,553	....	8.84	539

a Included under "Undistributed."

Lime sold in the United States in 1918 and 1919, by uses.

Use.	Percentage of total quantity.	Quantity (short tons).	Value.	Average value per ton.
1918.				
Building lime	28.5	914,186	$7,781,388	$8.51
Chemical works	17.7	566,532	4,177,302	7.37
Paper mills	10.1	325,172	2,610,645	8.03
Glassworks	1.1	34,051	265,855	7.81
Sugar factories	1.1	36,494	314,748	8.62
Tanneries	2.3	74,350	637,960	8.58
Agriculture	12.2	391,047	2,698,848	6.90
Metallurgy	7.9	253,778	1,884,672	7.43
Dealers—uses not specified	3.5	111,343	960,596	8.63
Other uses [a]	15.6	499,063	5,476,895	10.97
	100.0	3,206,016	26,808,909	8.36
Hydrated lime (included in total)	....	620,216	5,342,113	8.61
1919.				
Building lime	35.8	1,191,434	11,484,318	9.64
Chemical works	14.2	472,718	3,848,778	8.14
Paper mills	10.1	335,813	2,836,347	8.45
Glassworks	1.3	44,618	336,020	7.53
Sugar factories	.4	13,111	163,526	12.47
Tanneries	1.8	59,978	580,022	9.67
Agriculture	13.2	438,632	3,345,039	7.63
Metallurgy	8.9	295,622	2,152,554	7.28
Dealers—uses not specified	2.7	90,117	954,909	10.60
Other uses [a]	11.6	388,304	3,747,040	9.65
	100.0	3,330,347	29,448,553	8.84
Percentage of increase in 1919	....	3.9	9.8	5.7
Hydrated lime (included in total)	....	777,408	7,061,146	9.08
Percentage of increase of hydrated lime in 1919	....	25.3	32.2	5.5

[a] Includes lime for sand-lime brick, slag cement, alkali works, sheep dipping, disinfectant, manufacture of soap, cyanide plants, glue factories, purification of water, etc.

Lime sold in the United States in 1918 and 1919, by States and uses.

1918.

State.	Building.		Metallurgy.		Chemical works.		Paper mills.	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
Alabama	27,770	$257,070	6,877	$56,488	(a)	(a)	4,663	$38,308
Arizona	6,919	79,197	(a)	(a)	(a)	(a)	...	...
Arkansas	6,620	50,600	...	...	(a)	(a)	(a)	(a)
California	14,016	140,217	(a)	(a)	9,225	$93,417	(a)	(a)
Colorado	2,099	21,400	(a)	(a)	(a)	(a)	...	...
Connecticut	(a)	(a)	...	...	(a)	(a)	(a)	(a)
Florida	(a)	(a)	...	...	...	...	...	...
Hawaii	(a)	(a)	...	...	...	...	...	...
Idaho	(a)	(a)	...	...	...	...	(a)	(a)
Illinois	26,119	214,222	...	...	10,542	87,108	6,834	53,731
Indiana	8,008	60,366	2,454	19,098	36,187	260,505	22,320	173,551
Iowa	(a)	(a)	(a)	(a)	...	...	...	...
Kansas	(a)	(a)	...	...	...	...	...	...
Kentucky	(a)	(a)	...	...	...	...	...	...
Maine	32,521	422,444	(a)	(a)	(a)	(a)	(a)	(a)
Maryland	5,638	45,155	(a)	(a)	4,546	34,752	(a)	(a)
Massachusetts	36,823	328,398	(a)	(a)	18,028	147,075	57,930	470,516
Michigan	(a)	(a)	(a)	(a)	110,028	975,825	(a)	(a)
Minnesota	10,325	83,146	...	...	(a)	(a)	...	...
Missouri	42,047	377,334	35,760	279,432	43,881	357,646	7,786	64,542
Montana	(a)	(a)	(a)	(a)	(a)	(a)	...	...
Nevada	(a)	(a)	(a)	(a)	(a)	(a)	...	...
New Jersey	...	...	...	...	...	...	...	...
New Mexico	(a)	(a)	...	...	(a)	(a)	...	...
New York	17,264	147,580	9,122	91,781	3,169	32,000	24,381	227,996
North Carolina	(a)	(a)	(a)	(a)	...	...	(a)	(a)
Ohio	254,318	2,228,153	3,507	26,860	(a)	(a)	11,875	90,812
Oklahoma	(a)	(a)	...	...	...	...	...	...
Oregon	2,207	26,334	(a)	(a)	...	...	...	...
Pennsylvania	126,432	1,020,744	87,327	599,136	84,562	595,152	77,512	527,313
Porto Rico	1,118	9,535	...	...	...	...	...	...
Rhode Island	(a)	(a)	...	...	(a)	(a)	...	...
South Dakota	(a)	(a)	...	...	(a)	(a)	...	...
Tennessee	36,685	248,609	...	...	24,548	146,520	9,821	60,868
Texas	30,938	253,251	2,445	19,505	437	3,470	(a)	(a)
Utah	3,361	34,022	(a)	(a)	...	...	...	...
Vermont	4,142	50,818	(a)	(a)	10,907	122,786	4,479	45,679
Virginia	38,339	324,938	15,453	121,191	136,735	764,206	8,726	64,554
Washington	5,734	58,447	3,879	34,778	(a)	(a)	(a)	(a)
West Virginia	14,408	106,846	55,042	388,625	(a)	(a)	(a)	(a)
Wisconsin	90,442	610,277	...	...	197	1,567	14,400	98,860
Wyoming	(a)	(a)	...	...	...	...	...	...
Undistributed	69,893	582,285	31,912	247,778	73,540	555,273	74,445	693,915
	914,186	7,781,388	253,778	1,884,672	566,532	4,177,302	325,172	2,610,645

State.	Sugar factories.		Tanneries.		Glass works.		Agriculture.	
	Quantity (short tons).	Value.	Quantity (short tons.)	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
Alabama	(a)	(a)	(a)	(a)	...	...	1,947	$17,436
Arizona	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
Arkansas	(a)	(a)	...	...	...	...	(a)	(a)
California	17,254	$144,450	(a)	(a)	...	...	850	8,304
Colorado	...	...	...	...	...	...	...	...
Connecticut	...	...	...	...	...	...	(a)	(a)
Florida	...	...	...	...	...	...	...	...
Hawaii	(a)	(a)	...	...	...	...	...	...
Idaho	...	...	...	...	...	...	...	...
Illinois	(a)	(a)	(a)	(a)	...	...	...	...
Indiana	...	...	2,179	$17,559	3,006	$22,699	1,303	6,122
Iowa	...	...	...	...	...	...	...	...
Kansas	...	...	...	...	...	...	...	...
Kentucky	...	...	...	...	...	...	(a)	(a)
Maine	(a)	(a)	(a)	(a)	...	...	8,017	46,168
Maryland	...	...	...	...	...	...	68,807	534,852
Massachusetts	...	...	4,648	23,163	...	...	3,089	35,450
Michigan	...	...	2,968	26,186	...	...	(a)	(a)
Minnesota	...	...	...	...	...	...	(a)	(a)
Missouri	(a)	(a)	(a)	(a)	616	5,963	193	1,706
Montana	...	...	...	...	...	...	...	...
Nevada	(a)	(a)	...	...	...	...	...	...
New Jersey	...	...	...	...	...	...	2,208	12,268

a Included under "Undistributed."

Lime sold in the United States in 1918 and 1919, by States and uses—Continued.

1918—Continued.

State.	Sugar factories.		Tanneries.		Glass works.		Agriculture.	
	Quantity (short tons).	Value.	Quantity (short tons.)	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
New Mexico							(a)	(a)
New York	(a)	(a)	3,187	$40,836	(a)	(a)	5,931	$27,868
North Carolina			(a)	(a)				
Ohio			(a)	(a)	28,633	$225,652	40,001	275,561
Oklahoma								
Oregon								
Pennsylvania	2,964	$23,560	26,006	196,791	1,281	7,675	200,073	1,343,636
Porto Rico	1,997	27,961					823	6,329
Rhode Island							(a)	(a)
South Dakota								
Tennessee	8,690	66,071	(a)	(a)			3,311	15,333
Texas	1,921	13,787	(a)	(a)			(a)	(a)
Utah							(a)	(a)
Vermont			9,810	106,583			2,201	8,288
Virginia	(a)	(a)	3,988	30,516			34,444	232,204
Washington	(a)	(a)					(a)	(a)
West Virginia			(a)	(a)			16,053	116,554
Wisconsin			2,749	20,386	(a)	(a)	241	502
Wyoming								
Undistributed	3,668	38,919	18,815	175,940	515	3,866	1,555	10,267
	35,494	314,748	74,350	637,960	34,051	265,855	391,047	2,698,848

State.	Dealers.		Other uses.		Total.	
	Quantity (short tons.)	Value.	Quantity (short tons.)	Value.	Quantity (short tons.)	Value.
Alabama	(a)	(a)	(a)	(a)	49,209	$439,366
Arizona			(a)	(a)	11,212	126,390
Arkansas					8,320	62,250
California	7,018	$87,450	3,557	$36,588	55,588	558,058
Colorado			(a)	(a)	6,077	61,476
Connecticut					(a)	(a)
Florida					(a)	(a)
Hawaii					(a)	(a)
Idaho					(a)	(a)
Illinois	(a)	(a)	13,481	111,497	64,672	535,090
Indiana	8,093	64,695	32,771	241,002	116,321	865,597
Iowa					(a)	(a)
Kansas					(a)	(a)
Kentucky	(a)	(a)			1,884	14,925
Maine			(a)	(a)	83,034	906,179
Maryland			13,584	101,811	106,737	808,766
Massachusetts			(a)	(a)	123,697	1,030,929
Michigan	(a)	(a)	(a)	(a)	134,813	1,186,007
Minnesota			(a)	(a)	10,792	86,882
Missouri	39,473	366,112	30,096	249,900	201,737	1,721,800
Montana	(a)	(a)	(a)	(a)	(a)	(a)
Nevada					(a)	(a)
New Jersey					2,208	12,268
New Mexico			(a)	(a)	(a)	(a)
New York	(a)	(a)	23,460	338,941	87,127	913,366
North Carolina					(a)	(a)
Ohio	(a)	(a)	144,415	1,736,008	489,893	4,640,536
Oklahoma					(a)	(a)
Oregon					2,257	26,884
Pennsylvania	10,242	69,422	185,435	2,270,978	801,834	6,654,407
Porto Rico			35	222	3,973	44,047
Rhode Island					(a)	(a)
South Dakota					4,772	40,490
Tennessee	(a)	(a)	20,200	124,746	106,527	682,450
Texas			7,868	61,381	45,206	363,022
Utah			(a)	(a)	7,844	67,642
Vermont	(a)	(a)	3,358	35,965	35,728	382,363
Virginia	(a)	(a)	9,610	70,198	249,990	1,629,567
Washington	(a)	(a)	2,817	26,952	22,118	226,104
West Virginia	(a)	(a)			167,901	1,194,610
Wisconsin			814	5,888	109,303	740,700
Wyoming					(a)	(a)
Undistributed	46,517	372,917	7,562	64,818	95,242	786,738
	111,343	960,596	499,063	5,476,895	3,206,016	26,808,909

a Included under "Undistributed."

Lime sold in the United States in 1918 and 1919, by States and uses—Continued.

1919.

State.	Building.		Metallurgy.		Chemical works.		Paper mills.	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
Alabama	38,492	$391,191	72,619	$475,158	(a)	(a)	(a)	(a)
Arizona	6,849	92,150	(a)	(a)	(a)	(a)	....	....
Arkansas	10,614	113,364	....	....	(a)	(a)	(a)	(a)
California	25,180	273,551	(a)	(a)	2,800	$29,336	(a)	(a)
Colorado	949	11,560	(a)	(a)	....	....	....	....
Connecticut	(a)	(a)	....	....	....	....	....	....
Florida	(a)	(a)	....	....	....	....	....	....
Hawaii	(a)	(a)	....	....	....	....	....	....
Idaho	(a)	(a)	....	....	....	....	(a)	(a)
Illinois	36,024	322,947	(a)	(a)	7,029	58,712	5,559	$52,644
Indiana	13,790	108,922	3,415	26,533	21,261	181,098	26,489	209,940
Iowa	(a)	(a)	(a)	(a)	....	....	(a)	(a)
Kentucky	(a)	(a)	....	....	....	....	....	....
Maine	41,918	664,186	(a)	(a)	....	....	39,379	407,623
Maryland	7,606	67,690	(a)	(a)	....	....	(a)	(a)
Massachusetts	53,958	663,504	(a)	(a)	22,465	191,206	48,959	442,240
Michigan	10,427	105,731	1,364	12,930	114,339	1,082,198	9,945	90,478
Minnesota	22,273	279,409	....	....	(a)	(a)	....	....
Missouri	46,646	444,304	21,145	188,809	14,892	130,023	9,430	84,619
Montana	(a)	(a)	(a)	(a)	....	....	....	....
Nevada	(a)	(a)	(a)	(a)	(a)	(a)	....	....
New Jersey	(a)	(a)	(a)	(a)	....	....	....	....
New Mexico	608	6,215	....	....	....	....	....	....
New York	21,881	185,318	10,880	118,410	42,905	392,225	29,590	253,187
North Carolina	(a)	(a)	....	....	....	....	....	....
Ohio	316,394	2,624,930	6,973	52,007	4,075	30,618	17,540	130,270
Oklahoma	(a)	(a)	....	....	....	....	....	....
Pennsylvania	165,906	1,571,238	84,489	530,923	68,465	506,582	73,761	537,691
Porto Rico	2,587	21,945	....	....	....	....	....	....
Rhode Island	(a)	(a)	....	....	....	....	....	....
South Dakota	(a)	(a)	....	....	(a)	(a)	....	....
Tennessee	56,113	515,161	....	....	2,910	24,799	29,831	198,363
Texas	30,800	284,109	(a)	(a)	....	....	....	....
Utah	5,934	80,407	885	11,568	....	....	163	2,052
Vermont	8,115	103,512	(a)	(a)	7,325	82,788	8,592	91,460
Virginia	52,863	545,378	8,431	74,807	105,783	704,450	8,885	79,324
Washington	8,118	107,171	(a)	(a)	(a)	(a)	6,502	78,609
West Virginia	(a)	(a)	54,562	416,177	(a)	(a)	....	....
Wisconsin	105,727	894,594	....	....	(a)	(a)	13,662	113,565
Wyoming	(a)	(a)	....	....	....	....	....	....
Undistributed	101,662	1,005,831	30,859	245,232	58,469	434,743	7,526	64,282
	1,191,434	11,484,318	295,622	2,152,554	472,718	3,848,778	335,813	2,836,347

State.	Sugar factories.		Tanneries.		Glassworks.		Agriculture.	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
Alabama	....	....	(a)	(a)	....	....	(a)	(a)
Arizona	....	....	(a)	(a)	(a)	(a)	(a)	(a)
Arkansas	....	....	....	....	....	....	(a)	(a)
California	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
Connecticut	....	....	....	....	....	....	(a)	(a)
Hawaii	(a)	(a)	....	....	....	....	(a)	(a)
Illinois	(a)	(a)	(a)	(a)	....	....	....	....
Indiana	....	....	2,195	$20,552	(a)	(a)	5,868	$49,461
Kansas	....	....	....	....	....	....	(a)	(a)
Kentucky	....	....	....	....	....	....	(a)	(a)
Maine	(a)	(a)	(a)	(a)	....	....	8,763	59,558
Maryland	(a)	(a)	(a)	(a)	....	....	76,770	655,704
Massachusetts	....	....	....	....	....	....	4,673	25,532
Michigan	(a)	(a)	4,152	38,908	....	....	(a)	(a)
Missouri	249	$2,650	2,574	25,211	1,428	$15,725	1,123	8,540
Nevada	(a)	(a)	....	....	....	....	....	....
New Jersey	....	....	....	....	....	....	4,154	21,997
New York	(a)	(a)	4,384	63,765	....	....	6,206	34,574

a Included under "Undistributed."

Lime sold in the United States in 1918 and 1919, by States and uses—Continued.

1919—Continued.

State.	Sugar factories.		Tanneries.		Glassworks.		Agriculture.	
	Quantity (short tons).	Value.	Quantity (short tons.)	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
North Carolina			(a)	(a)			(a)	(a)
Ohio	(a)	(a)	(a)	(a)	36,717	$266,922	27,696	$212,156
Pennsylvania	(a)	(a)	11,416	$88,629	3,986	29,618	232,831	1,706,027
Porto Rico	1,170	$18,268					1,650	14,590
Rhode Island			(a)	(a)	(a)	(a)	(a)	(a)
South Dakota							(a)	(a)
Tennessee	5,339	46,555	2,815	24,032			730	6,020
Texas	(a)	(a)					(a)	(a)
Vermont			7,917	93,852			2,072	15,474
Virginia	(a)	(a)	4,546	38,212	(a)	(a)	35,712	290,032
Washington	(a)	(a)					(a)	(a)
West Virginia			(a)	(a)			25,253	191,125
Wisconsin			1,626	13,731			433	4,754
Undistributed	6,353	96,053	18,353	173,130	2,487	23,755	4,698	49,495
	13,111	163,526	59,978	580,022	44,618	336,020	438,632	3,345,039

State.	Dealers.		Other uses.		Total.	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
Alabama			17,984	$148,519	135,095	$1,062,542
Arizona			1,329	17,757	10,905	138,062
Arkansas			(a)	(a)	10,794	115,019
California	(a)	(a)	(a)	(a)	39,307	466,905
Colorado			(a)	(a)	2,136	26,102
Connecticut					(a)	(a)
Florida			(a)	(a)	(a)	(a)
Hawaii					(a)	(a)
Idaho					(a)	(a)
Illinois			11,042	98,699	65,060	580,041
Indiana	7,809	$65,008	25,078	228,752	107,460	902,469
Iowa					(a)	(a)
Kansas					(a)	(a)
Kentucky					988	9,275
Maine			(a)	(a)	96,582	1,207,508
Maryland			1,534	14,767	103,563	860,187
Massachusetts	(a)	(a)			131,762	1,339,464
Michigan	(a)	(a)	3,879	36,347	145,783	1,381,534
Minnesota					23,005	294,313
Missouri	44,578	472,801	38,684	363,023	180,749	1,735,705
Montana			(a)	(a)	3,340	35,834
Nevada					(a)	(a)
New Jersey			(a)	(a)	4,828	29,098
New Mexico			(a)	(a)	1,758	17,615
New York	(a)	(a)	8,921	62,439	126,404	1,131,860
North Carolina					(a)	(a)
Ohio			102,837	1,158,172	512,614	4,477,987
Oklahoma					(a)	(a)
Oregon	(a)	(a)			(a)	(a)
Pennsylvania	2,235	15,507	135,745	1,190,077	779,608	6,181,710
Porto Rico					5,407	54,803
Rhode Island	(a)	(a)	(a)	(a)	(a)	(a)
South Dakota					4,205	56,540
Tennessee	1,062	6,909	17,546	136,977	116,346	958,816
Texas	(a)	(a)	(a)	(a)	49,831	459,279
Utah					6,982	94,027
Vermont	(a)	(a)	3,577	45,589	37,850	436,000
Virginia	(a)	(a)	3,535	29,034	223,768	1,805,627
Washington			(a)	(a)	19,534	232,723
West Virginia	(a)	(a)			174,167	1,274,294
Wisconsin			(a)	(a)	123,620	1,094,725
Wyoming					(a)	(a)
Undistributed	34,433	394,684	16,613	216,888	86,896	988,489
	90,117	954,909	388,304	3,747,040	3,330,347	29,448,553

a Included under "Undistributed."

Lime reported as sold to chemical manufacturers in 1918 and 1919.

Use.	Quantity (short tons).	Value.
1918.		
Alkali works	145,031	$768,570
Potash salts	176	1,409
Ammonia works	13,975	99,831
Explosives (kind unspecified)	23,735	173,129
Nitrates and glycerin	2,059	12,468
Guncotton preparation and gelatin	10,755	88,784
Acids	38,388	298,660
Cyaniding	12,512	118,274
Calcium carbide	87,434	785,912
Alcohol:		
Dehydration and manufacture of	1,535	10,638
Wood distillation	13,986	121,678
Bleaching works	37,905	306,726
Phenol	25,002	196,463
Salt refining	1,791	13,388
Coal and water gas purification	171	1,959
Coke-oven by-products	24,451	174,437
Gas-plant by-products	2,371	19,309
Undistributed [a]	4,481	32,966
Unspecified	120,774	952,701
	566,532	4,177,302
1919.		
Alkali works	136,896	879,203
Ammonia works	5,323	43,848
Explosives	7,196	58,770
Acids	8,178	81,380
Cyaniding	5,206	61,107
Calcium carbide	140,165	1,309,478
Bleaching works	27,804	139,672
Coke and gas manufacture	17,207	142,552
Undistributed [b]	25,452	208,075
Unspecified	99,291	924,693
	472,718	3,848,778

[a] Includes lime sold for use in manufacture of calcium acetate, aluminum hydrate, barium products, and precipitated calcium carbonate.
[b] Includes lime used in manufacture of calcium acetate, alcohol, distillation of wood, phenol, salt, and oxygen.

Lime reported as sold for "other uses" in 1918 and 1919.

Use.	Quantity (short tons).	Value.
1918.		
Refractories	318,896	$4,097,819
Silica brick	26,517	182,659
Sand-lime brick	7,417	59,357
Soap	29,599	202,028
Lubricating grease, renovating of butter, etc	3,395	28,410
Kalsomine	999	9,076
Water purification and softening	75,448	596,667
Sewage purification and neutralization of acid water	9,514	68,668
Disinfectants	6,059	51,438
Glue manufacture	8,822	78,599
Pottery and porcelain manufacture	129	1,213
Polishing and buffing compounds	384	4,424
Cotton, thread, and woolen mills	2,117	21,425
Flour mills	164	1,785
Spraying	1,813	16,706
Undistributed [a]	7,790	56,621
	499,063	5,476,895
1919.		
Refractories	222,036	2,228,602
Silica brick	16,552	131,262
Sand-lime brick	5,096	65,684
Oil, fat, soap, etc	29,205	241,525
Paint, kalsomine, etc	2,275	22,788
Sanitation	82,522	733,480
Glue	4,499	45,707
Flour mills	350	2,810
Undistributed [b]	5,290	103,452
Unspecified	20,479	171,730
	388,304	3,747,040

[a] Includes small quantities of lime reported as sold for manufacture of candles, corn products, dyes, rubber, proprietary medicines, varnish, graphite, for refining gold and platinum, for use in slag cement, in print works, tobacco factories, copper and file works, for sheep dip, and other uses not specified.
[b] Includes small quantities of lime reported as sold for manufacture of corn products, dyes, rubber, textiles, baking powder, belting, lime pencils, dairy products, polishing and buffing compounds.

Hydrated lime manufactured and sold in the United States, 1915–1919.

Year.	Quantity (short tons).	Value.	Average value per ton.	Number of plants reporting operations.
1915	581,114	$2,457,602	$4.23	84
1916	717,382	3,626,998	5.06	89
1917	709,157	4,643,004	6.55	90
1918	620,216	5,342,113	8.61	90
1919	777,408	7,061,146	9.08	93

Hydrated lime sold in the United States in 1918 and 1919, by States.

State.	1918		1919	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.
Alabama	6,327	$61,271	6,939	$72,802
Arizona	(a)	(a)	(a)	(a)
California	(a)	(a)	(a)	(a)
Connecticut	(a)	(a)	(a)	(a)
Florida	(a)	(a)	(a)	(a)
Hawaii	(a)	(a)	(a)	(a)
Idaho	(a)	(a)	(a)	(a)
Illinois	(a)	(a)	(a)	(a)
Indiana	24,574	191,631	30,931	284,796
Maine	(a)	(a)	(a)	(a)
Maryland	25,218	232,629	38,044	366,695
Massachusetts	8,803	82,699	5,386	52,923
Michigan	(a)	(a)	(a)	(a)
Missouri	34,942	345,754	39,245	402,620
Nevada			(a)	(a)
New Jersey			(a)	(a)
New York	(a)	(a)	(a)	(a)
Ohio	234,902	2,060,369	303,771	2,526,120
Pennsylvania	133,583	1,126,957	166,282	1,607,090
Rhode Island			(a)	(a)
South Dakota	(a)	(a)	(a)	(a)
Tennessee	19,268	135,612	21,253	229,545
Texas	15,594	129,044	18,895	174,910
Utah			(a)	(a)
Vermont	(a)	(a)	(a)	(a)
Virginia	(a)	(a)	(a)	(a)
Washington	(a)	(a)	(a)	(a)
West Virginia	46,485	345,123	57,294	452,547
Wisconsin	16,883	117,754	23,470	202,587
Undistributed	53,637	513,270	65,898	688,511
	620,216	5,342,113	777,408	7,061,146

a Included under "Undistributed."

Hydrated lime sold in the United States in 1918 and 1919, by uses.

Use.	1918		1919	
	Quantity (short tons.)	Value.	Quantity (short tons).	Value.
Building	312,599	$2,800,077	455,811	$4,086,089
Chemical	31,107	282,501	24,219	217,177
Paper mills	10,756	101,523	6,000	61,120
Sugar factories	7,471	61,807	5,331	48,541
Tanneries	13,557	122,317	15,268	146,447
Glass factories	922	8,509	2,002	19,398
Agriculture	181,890	1,452,436	198,165	1,784,110
Dealers	32,555	249,590	27,426	258,537
Other	29,359	263,353	43,186	439,727
	620,216	5,342,113	777,408	7,061,146

Lime consumed in the United States in 1918, by States, in short tons.

State.	Production.	Shipments from State.	Shipments into State.	Consumption.					Population in 1918 (estimated).
				Quicklime.	Hydrated lime.	Total lime.	Per capita (estimated).		
							1917	1918	
Alabama	49,209	31,443	3,684	18,819	2,631	21,450	0.01	0.01	2,395,270
Alaska	....	....	27	27	....	27	....	.0004	64,990
Arizona	11,212	7,306	3,855	7,613	148	7,761	.02	.03	272,031
Arkansas	8,320	3,803	3,179	6,115	1,581	7,696	.006	.004	1,792,965
California	55,588	1,297	8,804	58,439	4,656	63,095	.03	.02	3,119,412
Colorado	6,077	....	6,581	11,631	1,030	12,661	.016	.01	1,014,581
Connecticut	(a)	(a)	18,905	28,195	3,503	31,698	.03	.02	1,286,268
Delaware	....	....	53,164	37,925	15,239	53,164	.19	.245	216,941
District of Columbia	....	....	10,942	4,125	6,817	10,942	.03	.03	374,584
Florida	(a)	(a)	5,107	3,939	5,111	9,050	....	.010	938,877
Georgia	....	....	24,477	15,816	8,661	24,477	.01	.01	2,935,617
Hawaii	(a)	....	(a)	2,683	146	2,829	.015	.01	223,419
Idaho	(a)	(a)	4,098	2,280	2,267	4,547	.01	.01	461,765
Illinois	64,672	26,336	143,531	155,812	26,055	181,867	.04	.03	6,317,734
Indiana	116,321	72,033	51,357	65,878	29,767	95,645	.03	.03	2,854,167
Iowa	(a)	(a)	19,669	18,056	8,646	26,702	.01	.01	2,224,771
Kansas	(a)	(a)	20,640	16,717	4,023	20,740	.01	.01	1,874,195
Kentucky	1,884	....	18,621	17,759	2,746	20,505	.008	.008	2,408,547
Louisiana	....	....	27,340	19,168	8,172	27,340	.015	.01	1,884,778
Maine	83,034	37,900	47,720	91,119	1,735	92,854	.13	.12	782,191
Maryland	106,737	53,595	91,782	105,307	39,617	144,924	.12	.10	1,384,539
Massachusetts	123,697	100,130	57,897	73,749	7,715	81,464	.03	.02	3,832,790
Michigan	134,813	9,241	67,083	163,729	28,926	192,655	.07	.02	3,133,678
Minnesota	10,792	5,324	13,562	12,788	6,242	19,030	.01	.01	2,345,287
Mississippi	....	....	7,648	7,204	444	7,648	.006	.004	2,001,466
Missouri	201,737	154,451	15,315	54,516	8,085	62,601	.02	.02	3,448,498
Montana	(a)	(a)	2,680	5,739	2,105	7,844	.015	.016	486,376
Nebraska	....	....	12,338	10,198	2,140	12,338	.01	.01	1,296,877
Nevada	(a)	(a)	1,197	5,444	....	5,444	.07	.05	114,742
New Hampshire	....	....	34,111	34,051	60	34,111	.068	.076	446,352
New Jersey	2,208	50	108,292	74,353	36,097	110,450	.04	.03	3,080,371
New Mexico	(a)	(a)	1,729	3,005	121	3,126	.007	.007	437,015
New York	87,127	48,999	177,730	169,081	46,777	215,858	.028	.02	10,646,989
North Carolina	(a)	(a)	38,148	35,265	6,278	41,543	.02	.02	2,466,025
North Dakota	....	....	1,845	610	1,235	1,845	.003	.002	791,437
Ohio	489,893	292,982	76,701	182,701	90,911	273,612	.055	.052	5,273,814
Oklahoma	(a)	(a)	16,439	13,946	5,220	19,166	.01	.01	2,377,629
Oregon	2,257	1,523	4,961	4,904	791	5,695	.015	.006	888,243
Pennsylvania	801,834	239,832	209,845	633,124	138,723	771,847	.10	.085	8,798,067
Porto Rico	3,973	....	....	3,973	....	3,973	.003	.003	1,247,677
Rhode Island	(a)	(a)	6,636	5,906	825	6,731	.016	.015	637,415
South Carolina	....	....	11,886	9,506	2,380	11,886	.01	.007	1,660,934
South Dakota	4,772	....	3,705	6,299	2,178	8,477	.01	.01	735,434
Tennessee	106,527	73,025	2,515	33,171	2,846	36,017	.01	.015	2,321,253
Texas	45,206	16,858	653	17,644	11,357	29,001	.01	.006	4,601,279
Utah	7,844	21	163	7,823	163	7,986	.025	.017	453,648
Vermont	35,728	32,929	537	2,805	531	3,336	.025	.01	366,192
Virginia	249,990	83,149	29,378	179,648	16,571	196,219	.10	.09	2,234,030
Washington	22,118	8,257	1,276	12,475	2,662	15,137	.01	.009	1,660,578
West Virginia	167,901	159,658	22,935	19,606	11,572	31,178	.025	.02	1,439,165
Wisconsin	109,303	55,276	61,174	102,942	12,259	115,201	.055	.045	2,553,983
Wyoming	(a)	....	(a)	1,244	722	1,966	.01	.01	190,380
Undistributed	95,242	51,198	2,094	....	....	....	....	....	....
	3,206,016	[b]1,566,616	1,553,959	2,574,872	618,487	3,193,359	.037	.030	106,795,270

[a] Included under "Undistributed."
[b] Includes 516 tons shipped to Mexico, 33 tons shipped to South America, and 12,108 tons shipped to Canada.

Lime consumed in the United States in 1919, by States, in short tons.

State.	Production.	Shipments from State.	Shipments into State.	Consumption.					Population in 1919 (estimated).
				Quicklime.	Hydrated lime.	Total lime.	Per capita (estimated).		
							1918.	1919.	
Alabama	135,095	33,777	4,589	101,406	4,501	105,907	0.001	0.04	2,348,174
Alaska	....	....	68	68	....	68	.0004	.0012	54,899
Arizona	10,905	7,564	2,657	5,726	272	5,998	.03	.0179	334,162
Arkansas	10,794	5,685	4,604	7,649	2,064	9,713	.004	.005	1,752,204
California	39,307	2,689	10,359	41,831	5,146	46,977	.02	.013	3,426,861
Colorado	2,136	24	11,910	12,756	1,266	14,022	.01	.014	939,629
Connecticut	(a)	(a)	15,720	29,716	4,704	34,420	.02	.024	1,380,631
Delaware	....	....	46,002	27,693	18,309	46,002	.245	.206	223,003
District of Columbia	....	....	11,963	8,227	3,736	11,963	.03	.027	437,571
Florida	(a)	(a)	6,427	8,074	6,976	15,050	.010	.015	968,470
Georgia	....	....	32,576	22,384	10,192	32,576	.01	.01	2,895,832
Hawaii	(a)	....	(a)	4,023	875	4,898	.01	.01	255,912
Idaho	(a)	(a)	1,596	1,938	129	2,067	.01	.004	431,866
Illinois	65,060	20,413	138,808	145,642	37,813	183,455	.03	.028	6,485,280
Indiana	107,460	64,842	54,280	59,822	37,076	96,898	.03	.03	2,930,390
Iowa	(a)	(a)	23,528	17,777	10,451	28,228	.01	.01	2,404,021
Kansas	(a)	....	(a)	15,630	5,490	21,120	.01	.01	1,769,257
Kentucky	988	....	19,596	16,763	3,821	20,584	.008	.008	2,416,630
Louisana	....	....	26,738	19,332	7,406	26,738	.01	.01	1,798,509
Maine	96,582	47,141	26,256	73,669	2,028	75,697	.12	.098	768,014
Maryland	103,563	41,285	80,479	88,191	54,566	142,757	.10	.098	1,449,661
Massachusetts	131,762	99,619	59,271	82,921	8,493	91,414	.02	.02	3,852,356
Michigan	145,783	19,711	87,388	165,993	47,467	213,460	.02	.05	3,668,412
Minnesota	23,005	8,575	13,316	20,845	6,901	27,746	.01	.01	2,387,125
Mississippi	....	....	10,835	9,062	1,773	10,835	.004	.006	1,790,618
Missouri	180,749	131,030	17,598	58,443	8,874	67,317	.02	.019	3,404,055
Montana	3,340	150	1,140	3,584	746	4,330	.016	.007	548,889
Nebraska	....	....	13,785	11,483	2,302	13,785	.01	.01	1,296,372
Nevada	(a)	(a)	1,237	1,237	....	1,237	.05	.015	77,407
New Hampshire	....	....	26,920	25,756	1,164	26,920	.076	.06	443,083
New Jersey	4,828	284	120,105	68,661	55,988	124,649	.03	.03	3,155,900
New Mexico	1,758	590	1,456	2,430	194	2,624	.007	.007	360,350
New York	126,404	23,303	197,627	243,907	56,821	300,728	.02	.02	10,385,227
North Carolina	(a)	(a)	47,084	42,174	9,240	51,414	.02	.02	2,559,123
North Dakota	....	....	2,738	1,663	1,075	2,738	.002	.004	646,872
Ohio	512,614	288,065	50,317	136,784	138,082	274,866	.052	.047	5,759,394
Oklahoma	(a)	(a)	29,926	26,451	5,735	32,186	.01	.01	2,028,283
Oregon	(a)	(a)	2,510	2,339	1,346	3,685	.006	.004	783,389
Pennsylvania	779,608	237,928	168,284	571,088	138,876	709,964	.085	.081	8,720,017
Porto Rico	5,407	....	....	5,407	....	5,407	.003	.004	1,299,809
Rhode Island	(a)	(a)	9,424	9,022	1,403	10,425	.015	.017	604,397
South Carolina	....	....	19,649	13,863	5,786	19,649	.007	.011	1,683,724
South Dakota	4,205	28	3,831	6,540	1,468	8,008	.01	.01	636,547
Tennessee	116,346	81,035	3,673	34,145	4,839	38,984	.015	.012	2,337,885
Texas	49,831	14,206	695	22,011	14,309	36,320	.006	.007	4,663,228
Utah	6,982	323	216	6,540	335	6,875	.017	.015	449,396
Vermont	37,850	32,407	978	6,112	309	6,421	.01	.01	352,428
Virginia	223,768	92,267	29,231	142,178	18,554	160,732	.09	.069	2,309,187
Washington	19,534	3,333	2,821	16,299	2,723	19,022	.009	.014	1,356,621
West Virginia	174,167	165,467	27,173	26,100	9,773	35,873	.02	.02	1,463,701
Wisconsin	123,620	64,829	32,299	77,017	14,073	91,090	.045	.034	2,632,067
Wyoming	(a)	....	(a)	1,790	327	2,117	.01	.01	194,402
Undistributed	86,896	42,431	24,980	....	....	....	....	....	....
	3,330,347	[b]1,529,001	1,524,613	2,550,162	775,797	3,325,959	.030	.031	107,321,240

[a] Included under "Undistributed."

[b] Includes 5 tons shipped to Mexico, 1 ton to South America, 30 tons to Japan, 33 tons to China, 40 tons to England and 4,279 tons to Canada.

IMPORTS AND EXPORTS.

The following figures showing the imports and exports of lime were compiled by J. A. Dorsey, of the United States Geological Survey, from the records of the Bureau of Foreign and Domestic Commerce, United States Department of Commerce:

Lime imported and entered for consumption in the United States, 1915–1919.[a]

Year.	Quantity (short tons).	Value.	Year.	Quantity (short tons).	Value.
1915	1,956	$22,489	1918	6,650	$73,458
1916	7,959	71,663	1919	8,679	128,519
1917	7,353	70,505			

[a] Most of the lime imported into the United States comes from Canada.

Lime exported from the United States, 1915–1919.

Year.	Quantity (short tons).	Value.	Average value per ton.	Year.	Quantity (short tons).	Value.	Average value per ton.
1915	16,223	$106,312	$6.55	1918	7,191	$105,803	$14.71
1916	23,973	132,769	5.54	1919	6,372	108,370	17.01
1917	18,794	168,671	8.97				

Lime exported from the United States, 1918–19, by countries.

Country.	1918		1919	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.
Canada	5,337	$59,186	4,676	$68,157
Newfoundland and Labrador	8	116	1	27
Mexico	520	9,702	665	12,133
Central America:				
British Honduras	3	55	10	201
Guatemala	(a)	5	(a)	4
Honduras	319	6,113	48	928
Nicaragua	145	3,887	79	1,546
Panama	161	5,430	75	2,132
West Indies:				
Cuba	31	549	67	1,620
Dominican Republic	303	10,210	117	3,727
Virgin Islands of the United States	30	603	69	1,552
Barbados	....	....	10	400
Bermuda	....	....	(a)	15
Other British West Indies	8	225	4	94
South America:				
Bolivia	....	....	1	25
Brazil	132	5,051	....	....
Colombia	....	....	10	210
French Guiana	....	....	(a)	7
Peru	171	3,941	222	6,656
England	....	....	44	1,200
Spain	....	....	34	393
New Zealand	....	....	5	75
Straits Settlements	2	185	....	....
Other British Oceania	(a)	8	2	53
French Oceania	4	78	7	195
Philippine Islands	2	61	....	....
Dutch East Indies	6	156	....	....
British West Africa	9	242	....	....
Portuguese Africa	....	....	226	7,020
	7,191	105,803	6,372	108,370

[a] Less than 1 ton.

CALCAREOUS MARL.

Calcareous tufa produced mostly in Virginia and West Virginia, deposits of calcium carbonate formed in fresh-water ponds and sometimes called "bog lime," marine marl or partly consolidated coquina from the Coastal Plain of North Carolina and South Carolina, and chalk from Arkansas are included under the term calcareous marl. All this material is sufficiently soft to be dug with little or no blasting and requires considerable drying. As marketed it comes in to competition with lime and limestone used for liming land.

Calcareous marl sold in the United States, 1916–1919.

Year.	Quantity. (short tons).	Value.	Average value per ton.
1916	58,088	$144,768	$2.49
1917	73,900	165,223	2.24
1918	98,694	261,082	2.65
1919	91,437	327,294	3.58
Percentage of increase or decrease in 1919	−7	+25	+35

More than 85 per cent of the output was used directly in agriculture. This material is used also in preparing patent fertilizers and in neutralizing acid waters. At a few places it is prepared for market by a simple process of screening and drying, but elsewhere it is dried in rotary dryers and crushed, screened, and pulverized to the required fineness. It is shipped both in bulk and in sacks.

The localities of production and the kind of product obtained in 1919 were as follows: "Clam shell" marl from Edenvale, Santa Clara County, Calif.; marine marl from Jones County, near New Bern, N. C., and near Charleston, Charleston County, S. C.; fresh-water marl from Harmonsburg, Crawford County, Pa.; Barber, Alleghany County, Daleville and Springwood, Botetourt County, Marlbrook and Riverside, Rockbridge County, and Claremont, Surry County, Va., and from Charles Town, Jefferson County, W. Va. Chalk from White Cliffs, Little River County, Ark., is also included, as it was sold for agricultural use. In only one State, Virginia, was there more than one producing company, and the total output of the State was 51,154 short tons, valued at $176,780, compared with 39,770 short tons, valued at $100,518, in 1918, an increase of nearly 29 per cent in quantity and of 76 per cent in value. The average value for the marl produced in the State in 1919 was $3.46 a short ton, an increase of 93 cents over the average value in 1918.

OYSTER-SHELL LIME.

Lime burned from oyster shells forms an industry of minor importance in Maryland, Virginia, Pennsylvania, and New Jersey. The total quantity sold in 1919 was 34,251 short tons, valued at $364,202. The production in Virginia was 18,098 tons, valued at $238,710, and in Maryland 14,853 tons, valued at $113,197. This lime is sold almost entirely for agricultural purposes and is in competition with pulverized limestone, calcareous marl, and lime burned from ordinary limestone.

STONE.

By G. F. Loughlin and A. T. Coons.

PRODUCTION.

GENERAL CONDITIONS.

About 65,539,000 short tons of stone were sold in the United States in 1919, 4 per cent less than in 1918 and 22 per cent less than in 1917. Increases were recorded for most of the products whose output was curtailed during the war, but decreases were recorded for the war products most urgently needed—flux, refractory materials, and limestone for use in manufactures—the quantity of flux decreasing 20 per cent and that of refractories 42 per cent.

The total value of the stone sold in 1919 was $96,709,143, a value greater than any previously recorded. The unusual increase in the value of the products of the stone industry, like the increase in the value of the products of other industries, is attributed to the higher cost of supplies, of fuel, and especially of labor. The producers reported that business was poor during the first part of the year but that it gradually improved until, during the last six months, the demand exceeded the output that could be made with the insufficient and inefficient labor available.

PRODUCTION BY KINDS AND USES.

Stone sold in the United States, 1916–1919.

Year.	Granite.		Basalt and related rocks (trap rock).		Sandstone.		Marble.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Short tons.		*Short tons.*		*Short tons.*		*Short tons.*	
1916	9,270,800	$17,456,838	10,233,640	$7,666,297	4,681,590	$5,603,778	409,970	$7,033,171
1917	5,564,200	15,544,957	9,103,580	7,570,885	3,880,500	5,512,421	310,130	6,330,387
1918	3,827,400	14,466,423	6,859,200	7,782,280	2,858,100	4,529,298	305,720	5,496,389
1919	4,221,220	19,345,714	7,410,770	8,944,686	2,623,270	5,283,842	333,400	8,042,297
Percentage of change in 1919	+10.3	+33.7	+8.0	+14.9	−8.2	+16.7	+9.1	+46.3

Year.	Limestone.		Other stone.[a]		Total.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Short tons.		*Short tons.*		*Short tons.*	
1916	67,235,000	$41,309,599	....	....	91,831,000	$79,069,683
1917	63,481,500	46,263,379	1,234,990	$993,642	83,574,900	82,215,671
1918	53,868,200	49,453,006	844,740	973,034	68,563,360	82,700,430
1919	49,759,800	53,171,701	1,190,540	1,92C,903	65,539,000	96,709,143
Percentage of change in 1919	−7.6	+7.5	+40.9	+97.4	−4.4	+16.9

[a] Includes mica schist used for furnace lining, conglomerate, argillite, and various light volcanic rocks used mainly for crushed stone, which can not be properly classified in any of the main groups.

Stone sold in the United States in 1918 and 1919.

Use.	1918		1919	
	Quantity.	Value.	Quantity.	Value.
Building stone......cubic feet..	8,616,900	$7,454,973	12,764,516	$10,613,683
Approximate equivalent in short tons......	719,200	....	996,840	....
Monumental stone......cubic feet..	4,072,343	9,912,167	4,759,995	15,042,369
Approximate equivalent in short tons......	343,100	....	399,070	....
Paving blocks......number..	28,516,910	1,714,011	35,630,885	2,590,690
Approximate equivalent in short tons......	298,650	....	386,530	....
Curbing......cubic feet..	951,650	661,188	1,826,663	1,288,828
Approximate equivalent in short tons......	80,570	....	150,060	....
Flagging......cubic feet..	798,934	373,729	962,173	502,871
Approximate equivalent in short tons......	65,900	....	78,870	....
Rubble......short tons..	482,365	635,895	601,146	818,565
Riprap......do....	2,273,852	1,923,154	1,751,677	1,922,823
Crushed stone......do....	29,373,342	27,951,393	33,673,339	36,405,186
Furnace flux (limestone and marble).long tons..	23,917,040	23,512,635	19,031,520	19,419,438
Equivalent in short tons......	26,787,085	....	21,315,300	....
Refractory stone [a]......short tons..	1,825,183	2,363,154	1,060,741	1,429,775
Manufacturing industries [b]......do....	4,838,108	4,194,013	4,370,936	5,179,387
Other uses......do....	1,476,005	2,004,118	754,491	1,495,528
Total (quantities, approximate in short tons)......	68,563,360	82,700,430	65,539,000	96,709,143

[a] Ganister, mica schist, and dolomite.
[b] Limestone and marble in 1918. Limestone alone in 1919.

Building stone.—The output of building stone, which in 1916 represented more than 2.3 per cent of the total stone produced, was in 1919 about 1.5 per cent of the total stone produced and showed an increase of nearly 48 per cent over 1918. Nearly 43 per cent of the building stone sold was limestone, of which the Bedford-Bloomington limestone district in Indiana furnished the greater part. This district, which decreased its output 60 per cent in 1918, apparently recovered much of its lost ground in 1919, but the quantity sold, 4,788,639 cubic feet, did not equal that sold in 1917. This output, most of which was quarried during the second half of the year, was a little more than half the average quantity sold annually during the five years from 1912 to 1916. The year 1920 began promisingly, but a two months' strike, which ended May 26, so greatly retarded the recovery of the industry that the sales in 1920 may not have exceeded those in 1917. For the other limestone districts in which building stone was sold in 1919, the output was a little less than in 1918.

There was an increase of nearly 14 per cent in the quantity of marble sold for use in buildings in 1919. The demand was reported as exceptionally good during the second half of the year. More than 80 per cent of the granite used annually in buildings is quarried in the eastern part of the country, where the production in 1919 decreased about 35 per cent. The quantity of rough stone sold for the construction of such works as sea walls decreased 62 per cent; that of dressed stone sold for use in similar works decreased 45 per cent; and that of rough and dressed stone sold for use in buildings decreased about 27 per cent. An increase of 89 per cent in the sale of sandstone for use in buildings was reported in 1919, but this increase was not sufficient to bring the figures up to the total for 1917.

The total value of building stone increased about 42 per cent in 1919, and prices were reported to be from 20 to 40 per cent higher.

At stone-dressing plants the minimum wages of stonecutters, in accordance with trade agreements, were more than 22 per cent higher than in 1918, and on account of the shortage of labor, in an endeavor to complete contracts, pay was frequently increased above the minimum. The wages of quarrymen, laborers, derrickmen, and engineers were in most localities increased in practically the same proportion as those of cutters, and the total increase in the cost of labor amounted to about 25 per cent. This added burden was said to have been increased by the fact that labor was at least 10 per cent less efficient in 1919 than in 1918. The cost of fuel and supplies increased more than that of labor, but this increase was generally a smaller factor in the total cost of production.

Monumental stone.—The sales of monumental stone, which was one of the few kinds of stone that showed an increase in output in 1918, continued to increase in 1919. Leading producers of marble stated that they devoted almost all the capacity of their plants in 1919 to the production of monumental marble. Reports from the limestone districts in Indiana, Missouri, and Kentucky showed that an unusual quantity of limestone was sold for monumental work.

The granite district at Barre, Vt., which produces more than half the monumental granite sold in the United States, had about the same output as in 1918, but the value increased 56 per cent.

The labor conditions that affected the production of monumental stone were practically the same as those that affected the production of building stone, and the price of dressed stone increased more than that of rough stone.

Paving blocks, curbing, flagging, and crushed stone.—The stone products associated with road and street construction increased in both quantity and value and also in average value. The most serious complaint of quarrymen who furnish construction material of this class was car shortage, but lack of labor and high cost of labor and materials were also keenly felt. Many crushed-stone plants that were inactive in 1917 and 1918 resumed operations in 1919, but some were obliged to shut down again on account of the industrial conditions.

Flux.—The quantity of limestone sold or used as flux reached its maximum in 1917, and its decrease of 6 per cent in 1918 was followed by a further decline of 20 per cent in 1919.

Refractory stone.—Dolomite used for making refractory products, quartzite (ganister) used for making silica brick, for furnace lining, and for the manufacture of ferrosilicon, and mica schist used for lining furnaces and kilns decreased materially in both quantity and value of output in 1919.

Other uses.—The greater part of the stone sold for other uses than those noted above was stone used by alkali works, almost all of which was quarried by the users. There was a considerable decrease in the output of this stone in 1919, as well as in stone quarried for use by sugar factories, paper mills, glass works, and other industrial works. Pulverized limestone for improving the soil increased about 28 per cent in quantity and 48 per cent in value.

TOTAL PRODUCTION BY STATES.

The following tables show the total production of stone by States, and the table for 1919 gives for the first time the total quantity of stone produced by the different States. The different units by which stone is sold cause difficulty in the conversion of the quantities into tons. The conversion from one unit to another has in general been based on the specific gravity of the stone.

Value of stone sold in the United States in 1918, by States.

State.	Number of plants.	Total value.	Percentage of total.	State.	Number of plants.	Total value.	Percentage of total
Pennsylvania	364	$15,783,147	19.08	South Carolina	9	$599,964	0.73
Ohio	128	7,917,740	9.57	Rhode Island	13	577,494	.70
Vermont	40	5,505,895	6.66	Kansas	46	561,382	.68
Michigan	34	5,264,432	6.37	Arkansas	13	481,998	.58
New York	123	5,208,752	6.30	Hawaii	5	467,145	.56
Massachusetts	82	3,069,461	3.71	Iowa	38	379,029	.46
Illinois	54	2,990,150	3.62	Washington	30	365,098	.44
Indiana	69	2,819,083	3.41	Utah	13	355,579	.43
California	91	2,564,614	3.10	Nebraska	13	315,200	.38
Wisconsin	123	2,392,456	2.89	Florida	10	304,807	.37
New Jersey	54	2,210,407	2.67	Montana	15	282,228	.34
West Virginia	40	2,024,525	2.45	Arizona	10	278,127	.34
Georgia	31	1,903,255	2.30	Oregon	18	233,521	.28
Minnesota	50	1,710,267	2.07	Wyoming	11	182,087	.22
Alabama	23	1,669,721	2.02	Delaware	2	(a)	....
Missouri	112	1,668,789	2.02	South Dakota	12	97,894	.12
Virginia	62	1,638,077	1.98	Nevada	3	95,821	.12
North Carolina	30	1,581,381	1.91	New Mexico	6	86,343	.10
Tennessee	51	1,493,858	1.81	Louisiana	1	(a)	....
Maine	36	1,212,643	1.47	Alaska	1	(a)	....
Connecticut	32	1,025,475	1.24	Idaho	8	68,367	.08
New Hampshire	19	1,013,526	1.23	District of Columbia	5	7,585	.01
Kentucky	64	970,494	1.17	Mississippi	2	(a)	....
Maryland	35	921,199	1.11	Undistributed	....	286,460	.35
Colorado	38	771,472	.93				
Oklahoma	23	696,195	.84		2,118	82,700,430	100.00
Texas	26	647,287	.78				

a Included under "Undistributed."

Stone sold in the United States in 1919, by States.

State.	Number of plants.	Quantity (approximate). Short tons.	Quantity (approximate). Per cent.	Value. Dollars.	Value. Per cent.
Pennsylvania	405	13,262,310	20.2	16,529,971	17.1
Vermont	51	273,130	.4	8,219,459	8.5
Ohio	126	8,011,530	12.2	8,009,649	8.3
New York	102	4,093,210	6.2	5,856,875	6.1
Indiana	83	1,645,450	2.5	4,953,903	5.1
Massachusetts	81	1,370,830	2.1	4,363,813	4.5
Michigan	24	7,222,200	11.0	3,859,930	4.0
Illinois	51	5,035,770	7.7	3,790,133	3.8
Wisconsin	92	1,556,880	2.4	3,179,894	3.3
California	109	2,851,820	4.4	2,798,918	2.9
Georgia	27	380,020	.6	2,741,616	2.8
New Jersey	61	1,625,870	2.5	2,521,860	2.6
Minnesota	54	462,040	1.0	2,345,162	2.4
West Virginia	35	1,995,210	3.0	2,270,618	2.3
Missouri	96	1,146,040	1.7	2,190,884	2.3
Tennessee	48	677,110	1.0	1,762,596	1.8
Virginia	52	1,632,960	2.5	1,705,749	1.7
North Carolina	26	629,550	1.0	1,683,203	1.7
Connecticut	39	1,288,650	2.0	1,505,748	1.6
Alabama	20	915,910	1.4	1,465,733	1.5
Kentucky	74	1,215,330	1.8	1,447,352	1.5
New Hampshire	24	104,690	.2	1,443,204	1.5
Maryland	41	871,750	1.3	1,331,710	1.4
Maine	48	173,050	.3	1,327,330	1.4
Kansas	41	680,400	.6	860,851	1.0
Oregon	36	523,040	.8	728,863	.9
Oklahoma	22	664,710	1.0	726,059	.9
Colorado	36	529,800	.8	723,430	.8
South Carolina	10	403,780	.6	721,215	.7
Rhode Island	16	117,700	.2	635,112	.7
Texas	23	650,360	1.0	630,584	.7
Arkansas	14	408,830	.6	547,646	.6
Iowa	29	513,030	.8	508,606	.5
Washington	21	261,310	.4	423,653	.4
Arizona	13	566,610	1.0	399,271	.4
Utah	13	318,730	.5	333,342	.4
Nebraska	9	203,550	.3	280,662	.3
Hawaii	5	183,730	.3	250,538	.2
Idaho	12	112,510	.2	248,789	.2
South Dakota	11	140,400	.2	222,490	.2
Wyoming	11	118,040	.2	212,608	.2
Florida	6	129,030	.2	185,531	.2
Montana	13	209,140	.3	183,703	.1
Delaware	3	88,730	.1	148,267	.1
Porto Rico	17	67,000	.1	101,186	.1
Louisiana	1	(a)	.1	(a)	(a)
Nevada	2	53,720	.1	88,566	.1
Alaska	1	(a)	....	(a)	(a)
New Mexico	4	52,990	.1	56,373	(a)
District of Columbia	3	5,700	....	15,627	(a)
Mississippi	1	(a)	....	(a)	(a)
Undistributed	....	64,850	.1	170,861	.2
	2,142	65,539,000	100.0	96,709,143	100.0

a Included under "Undistributed."

EXPORTS AND IMPORTS.[1]

Stone exported from the United States, 1915-1919.

Kind.	1915	1916	1917	1918	1919
Marble and stone, unmanufactured	$400,510	$403,303	$572,097	$552,261	$770,392
All others, manufactured	635,614	1,077,447	1,108,185	1,208,164	1,508,997
	1,036,124	1,480,750	1,680,282	1,760,425	2,279,389

[1] The tables of exports and imports were compiled by J. A. Dorsey, of the United States Geological Survey, from the records of the Bureau of Foreign and Domestic Commerce, Department of Commerce.

Stone (including marble) exported from the United States in 1918 and 1919.

Country.	Manufactured.	Unmanufactured.
1918.		
Europe:		
France	$18,787	....
Great Britain	77,461	....
Iceland and Faroe Islands	1,591	....
Italy	7,997	....
Norway	2,062	....
Portugal	2,086	....
Spain	28,598	....
Switzerland	6,120	....
	144,702	....
North America:		
Canada	564,115	$477,985
Newfoundland	10,354	1,200
Mexico	27,400	5,575
Central America	6,362	1,453
Panama	18,695	115
Cuba	101,581	59,313
Jamaica	9,303	5,545
Bermuda	382	21
Other British West Indies	6,331	57
Dutch West Indies	1,619	....
French West Indies	370	....
Virgin Islands	689	....
Haiti	2,305	....
Dominican Republic	3,664	51
	753,170	551,315
South America:		
Argentina	17,288	....
Brazil	23,261	....
Chile	94,213	....
Colombia	8,766	706
Ecuador	5,356	....
Peru	6,017	....
Venezuela	3,025	....
Other South America	3,562	10
	161,488	716
Asia:		
China	10,769	28
British India	7,035	....
Dutch East Indies	36,679	5
Japan	27,500	....
Other Asia	2,521	17
	84,504	50
Oceania:		
Australia	24,365	....
New Zealand	10,698	....
Philippines	5,284	180
Other Oceania	1,397	....
	41,744	180
Africa:		
British South Africa	20,694	....
Other Africa	1,862	....
	22,556	....
Total exports	1,208,164	552,261
Grand total	1,760,425	

Country.	Manufactured.	Unmanufactured.
1919.		
Europe:		
Belgium	$5,849	....
Denmark	1,852	....
France	52,831	....
Iceland and Faroe Islands	1,396	....
Italy	4,660	....
Netherlands	18,020	$800
Norway	7,163	....
Portugal	1,500	....
Russia	2,474	....
Spain	37,391	....
Sweden	6,960	....
Switzerland	3,065	....
United Kingdom:		
England	114,042	100
Scotland	23,578	....
Ireland	268	....
Other Europe	474	....
	281,523	900
North America:		
British West Indies:		
Barbados	4,443	....
Jamaica	4,215	....
Other	10,855	....
Canada	555,998	635,924
Central America	36,234	65
Cuba	161,687	83,924
Dominican Republic	11,268	116
Dutch West Indies	842	....
French West Indies	589	243
Haiti	1,229	30
Mexico	55,125	37,123
Miquelon, Langley, etc	14	....
Newfoundland and Labrador	10,653	7,730
Virgin Islands	1,542	....
	854,694	765,155
South America:		
Argentina	26,995	....
Brazil	48,809	....
Chile	26,531	....
Colombia	11,452	160
Ecuador	5,193	....
Peru	13,351	....
Venezuela	3,277	....
Other South America	5,236	....
	140,844	160
Asia:		
British India	26,054	....
China	8,868	....
Dutch East Indies	42,810	35
Japan	46,130	2,949
Other Asia	7,118	....
	130,980	2,984
Oceania:		
Australia	34,856	20
New Zealand	17,649	1,153
Philippine Islands	8,633	20
Other Oceania	1,412	....
	62,550	1,193
Africa:		
British West Africa	4,328	....
British South Africa	32,727	....
Other Africa	1,351	....
	38,406	....
Total exports	1,508,997	770,392
Grand total	2,279,389	

Stone imported for consumption in the United States in 1917, 1918, and 1919.

Kind.	1917 Quantity.	1917 Value.	1918 Quantity.	1918 Value.	1919 Quantity.	1919 Value.
Marble:						
In blocks, rough, etc.......cubic feet..	267,250	$428,396	96,478	$192,641	209,945	$593,340
Sawed.........do....	9	25	....	....	9	90
Slabs or paving tiles......square feet..	124,935	27,884	26,118	5,304	104,102	25,841
All other manufactures..........	....	87,177	....	28,798	....	46,622
Mosaic cubes:						
Loose..........	....	13,434	....	5,508	....	3,888
Attached to paper..........	....	....	....	....	....	974
	....	556,916	....	232,251	....	670,755
Onyx:						
In blocks, rough, etc.......cubic feet..	6,935	22,439	1,398	3,046	2,040	9,517
Slabs or paving tiles......square feet..	5,976	1,595	....	....	....	....
All other manufactures..........	....	472	....	133	....	2,053
	....	24,506	....	3,179	....	11,570
Granite:						
Dressed..........	....	25,119	....	1,328	....	9,983
Rough..........cubic feet..	18,982	9,923	18,473	9,653	23,240	17,796
	....	35,042	....	10,981	....	27,779
Stone (other):						
Dressed..........	....	15,296	....	5,060	....	21,444
Rough (monumental or building stone)..........cubic feet..	53,537	40,330	11,995	12,716	13,807	14,228
Rough (other)..........	....	9,385	....	4,390	....	42,185
	....	65,011	....	22,166	....	77,857
Grand total..........	....	681,475	....	268,577	....	787,961

General imports of marble and onyx, rough and manufactured, into the United States in 1918 and 1919.

Country.	1918 Marble and breccia.[a] Value.	1918 Marble, breccia, and onyx.[b] Quantity (cubic feet).	1918 Marble, breccia, and onyx.[b] Value.	1918 Manufactured. Value.	1918 Total value.	1919 Marble, breccia, and onyx. Quantity (cubic feet).	1919 Marble, breccia, and onyx. Value.	1919 Manufactured. Value.	1919 Total value.
Belgium..........	....	....	....	....	....	10,114	$18,863	$3,222	$22,085
France..........	$1,690	123	$286	$652	$2,628	6,878	10,384	9,566	19,950
Germany..........	....	....	....	8	8	....	....	....	....
Greece..........	....	....	....	....	....	3,568	12,422	....	12,422
Italy..........	187,139	32,657	64,018	6,529	257,686	188,391	546,428	59,829	606,257
Netherlands..........	....	....	....	....	....	477	923	121	1,044
Portugal..........	125	....	....	....	125	....	....	....	....
Spain..........	56	....	....	61	117	....	....	65	65
England..........	2,008	....	....	1,252	3,260	....	....	3,225	3,225
Total Europe.	191,018	32,780	64,304	8,502	263,824	209,428	589,020	76,028	665,048
Canada..........	850	423	2,216	25	3,091	250	2,003	2,175	4,178
Mexico..........	133	....	....	95	228	1,366	6,147	6	6,153
Total North America....	983	423	2,216	120	3,319	1,616	8,150	2,181	10,331
Cuba..........	....	....	....	....	....	....	....	3,125	3,125
Japan..........	885	....	....	175	1,060	....	....	686	686
Other countries [c]...	87	....	....	176	263	30	423	509	932
	972	....	....	351	1,323	30	423	4,320	4,743
Grand total...	192,973	33,203	66,520	8,973	268,466	211,074	597,593	82,529	680,122

[a] Figures for January to June, inclusive.
[b] Figures for July to December, inclusive.
[c] In 1918 includes Barbados, Trinidad and Tobago, China, British India, Hongkong, and Australia; in 1919 Brazil, Venezuela, China, British India, Hongkong, and New Zealand.

PRODUCTION BY STATES AND KINDS.

GRANITE.

Value of granite sold in the United States, 1915–1919.

State.	1915	1916	1917	1918	1919
Arizona	$71,087	$203,702	$135,080	$76,287	$155,889
Arkansas	(a)	....	....	....	13,270
California	1,656,706	1,433,022	844,453	838,786	935,716
Colorado	65,876	78,823	113,800	112,461	142,993
Connecticut	318,909	270,740	212,665	148,317	205,124
Delaware	131,379	121,354	216,346	(a)	148,267
District of Columbia	5,775	3,315	4,615	7,585	15,627
Georgia	660,454	813,068	568,143	558,296	866,922
Idaho	(a)	....	....	....	....
Maine	1,062,283	1,068,485	1,254,529	1,211,743	1,274,474
Maryland	662,466	633,218	603,062	180,199	355,889
Massachusetts	2,071,203	1,997,150	1,932,511	1,805,396	2,477,938
Minnesota	841,943	1,048,816	1,102,493	1,167,873	1,765,308
Missouri	85,625	80,390	58,241	54,523	(a)
Montana	28,829	18,175	25,831	28,894	12,401
New Hampshire	1,234,149	1,141,810	909,700	1,003,328	1,443,204
New Jersey	95,986	71,421	47,372	31,500	57,198
New Mexico	....	(a)	(a)	(a)	....
New York	747,242	368,119	182,515	191,551	94,820
North Carolina	1,246,810	1,798,087	1,486,541	1,155,626	1,542,020
Oklahoma	29,141	80,597	37,071	116,231	64,363
Oregon	7,246	17,080	(a)	(a)	(a)
Pennsylvania	506,360	446,868	290,748	310,050	444,330
Rhode Island	691,765	631,237	477,779	525,052	426,868
South Carolina	319,030	447,570	427,531	599,864	721,215
South Dakota	22,379	(a)	(a)	(a)	(a)
Texas	86,968	84,379	95,867	46,297	103,158
Utah	(a)	(a)	(a)	(a)	....
Vermont	2,778,730	2,598,835	2,850,615	2,689,652	4,031,735
Virginia	869,384	451,697	307,224	336,696	189,564
Washington	260,688	90,525	52,053	65,293	74,958
Wisconsin	1,256,851	1,390,968	1,248,112	962,869	1,634,895
Undistributed	49,175	67,387	60,060	242,054	147,568
	17,864,439	17,456,838	15,544,957	14,466,423	19,345,714

[a] Included under "Undistributed."

Granite sold in the United States in 1918 and 1919.

Use.	1918		1919	
	Quantity.	Value.	Quantity.	Value.
Building stone (rough and dressed)..cubic feet..	2,771,013	$2,349,796	3,651,200	$2,267,875
Approximate equivalent in short tons	232,770	....	303,950	....
Monumental stone..........cubic feet..	3,358,431	6,964,879	3,658,422	10,143,313
Approximate equivalent in short tons	282,000	....	304,890	....
Paving..........number of blocks..	25,923,526	1,547,612	33,601,520	2,369,521
Approximate equivalent in short tons	272,200	....	364,260	....
Curbing and flagging..........cubic feet..	382,000	324,381	618,000	641,726
Approximate equivalent in short tons	33,600	....	50,800	....
Rubble..........short tons..	140,472	151,408	97,635	140,694
Riprap..........do....	624,954	480,666	379,424	373,728
Crushed stone..........do....	2,069,473	2,583,449	2,700,074	3,300,280
Other stone..........do....	171,944	64,232	20,187	108,577
Total (quantities approximate, in short tons)	3,827,400	14,466,423	4,221,220	19,345,714

Granite sold in the United States in 1918.

State.	Building.				Monumental.				Paving blocks.		Curbing and flagging.	
	Rough.		Dressed.		Rough.		Dressed.					
	Quantity (cubic feet).	Value.	Quantity (cubic feet).	Value.	Quantity (cubic feet).	Value.	Quantity (cubic feet).	Value.	Number of blocks.	Value.	Quantity (cubic feet).	Value.
Arizona					(a)	(a)	(a)	(a)				
California	(b)	(b)	b45,549	b$81,421	75,935	$58,937	66,618	$262,912	101,375	$5,142	6,140	$3,336
Colorado					(b)	(b)	b29,683	b112,061				
Connecticut	33,811	$21,319	6,812	27,302	17,853	36,271	5,167	33,733	(a)	(a)	4,556	7,386
Delaware	(a)	(a)										
District of Columbia	(a)	(a)										
Georgia	(b)	(b)	b64,365	b77,525	26,295	26,389	23,585	72,910	511,100	24,622	82,340	67,504
Maine	198,590	58,305	152,485	579,012	56,658	51,846	7,386	19,518	6,573,847	432,075	97,120	46,374
Maryland	(a)	(a)			(a)	(a)			(a)	(a)		
Massachusetts	470,376	163,389	227,797	527,773	c400,475	c436,383	(c)	(c)	4,523,302	284,634	76,162	85,644
Minnesota	(b)	(b)	b29,444	b81,187	83,696	112,923	199,773	903,720	195,334	14,975	(a)	(a)
Missouri					(a)	(a)			236,000	16,435		
Montana			2,970	11,143	(b)	(b)	b2,957	b17,653				
New Hampshire	17,379	8,095	36,825	135,155	143,303	189,604	89,840	393,557	3,980,651	213,688	18,480	28,301
New Jersey												
New Mexico												
New York	c45,254	c15,016	(c)	(c)	(b)	(b)	b2,659	b8,311	1,432,018	75,844		
North Carolina	c9,028	c1,710	(c)	(c)	(b)	(b)	b150,486	b457,117	2,265,206	119,188	81,800	69,820
Oklahoma			(a)	(a)	c14,150	c19,820	(c)	(c)				
Oregon					(a)	(a)	(a)	(a)				
Pennsylvania	c1,148,768	c160,400	(c)	(c)	(a)	(a)	(a)	(a)	(a)	(a)	4,300	4,439
Rhode Island	(b)	(b)	b89,995	b211,307	c112,371	c267,605	(c)	(c)	(a)	(a)	(a)	(a)
South Carolina			(a)	(a)	(a)	(a)			(a)	(a)	(a)	(a)
South Dakota							(a)	(a)				
Texas	(a)	(a)			17,274	21,142	4,300	22,200			(a)	(a)
Utah	(a)	(a)			(a)	(a)						
Vermont			(a)	(a)	1,481,927	2,043,826	81,938	495,437	(a)	(a)		
Virginia	(a)	(a)			(a)	(a)			232,000	11,223	(a)	(a)
Washington			(a)	(a)	c14,461	c21,744	(c)	(c)			(a)	(a)
Wisconsin	(a)	(a)	(a)	(a)	17,151	21,823	84,247	613,745	3,491,040	211,187	(a)	(a)
Undistributed	150,409	31,623	41,156	158,114	133,734	165,474	14,509	78,218	2,381,653	138,599	11,102	11,577
	2,098,543	442,586	672,470	1,907,210	2,655,671	3,408,704	702,760	3,556,175	25,923,526	1,547,612	382,000	324,381
Average value		$0.21		$2.84		$1.28		$5.06		d$59.70		$0.85

a Included under "Undistributed." b Rough stone included under dressed stone. c Dressed stone included under rough stone. d Per M.

Granite sold in the United States in 1918—Continued.

State.	Rubble.		Riprap.		Crushed stone.						Other.		Total value.
					Road metal.		Railroad ballast.		Concrete.				
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	
Arizona			(a)	(a)									$76,287
California			315,445	$166,044	272,730	$142,166	102,089	$51,338	124,889	$66,590	(a)	(a)	838,786
Colorado											(a)	(a)	112,461
Connecticut	(a)	(a)	5,633	4,625	(a)	(a)			(a)	(a)	(a)	(a)	148,317
Delaware			(a)	(a)	(a)	(a)			(a)	(a)			(a)
District of Columbia	(a)	(a)			(a)	(a)			(a)	(a)			7,585
Georgia	13,890	$17,538	2,194	5,106	(a)	(a)	20,663	35,660	138,833	209,728	(a)	(a)	558,296
Maine			(a)	(a)	1,739	2,020	(a)	(a)	14,886	17,983	165	$1,071	1,211,743
Maryland	(a)	(a)	(a)	(a)	(a)	(a)	24,161	46,259	30,427	59,348			180,199
Massachusetts	62,086	72,296	(a)	(a)	44,400	81,400	(a)	(a)	74,586	147,638	(a)	(a)	1,805,396
Minnesota	(a)	(a)	19,225	12,839	(a)	(a)			(a)	(a)			1,167,873
Missouri			(a)	(a)	(a)	(a)			(a)	(a)			54,523
Montana											(a)	(a)	28,894
New Hampshire	3,321	4,828	5,768	4,076	(a)	(a)			8,083	11,274			1,003,328
New Jersey	(a)	(a)	(a)	(a)	(a)	(a)			(a)	(a)			31,500
New Mexico							(a)	(a)					(a)
New York	(a)	(a)	(a)	(a)	35,200	54,260			(a)	(a)	(a)	(a)	191,551
North Carolina	7,508	8,669	5,114	4,209	36,270	55,518	(a)	(a)	252,912	373,289	(a)	(a)	1,155,626
Oklahoma	(a)	(a)	(a)	(a)					(a)	(a)	(a)	(a)	116,231
Oregon													(a)
Pennsylvania	(a)	(a)	(a)	(a)	6,506	12,035	2,099	3,943	5,727	9,478	(a)	(a)	310,050
Rhode Island	(a)	(a)	(a)	(a)	14,640	22,656			500	650	(a)	(a)	525,052
South Carolina	(a)	(a)	(a)	(a)	(a)	(a)			166,348	304,197	(a)	(a)	599,864
South Dakota													(a)
Texas			(a)	(a)									46,297
Utah													(a)
Vermont			(a)	(a)					(a)	(a)			2,689,652
Virginia	(a)	(a)	18,555	31,832	99,058	142,016	59,550	53,050	62,462	82,684			336,696
Washington			(a)	(a)									65,293
Wisconsin	23,104	13,960	(a)	(a)	(a)	(a)			76,996	76,713	(a)	(a)	962,869
Undistributed	30,563	34,117	253,020	251,935	166,749	287,649	163,338	139,972	63,632	93,935	171,779	63,161	242,054
	140,472	151,408	624,954	480,666	677,292	799,720	371,900	330,222	1,020,281	1,453,507	171,944	64,232	14,466,423
Average value		$1.08		$0.77		$1.18		$0.89		$1.42		$0.37	

a Included under "Undistributed."

Granite sold in the United States in 1919.

State.	Number of plants.	Building. Rough. Quantity (cubic feet).	Building. Rough. Value.	Building. Dressed. Quantity (cubic feet).	Building. Dressed. Value.	Monumental. Rough. Quantity (cubic feet).	Monumental. Rough. Value.	Monumental. Dressed. Quantity (cubic feet).	Monumental. Dressed. Value.	Paving blocks. Number of blocks.	Paving blocks. Value.	Curbing and flagging. Quantity (linear feet).	Curbing and flagging. Value.
Arizona	5							(a)	(a)				
Arkansas	3			(a)	(a)	(a)	(a)						
California	40	35,860	$76,418	27,639	$129,065	34,383	$55,757	21,865	$168,333	(a)	(a)	6,218	$5,896
Colorado	10	(a)	(a)			(b)	(b)	b 29,671	b 133,410				
Connecticut	14	17,335	7,332	3,270	12,900	25,765	60,371	2,118	19,058	243,239	$23,422	15,750	8,438
Delaware	3	c 311,587	c 69,403	(c)	(c)							(a)	(a)
District of Columbia	3	(a)	(a)										
Georgia	19	33,411	22,410	24,200	139,586	49,261	59,833	7,150	25,120	2,669,600	153,553	360,478	205,572
Maine	44	243,696	142,301	48,599	223,863	75,503	90,141	60,688	172,396	8,331,436	547,128	64,956	57,980
Maryland	9	c 166,148	c 49,634	(c)	(c)	c 25,150	c 34,765	(c)	(c)	(a)	(a)		
Massachusetts	45	239,965	212,294	86,075	254,176	495,012	741,039	11,546	104,781	6,122,089	513,422	196,980	175,710
Minnesota	31			(a)	(a)	135,706	326,820	226,538	1,352,887	200,000	16,000		
Missouri	2					(a)	(a)			(a)	(a)		
Montana	3	(a)	(a)	(a)	(a)	(b)	(b)	b 3,117	b 8,176			(a)	(a)
New Hampshire	24	95,351	78,858	71,141	347,897	181,892	208,840	83,463	397,975	4,510,958	287,718	46,887	79,378
New Jersey	3	(a)	(a)										
New York	6	c 19,794	c 8,673	(c)	(c)	c 1,928	c 6,703	(c)	(c)	(a)	(a)		
North Carolina	20	12,766	17,800	17,785	67,005	79,146	83,219	35,596	288,454	2,269,004	146,780	105,326	91,228
Oklahoma	5	(a)	(a)	(a)	(a)	(b)	(b)	b 15,950	b 62,463				
Oregon	2							(a)	(a)				
Pennsylvania	33	c 2,060,742	c 253,814	(c)	(c)	30,802	47,393			868,705	82,069	(a)	(a)
Rhode Island	10	(b)	(b)	b 4,715	b 12,235	c 121,058	c 322,686	(c)	(c)	(a)	(a)		
South Carolina	10			(a)	(a)	c 136,050	c 194,580	(c)	(c)			(a)	(a)
South Dakota	1							(a)	(a)				
Texas	8	18,521	27,188			19,135	31,140						
Vermont	29	(b)	(b)	b 31,891	b 54,950	1,480,903	3,227,888	90,209	744,234	41,500	2,800	(a)	(a)
Virginia	5	(a)	(a)			(a)	(a)					(a)	(a)
Washington	6	(b)	(b)	b 3,510	b 16,180	10,786	13,743	8,975	36,238				
Wisconsin	15					32,250	54,032	101,762	942,880	6,855,718	491,286	(a)	(a)
Undistributed		72,561	27,668	4,638	16,225	15,344	38,222	9,700	89,736	1,489,271	105,343	26,372	17,524
	408	3,338,367	1,000,338	312,833	1,267,537	2,975,894	5,625,657	682,528	4,517,656	33,601,520	2,369,521	822,967	641,726
Average value			$0.30		$4.05		$1.89		$6.62		d $70.52		$0.78

a Included under "Undistributed." b Rough stone included under dressed stone. c Dressed stone included under rough stone. d Per M.

Granite sold in the United States in 1919—Continued.

State.	Number of plants.	Rubble.		Riprap.		Crushed stone.				Other.		Total.	
						Road metal and concrete.		Railroad ballast.					
		Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (approximate short tons).	Value.
Arizona	5					(a)	(a)	(a)	(a)			323,800	$155,889
Arkansas	3			(a)	(a)	(a)	(a)					6,770	13,270
California	40	(a)	(a)	162,818	$79,053	524,999	$354,481	(a)	(a)	(a)	(a)	852,080	935,716
Colorado	10									(a)	(a)	2,800	142,993
Connecticut	14	(a)	(a)	10,293	12,013	(a)	(a)			(a)	(a)	52,730	205,124
Delaware	3			(a)	(a)	(a)	(a)			(a)	(a)	88,730	148,267
District of Columbia	3	(a)	(a)									5,700	15,627
Georgia	19	30,317	$39,565	(a)	(a)	63,710	132,577	41,845	$73,706	(a)	(a)	209,560	866,922
Maine	44	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	1,351	$10,402	149,820	1,274,474
Maryland	9	(a)	(a)	(a)	(a)	42,433	99,644	51,047	98,284	(a)	(a)	138,360	355,889
Massachusetts	45	17,393	24,511	(a)	(a)	208,996	439,604	(a)	(a)			383,760	2,477,938
Minnesota	31	(a)	(a)	3,658	3,984	38,926	53,893					75,590	1,765,308
Missouri	2			(a)	(a)	(a)	(a)					(a)	(a)
Montana	3											570	12,401
New Hampshire	24			(a)	(a)	12,644	25,193	(a)	(a)	(a)	(a)	104,690	1,443,204
New Jersey	3			(a)	(a)	19,375	34,875					33,740	57,198
New York	6					21,836	24,459	(a)	(a)	(a)	(a)	49,670	94,820
North Carolina	20	(a)	(a)	7,900	4,200	400,675	701,029	(a)	(a)	(a)	(a)	547,350	1,542,020
Oklahoma	5			(a)	(a)					(a)	(a)	2,900	64,363
Oregon	2											(a)	(a)
Pennsylvania	33	1,396	4,176	(a)	(a)	29,527	45,714	(a)	(a)			215,670	444,330
Rhode Island	10	(a)	(a)			25,922	67,427					40,509	426,868
South Carolina	10	9,235	13,444	(a)	(a)	377,661	499,572			(a)	(a)	403,780	721,215
South Dakota	1											(a)	(a)
Texas	8			(a)	(a)							50,990	103,158
Vermont	29					(a)	(a)					133,630	4,031,735
Virginia	5	(a)	(a)	(a)	(a)	71,934	98,215	(a)	(a)			100,760	189,564
Washington	6	(a)	(a)							(a)	(a)	8,450	74,958
Wisconsin	15	5,628	4,146	27,342	13,162	113,070	123,631			(a)	(a)	229,800	1,634,895
Undistributed		33,666	54,852	167,413	261,316	171,366	154,341	484,109	273,635	18,836	98,175	9,020	147,568
	408	97,635	140,694	379,424	373,728	2,123,073	2,854,655	577,001	445,625	20,187	108,577	4,221,220	19,345,714
Average value			$1.44		$0.98		$1.34		$0.77		$5.38		$4.58

[a] Included under "Undistributed."

BASALT AND RELATED ROCKS (TRAP ROCK).

Value of basalt and related rocks (trap rock) sold in the United States, 1915–1919.

State.	1915	1916	1917	1918	1919
Arkansas	$147,442	$185,360	(a)	(a)	(b)
California	1,136,589	938,140	$1,150,248	$1,005,112	$922,979
Colorado	(a)	(a)	(a)	(a)	....
Connecticut	698,744	788,661	974,320	848,442	1,226,943
Hawaii	195,500	381,771	483,453	466,093	250,538
Idaho	....	(a)	....	(a)	(a)
Maryland	(c)	(c)	(c)	425,817	496,760
Massachusetts	632,989	647,044	535,437	610,161	787,333
Michigan	105,855	83,072	70,197	53,269	(a)
Minnesota	80,640	130,863	141,380	(a)	137,490
New Jersey	1,281,545	1,293,217	1,372,956	1,475,358	1,916,694
New York	762,370	956,100	684,550	621,750	619,799
Oregon	739,380	303,909	327,770	160,586	630,540
Pennsylvania	1,101,778	1,041,203	1,178,664	1,355,332	1,497,526
Texas	(a)	(a)	(a)	(a)	(a)
Virginia	(c)	(c)	(c)	(c)	(a)
Washington	1,452,869	754,831	328,331	154,205	252,435
Wisconsin	(a)	(a)	(a)	(a)	(a)
Undistributed	153,521	162,126	323,579	606,155	205,649
	8,489,222	7,666,297	7,570,885	7,782,280	8,944,686

a Included under "Undistributed."
b Included under Miscellaneous varieties of stone.
c Included under Granite.

Basalt and related rocks (trap rock) sold in 1918 and 1919.

Use.	1918		1919	
	Quantity.	Value.	Quantity.	Value.
Building stone ... cubic feet	165,377	$10,808	366,754	$27,403
Approximate equivalent in short tons	14,880	....	29,900	....
Paving blocks ... number	404,965	18,308	140,875	4,110
Approximate equivalent in short tons	4,550	....	1,550	....
Rubble ... short tons	130,544	267,160	79,952	91,348
Riprap ... do	119,426	116,050	231,780	285,633
Crushed stone ... do	6,556,888	7,306,168	7,052,876	8,481,608
Other ... do	32,946	63,786	14,712	54,584
Total (quantities approximate, in short tons)	6,859,200	7,782,280	7,410,770	8,944,686

Basalt and related rocks (trap rock) sold in the United States in 1918.

State.	Building. Quantity (cubic feet).	Building. Value.	Riprap and rubble. Quantity (short tons).	Riprap and rubble. Value.	Paving blocks. Number of blocks.	Paving blocks. Value.	Crushed stone. Road metal. Quantity (short tons).	Crushed stone. Road metal. Value.
Arkansas	....	....	....	....	....	....	(a)	(a)
California	(a)	(a)	18,738	$16,558	(a)	(a)	380,059	$267,543
Colorado	....	....	....	....	....	....	....	....
Connecticut	96,305	$4,834	(a)	(a)	....	....	336,806	320,403
Hawaii	....	....	(a)	(a)	....	....	(a)	(a)
Idaho	....	....	....	....	....	....	(a)	(a)
Maryland	....	....	(a)	(a)	....	....	62,055	88 918
Massachusetts	(a)	(a)	(a)	(a)	....	....	364,409	453,363
Michigan	....	....	....	....	....	....	23,686	32,605
Minnesota	(a)	(a)	(a)	(a)	....	....	(a)	(a)
New Jersey	(a)	(a)	....	....	(a)	(a)	419,063	591,997
New York	....	....	....	....	....	....	215,500	279 000
Oregon	....	....	(a)	(a)	....	....	62,056	62,701
Pennsylvania	29,522	4,240	7,359	9,718	(a)	(a)	346,911	453,671
Texas	....	....	(a)	(a)	....	....	(a)	(a)
Washington	....	....	98,622	90,347	(a)	(a)	29,427	29,653
Wisconsin	....	....	(a)	(a)	....	....	(a)	(a)
Undistributed	39,550	1,734	125,251	266,587	404,965	$18,308	244,868	302,420
	165,377	10,808	249,970	383,210	404,965	18,308	2,484,840	2,882,274
Average value	....	$0.07	....	$1.53	....	[b] $45.21	....	$1.16

State.	Crushed stone—Continued. Railroad ballast. Quantity (short tons).	Crushed stone—Continued. Railroad ballast. Value.	Crushed stone—Continued. Concrete. Quantity (short tons).	Crushed stone—Continued. Concrete. Value.	Other. Quantity (short tons).	Other. Value.	Total value.
Arkansas	(a)	(a)	(a)	(a)	....	....	(a)
California	73,147	$56,950	887,964	$652,781	....	....	$1,005,112
Colorado	(a)	(a)	(a)	(a)	....	....	(a)
Connecticut	91,898	93,504	450,718	428,705	(a)	(a)	848,442
Hawaii	....	....	97,753	140,836	....	....	466,093
Idaho	....	....	(a)	(a)	....	....	(a)
Maryland	(a)	(a)	214,239	279,566	....	....	425,817
Massachusetts	(a)	(a)	136,778	153,026	(a)	(a)	610,161
Michigan	....	....	(a)	(a)	(a)	(a)	53,269
Minnesota	....	....	(a)	(a)	....	....	(a)
New Jersey	233,517	282,402	375,440	573,718	13,249	$26,498	1,475,358
New York	54,250	60,500	(a)	(a)	....	....	621,750
Oregon	(a)	(a)	80,073	77,969	(a)	(a)	160,586
Pennsylvania	426,030	467,666	326,862	402,742	12,000	16,996	1,355,332
Texas	(a)	(a)	(a)	(a)	(a)	(a)	(a)
Washington	(a)	(a)	26,969	23,779	(a)	(a)	154,205
Wisconsin	....	....	....	....	....	....	(a)
Undistributed	144,598	143,025	451,812	586,725	7,697	20,292	606,155
	1,023,440	1,104,047	3,048,608	3,319,847	32,946	63,786	7,782,280
Average value	....	$1.08	....	$1.09	....	$1.94	....

[a] Included under "Undistributed."
[b] Per M.

Basalt and related rocks (trap rock) sold in the United States in 1919.

State.	Number of plants.	Building.		Paving blocks.		Riprap and rubble.		Crushed stone.				Other.		Total.	
								Concrete and road metal.		Railroad ballast.					
		Quantity (cubic feet).	Value.	Number of blocks.	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (approximate short tons).	Value.
California	26			(a)	(a)	(a)	(a)	1,181,946	$867,190	61,322	$43,681			1,269,980	$922,979
Connecticut	19	267,132	$17,227					1,130,649	1,155,688	49,074	54,028			1,203,760	1,226,943
Hawaii	5					70,625	$79,902	(a)	(a)			(a)	(a)	183,730	250,538
Idaho	1							(a)	(a)					(a)	(a)
Maryland	10	(a)	(a)					203,939	321,056	(a)	(a)			342,590	496,760
Massachusetts	17	(a)	(a)			(a)	(a)	542,585	752,511	33,290	33,009			577,060	787,333
Michigan	1							(a)	(a)			(a)	(a)	(a)	(a)
Minnesota	3					(a)	(a)	138,240	134,165			(a)	(a)	142,250	137,490
New Jersey	39			(a)	(a)	5,573	9,601	1,002,166	1,695,649	185,814	208,635			1,194,790	1,916,694
New York	4							512,810	602,599	(a)	(a)			527,910	619,799
Oregon	29					(a)	(a)	345,416	457,729	(a)	(a)			486,570	630,540
Pennsylvania	31	(a)	(a)			12,425	18,089	673,738	927,047	445,799	546,975			1,134,400	1,497,526
Texas	1					(a)	(a)	(a)	(a)	(a)	(a)				(a)
Virginia	1							(a)	(a)						(a)
Washington	10			(a)	(a)	94,093	109,190	116,404	142,544					210,680	252,435
Wisconsin	2							(a)	(a)			(a)	(a)	(a)	(a)
Undistributed		99,622	10,176	140,875	$4,110	129,016	160,199	231,204	319,743	198,480	219,359	14,712	$54,584	137,050	205,649
	199	366,754	27,403	140,875	4,110	311,732	376,981	6,079,097	7,375,921	973,779	1,105,687	14,712	54,584	7,410,770	8,944,686
Average value			$0.07		[b] $29.17		$1.21		$1.21		$1.14		$3.71		$1.21

a Included under "Undistributed."

b Per M.

MARBLE.

Value of marble sold in the United States, 1915–1919.

State.	1915	1916	1917	1918	1919
Alabama	(a)	(a)	(a)	b $319,040	b $395,195
Alaska	(a)	(a)	(a)	b 80,059	(a)
Arkansas	(a)	(a)	(a)	(b)	(b)
California	$47,976	$62,397	$109,504	50,776	66,670
Colorado	(a)	(a)	(a)	....	....
Georgia	973,605	903,343	1,073,783	1,152,444	1,574,687
Kentucky	(a)	....	....	....	....
Maryland	(a)	(c)	(c)	b 44,499	b 38,328
Massachusetts	223,203	154,090	118,808	93,433	123,978
Michigan	....	....	....	....	(a)
Missouri	122,238	156,942	227,520	238,111	360,287
Nevada	....	....	....	....	(a)
New Mexico	(a)	(a)	(a)	(b)	(b)
New York	202,843	268,391	249,180	135,756	250,244
North Carolina	(a)	(a)	(a)	b 31,779	....
Oregon	(a)	....	....	(b)	....
Pennsylvania	60,819	c 107,212	c 36,442	(b)	(b)
South Carolina	(a)	(a)	....	(b)	....
Tennessee	959,037	1,000,266	884,684	599,096	1,069,333
Texas	(a)	(a)	(a)	(b)	(b)
Utah	(a)	(a)	(a)	(b)	....
Vermont	2,792,764	3,062,743	3,024,315	2,751,396	4,083,866
Virginia	(a)	....	(a)	(b)	....
Washington	....	(a)	(a)	(b)	....
Undistributed	1,533,540	1,317,787	606,151	....	79,709
	6,916,025	7,033,171	6,330,387	5,496,389	8,042,297

a Included under "Undistributed."
b Alabama includes Arkansas, New Mexico, and Texas; Alaska includes Oregon, Utah, and Washington; Maryland includes Pennsylvania; North Carolina includes South Carolina and Virginia.
c Pennsylvania includes Maryland.

Marble sold in the United States in 1918 and 1919.

Use.	1918			1919		
	Quantity.	Value.	Average value.	Quantity.	Value.	Average value.
Building stone:						
Rough—						
Exterior .... cubic feet..	178,090	$274,704	$1.54	209,582	$282,593	$1.35
Interior .... do....	375,651	679,975	1.81	542,802	1,127,892	2.08
Dressed—						
Exterior .... do....	151,490	394,349	2.60	83,974	371,196	4.42
Interior .... do....	174,866	903,234	5.16	163,586	1,103,294	6.74
Total exterior .... do....	329,580	669,053	2.03	293,556	653,789	2.23
Total interior .... do....	550,517	1,583,209	2.88	706,388	2,231,186	3.16
Total building stone ...... do....	880,097	2,252,262	2.56	999,944	2,884,975	2.89
Monumental stone:						
Rough .... do....	349,823	1,126,259	3.22	554,940	1,621,452	2.92
Dressed .... do....	364,089	1,821,029	5.00	546,633	3,277,604	6.00
Total monumental stone..do....	713,912	2,947,288	4.13	1,101,573	4,899,056	4.45
Total building and monumental .... cubic feet..	1,594,009	5,199,550	3.26	2,101,517	7,784,031	3.70
Marble for other uses ...... short tons..	169,432	296,839	1.75	153,719	258,266	1.68
Total marble sold: Cubic feet a..	3,575,670	5,496,389	1.54	3,899,420	8,042,297	2.06
Short tons a..	305,720	....	17.98	333,400	....	24.12

a Approximately.

SERPENTINE.

Serpentine (verde antique) sold in the United States in 1918 and 1919.

	1918		1919	
	Quantity.	Value.	Quantity.	Value.
Cubic feet	19,154	$117,632	32,650	$118,395
Short tons	9,509	17,506	15,740	28,359
		135,138		146,754

LIMESTONE.

Value of limestone sold in the United States, 1915–1919.

State.	1915	1916	1917	1918	1919
Alabama	$426,266	$917,559	$1,278,908	$1,370,667	$1,090,065
Arizona	9,800	98,877	140,674	150,850	140,846
Arkansas	32,917	64,809	84,654	89,640	(a)
California	338,179	277,521	364,066	366,826	409,082
Colorado	337,899	406,974	532,539	570,649	532,973
Connecticut	26,246	(a)	(a)	(a)	(a)
Florida	354,673	479,837	494,568	256,807	133,747
Georgia	86,254	82,799	155,172	192,515	213,968
Hawaii	(a)	(a)		(a)	
Idaho	(a)	27,721	37,942	21,377	155,716
Illinois	2,864,103	3,362,751	3,279,737	2,951,045	3,735,401
Indiana	4,204,092	4,657,813	4,449,809	2,819,083	4,945,903
Iowa	535,656	561,015	519,933	379,029	508,606
Kansas	535,240	599,995	673,706	561,012	860,851
Kentucky	993,388	1,315,702	1,022,317	932,667	1,357,618
Louisiana	(a)	(a)	(a)	(a)	(a)
Maine			(a)	(a)	52,856
Maryland	180,723	223,182	307,679	274,907	397,905
Massachusetts	(a)	(a)	68,392	92,804	269,718
Michigan	1,828,766	2,389,763	3,320,895	5,186,867	3,797,522
Minnesota	395,763	467,942	385,728	310,583	379,852
Mississippi			(a)	(a)	(a)
Missouri	1,927,534	1,990,419	1,679,677	1,359,755	1,759,029
Montana	228,637	237,923	224,986	246,650	159,079
Nebraska	320,341	405,867	475,507	314,280	280,602
Nevada			31,625	95,821	(a)
New Jersey	159,549	245,019	413,477	674,397	506,193
New Mexico	(a)	(a)	(a)	(a)	(a)
New York	3,018,871	3,035,786	3,513,874	3,918,982	4,406,721
North Carolina	82,672	75,418	109,719	58,055	133,198
Ohio	4,405,590	5,337,085	5,400,578	6,960,205	6,415,233
Oklahoma	398,636	516,230	575,165	574,795	656,843
Oregon	(a)	(a)	4,939	(a)	68,013
Pennsylvania	6,367,446	8,167,639	10,589,524	12,302,255	12,640,411
Porto Rico	(b)	(b)	(b)	(b)	101,186
Rhode Island	(a)	(a)	(a)	(a)	(a)
South Carolina	(a)				
South Dakota	17,485	19,435	46,130	18,825	23,989
Tennessee	855,245	752,649	750,639	893,763	689,597
Texas	492,255	459,918	485,389	464,061	453,113
Utah	196,271	249,998	242,707	341,804	329,150
Vermont	49,405	68,098	45,869	64,847	103,858
Virginia	1,534,545	1,062,247	1,263,284	1,230,412	1,454,989
Washington	11,550	30,338	59,529	99,992	45,957
West Virginia	922,766	1,452,393	1,788,528	1,958,785	2,228,209
Wisconsin	894,158	1,089,111	1,172,567	1,065,678	1,246,837
Wyoming	(a)	(a)	130,497	155,792	185,909
Undistributed	196,945	179,766	142,450	126,524	300,956
	35,229,866	41,309,599	46,263,379	49,453,006	53,171,701

a Included under "Undistributed."
b Statistics not collected.

Limestone sold in the United States in 1918 and 1919.

Use.	1918		1919	
	Quantity.	Value.	Quantity.	Value.
Building stone.....cubic feet..	3,698,035	$2,266,654	5,477,220	$4,258,336
Approximate equivalent in short tons.....	310,640	....	393,650	....
Curbing, flagging, and paving.....cubic feet..	37,698	37,836	77,238	44,498
Approximate equivalent in short tons.....	3,170	....	6,560	....
Rubble.....short tons..	106,327	109,369	328,295	430,113
Riprap.....do..	1,118,109	969,276	833,622	908,595
Crushed stone.....do..	19,120,858	16,273,184	21,761,946	21,709,206
Fluxing stone.....long tons..	23,862,029	23,427,736	18,928,886	19,271,674
Equivalent in short tons.....	26,725,472	....	21,200,350	....
Alkali works.....short tons..	3,437,066	2,263,821	2,215,660	1,539,899
Sugar factories.....do..	435,555	649,589	503,835	821,912
Glass works.....do..	202,211	332,744	166,106	278,467
Paper mills.....do..	100,247	117,829	92,421	129,649
Agriculture.....do..	1,091,918	1,626,292	1,392,914	2,409,460
Other uses [a].....do..	1,216,633	1,378,676	864,441	1,369,892
Total (quantities approximate, in short tons)....	53,868,200	49,453,006	49,759,800	53,171,701

[a] Includes stone sold as a filler for asphalt, paint, rubber, soap, and other material; stone sold for the manufacture of basic magnesium carbonate; stone sold to alcohol works and calcium carbide works; dolomite sold for use in making refractory products; stone sold for chicken grit and other products.

Limestone sold in the United States in 1918.

State.	Building.				Paving, curbing, and flagging.	
	Rough.		Dressed.			
	Quantity (cubic feet).	Value.	Quantity (cubic feet).	Value.	Quantity (cubic feet).	Value.
Alabama	(a)	(a)				
Arizona						
Arkansas						
California						
Colorado						
Connecticut						
Florida						
Georgia						
Hawaii						
Idaho						
Illinois	(a)	(a)	(a)	(a)		
Indiana	1,639,443	$618,281	1,063,802	$1,203,377	(a)	(a)
Iowa	b 45,711	b 22,749	(b)	(b)		
Kansas	b 113,497	b 20,279	(b)	(b)		
Kentucky	b 137,234	b 60,520	(b)	(b)	(a)	(a)
Louisiana						
Maine						
Maryland						
Massachusetts						
Michigan	(a)	(a)				
Minnesota	74,078	25,184	39,450	77,948		
Mississippi						
Missouri	169,903	108,114	17,788	35,760	2,243	$1,138
Montana						
Nebraska						
Nevada						
New Jersey						
New Mexico						
New York			(a)	(a)		
North Carolina						
Ohio						
Oklahoma	(a)	(a)				
Oregon						
Pennsylvania	303,343	37,054				
Rhode Island						
South Dakota						
Tennessee	(a)	(a)				
Texas	(a)	(a)				
Utah						
Vermont						
Virginia						
Washington						
West Virginia						
Wisconsin	b 5,841	b 616	(b)	(b)	28,239	30,740
Wyoming						
Undistributed	84,945	55,622	3,000	1,150	7,216	5,958
	2,561,600	943,735	1,136,435	1,322,919	37,698	37,836

a Included under "Undistributed."
b Dressed stone included under rough stone.

Limestone sold in the United States in 1918—Continued.

State.	Rubble.		Riprap.		Crushed stone. Road metal.	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
Alabama			(a)	(a)	(a)	(a)
Arizona						
Arkansas			(a)	(a)	(a)	(a)
California					(a)	(a)
Colorado						
Connecticut						
Florida			(a)	(a)	19,646	$16,356
Georgia					(a)	(a)
Hawaii						
Idaho	(a)	(a)				
Illinois	7,215	$6,503	189,831	$171,504	748,592	489,360
Indiana	2,427	3,963	71,538	42,219	498,901	397,964
Iowa	1,908	1,842	81,314	70,037	50,258	51,729
Kansas	11,885	5,342	36,386	25,246	15,447	15,361
Kentucky	2,310	3,375	32,808	33,280	315,573	355,814
Louisiana						
Maine						
Maryland					60,261	100,579
Massachusetts						
Michigan	(a)	(a)	(a)	(a)	591,781	251,265
Minnesota	6,450	5,280	37,499	24,693	(a)	(a)
Mississippi						
Missouri	18,801	22,993	301,069	249,776	158,759	184,368
Montana	(a)	(a)	(a)	(a)	20,486	18,465
Nebraska	(a)	(a)	64,760	61,125	(a)	(a)
Nevada						
New Jersey			(a)	(a)	12,690	18,532
New Mexico						
New York	19,671	18,123	(a)	(a)	640,566	552,285
North Carolina						
Ohio	8,048	9,505	7,843	6,122	1,628,823	1,350,653
Oklahoma	2,111	2,720	20,888	12,681	22,097	24,483
Oregon						
Pennsylvania	1,743	1,792	(a)	(a)	284,813	381,928
Rhode Island						
South Dakota			(a)	(a)		
Tennessee			(a)	(a)	309,041	243,774
Texas	(a)	(a)	7,170	6,875	107,945	65,425
Utah			(a)	(a)	(a)	(a)
Vermont	(a)	(a)	(a)	(a)	2,625	3,997
Virginia	(a)	(a)			103,193	105,996
Washington						
West Virginia					101,462	135,270
Wisconsin	15,419	22,826	126,543	142,514	267,012	264,502
Wyoming						
Undistributed	8,339	5,105	140,460	123,204	125,366	149,395
	106,327	109,369	1,118,109	969,276	6,085,337	5,177,501

a Included under "Undistributed."

Limestone sold in the United States in 1918—Continued.

State.	Crushed stone—Continued.				Flux.	
	Railroad ballast.		Concrete.			
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (long tons).	Value.
Alabama			21,749	$23,548	876,124	$1,060,121
Arizona			(a)	(a)	154,579	146,273
Arkansas	(a)	(a)				
California	(a)	(a)	(a)	(a)	57,973	111,924
Colorado					483,066	422,638
Connecticut			(a)	(a)	(a)	(a)
Florida	(a)	(a)	53,745	54,176		
Georgia			19,461	28,222	(a)	(a)
Hawaii						
Idaho					(a)	(a)
Illinois	717,520	$457,144	1,335,978	964,140	1,015,716	614,958
Indiana	128,316	65,187	145,889	109,304	336,600	209,993
Iowa	(a)	(a)	211,404	192,869	13,172	14,238
Kansas	94,801	87,733	278,379	279,467		
Kentucky	527,454	371,085	78,243	73,330	7,924	7,019
Louisiana			(a)	(a)		
Maine						
Maryland	18,519	21,374	22,781	43,452	119,444	103,969
Massachusetts					(a)	(a)
Michigan	(a)	(a)	389,176	261,877	4,289,289	2,892,179
Minnesota	(a)	(a)	143,041	159,213	(a)	(a)
Mississippi						
Missouri	155,110	110,494	317,844	354,782	89,151	124,988
Montana	(a)	(a)	(a)	(a)	327,800	214,869
Nebraska	(a)	(a)	180,802	218,771	(a)	(a)
Nevada					(a)	(a)
New Jersey			(a)	(a)	481,642	602,546
New Mexico			(a)	(a)		
New York	703,524	710,552	929,566	1,358,690	481,043	425,466
North Carolina			(a)	(a)	(a)	(a)
Ohio	1,129,747	684,192	1,213,899	872,166	3,917,828	3,357,065
Oklahoma	409,145	334,050	201,316	198,611		
Oregon					(a)	(a)
Pennsylvania	86,737	74,361	434,573	550,611	8,689,007	10,473,227
Rhode Island					(a)	(a)
South Dakota			(a)	(a)		
Tennessee	327,962	130,528	308,051	265,291	167,283	139,853
Texas	27,522	15,014	305,247	250,225	89,095	86,663
Utah			(a)	(a)	215,849	168,379
Vermont			12,558	20,608	(a)	(a)
Virginia	521,961	403,377	310,222	326,709	375,824	338,653
Washington					67,418	76,741
West Virginia	137,361	92,686	75,832	96,032	1,392,158	1,595,368
Wisconsin	29,704	19,841	440,287	402,642	140,638	154,151
Wyoming						
Undistributed	494,528	324,064	95,567	89,265	73,406	86,455
	5,509,911	3,901,682	7,525,610	7,194,001	23,862,029	23,427,736

[a] Included under "Undistributed."

Limestone sold in the United States in 1918—Continued.

State.	Sugar factories.		Glass works.		Paper mills.	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
Alabama						
Arizona						
Arkansas						
California	43,561	$63,023	(a)	(a)		
Colorado	77,751	147,798				
Connecticut						
Florida						
Georgia					(a)	(a)
Hawaii	(a)	(a)				
Idaho	(a)	(a)				
Illinois			(a)	(a)		
Indiana	19,032	24,012	27,303	$37,598		
Iowa	4,173	5,842				
Kansas						
Kentucky						
Louisiana						
Maine					(a)	(a)
Maryland						
Massachusetts						
Michigan	(a)	(a)			27,309	$25,153
Minnesota	(a)	(a)				
Mississippi						
Missouri	(a)	(a)	39,474	59,237	(a)	(a)
Montana	(a)	(a)				
Nebraska	(a)	(a)				
Nevada	(a)	(a)				
New Jersey						
New Mexico	(a)	(a)				
New York			(a)	(a)	15,734	18,920
North Carolina						
Ohio	(a)	(a)	45,544	66,713		
Oklahoma						
Oregon						
Pennsylvania			51,185	93,653	29,404	36,670
Rhode Island						
South Dakota	(a)	(a)				
Tennessee						
Texas			(a)	(a)		
Utah	(a)	(a)				
Vermont					(a)	(a)
Virginia					(a)	(a)
Washington	(a)	(a)			(a)	(a)
West Virginia			(a)	(a)		
Wisconsin					(a)	(a)
Wyoming	89,947	155,792				
Undistributed	201,091	253,122	38,705	75,543	27,800	37,086
	435,555	649,589	202,211	332,744	100,247	117,829

[a] Included under "Undistributed."

Limestone sold in the United States in 1918—Continued.

State.	Agriculture.		Other.		Total value.
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	
Alabama	6,241	$8,266	150,200	$230,047	$1,370,667
Arizona					150,850
Arkansas	(a)	(a)			89,640
California	26,077	77,866	33,684	79,694	366,826
Colorado			(a)	(a)	570,649
Connecticut	(a)	(a)	(a)	(a)	(a)
Florida	7,501	14,942	(a)	(a)	256,807
Georgia	36,690	78,492	(a)	(a)	192,515
Hawaii					(a)
Idaho					21,377
Illinois	209,521	185,176	64,026	48,118	2,951,045
Indiana	71,122	64,317	25,640	37,082	2,819,083
Iowa	34,489	19,273			379,029
Kansas			111,317	127,584	561,012
Kentucky	12,959	26,603	1,604	1,469	932,667
Louisiana	(a)	(a)			(a)
Maine					(a)
Maryland	(a)	(a)	(a)	(a)	274,907
Massachusetts	(a)	(a)			92,804
Michigan	160,016	150,604	2,607,546	1,401,900	5,186,867
Minnesota	2,377	2,989	(a)	(a)	310,583
Mississippi	(a)	(a)			(a)
Missouri	5,263	7,211	28,464	91,531	1,359,755
Montana					246,650
Nebraska			(a)	(a)	314,280
Nevada			(a)	(a)	95,821
New Jersey	57,792	51,560			674,397
New Mexico					(a)
New York	58,730	123,774	734,991	699,141	3,918,982
North Carolina	32,365	37,889			58,055
Ohio	61,502	114,726	551,505	496,450	6,960,205
Oklahoma	(a)	(a)	(a)	(a)	574,795
Oregon	(a)	(a)			(a)
Pennsylvania	131,061	325,982	258,562	326,284	12,302,255
Rhode Island					(a)
South Dakota					18,825
Tennessee	63,669	94,399			893,763
Texas	(a)	(a)	(a)	(a)	464,061
Utah			7,544	3,311	341,804
Vermont	12,831	32,542			64,847
Virginia	26,136	38,252	14,812	15,373	1,230,412
Washington	641	2,052	102	430	99,992
West Virginia	2,949	7,974	3,166	1,455	1,958,785
Wisconsin	5,759	8,489	21,053	11,638	1,065,678
Wyoming					155,792
Undistributed	66,227	152,914	39,483	70,990	126,524
	1,091,918	1,626,292	4,653,699	3,642,497	[b] 49,453,006

[a] Included under "Undistributed."
[b] Value of 53,868,200 short tons.

Limestone sold in the United States in 1919.

State.	Number of plants.	Building.				Paving and curbing.		Rubble.		Riprap.		Crushed stone.			
		Rough.		Dressed.								Concrete and road metal.		Railroad ballast.	
		Quantity (cubic feet).	Value.	Quantity (cubic feet).	Value.	Quantity (cubic feet).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
Alabama	15	(a)	(a)									76,390	$90,880		
Arizona	5									73,177	$65,578	(a)	(a)		
Arkansas	2											(a)	(a)	(a)	(a)
California	20							(a)	(a)	(a)	(a)	21,820	42,927	(a)	(a)
Colorado	16														
Connecticut	2											(a)	(a)		
Florida	5											29,787	34,285	(a)	(a)
Georgia	6											54,755	104,684		
Idaho	6							(a)	(a)			(a)	(a)		
Illinois	49	b 11,912	b $5,802	(b)	(b)			35,897	$44,417	107,126	170,326	3,126,214	2,355,854	541,807	$351,048
Indiana	82	3,390,387	1,865,508	1,403,278	$1,933,610	(a)	(a)	4,531	6,124	25,852	15,517	873,437	749,432	76,741	53,188
Iowa	29	21,825	1,816					6,247	5,849	64,393	77,452	379,874	374,685	(a)	(a)
Kansas	41	b 99,655	b 19,711	(b)	(b)			19,461	16,854	25,214	27,597	414,089	555,228	144,730	119,889
Kentucky	69	b 148,729	b 47,415	(b)	(b)	(a)	(a)	1,637	3,106	26,586	22,997	386,871	579,713	728,398	553,871
Louisiana	1											(a)	(a)		
Maine	4											(a)	(a)		
Maryland	18											148,557	220,755	23,525	28,041
Massachusetts	5														
Michigan	18							(a)	(a)			1,056,570	594,862	(a)	(a)
Minnesota	17	27,476	18,767	41,063	95,446			13,793	14,178	36,814	36,110	152,199	206,624		
Mississippi	1														
Missouri	87	156,918	146,984	13,534	34,799	(a)	(a)	73,789	136,309	258,198	287,789	565,629	871,249	45,366	52,070
Montana	8											35,449	36,445	(a)	(a)
Nebraska	8									37,610	42,818	155,969	219,173		
Nevada	1														
New Jersey	14									(a)	(a)	8,476	12,442		
New Mexico	1											(a)	(a)		
New York	63	b 15,075	b 9,490	(b)	(b)			47,703	42,489	(a)	(a)	1,496,931	2,460,293	722,744	602,287
North Carolina	4											21,583	24,403		
Ohio	107	(a)	(a)					10,246	16,227	5,409	6,379	3,130,638	2,703,788	861,047	578,722
Oklahoma	15							(a)	(a)	52,803	45,928	375,622	425,607	204,388	178,468
Oregon	4											(a)	(a)		
Pennsylvania	241	(a)	(a)					36,771	59,630	4,944	9,488	1,660,402	2,228,902	181,383	185,976

Porto Rico	17											67,000	101,186		
Rhode Island	1														
South Dakota	4							(a)	(a)	(a)	(a)	(a)	(a)		
Tennessee	31											322,150	401,146	152,577	127,986
Texas	13	37,568	18,860			(a)	(a)	(a)	(a)	(a)	(a)	469,669	392,111	(a)	(a)
Utah	11	(a)	(a)							(a)	(a)	(a)	(a)		
Vermont	10	(a)	(a)									17,770	31,719	(a)	(a)
Virginia	43	(a)	(a)			(a)	(a)					384,964	355,324	730,375	677,910
Washington	4														
West Virginia	25											326,411	401,967	131,393	127,954
Wisconsin	61	(a)	(a)			23,959	$16,622	51,924	52,561	45,320	42,608	929,593	976,585	(a)	(a)
Wyoming	8														
Undistributed		109,800	60,128			53,279	27,876	26,296	32,369	70,176	58,008	268,067	334,899	260,586	184,628
	1,192	4,006,620	2,184,891	1,470,600	2,073,445	77,238	44,498	328,295	430,113	833,622	908,595	16,956,886	17,887,168	4,805,060	3,822,038
Average value			$0.55		$1.40		$0.58		$1.31		$1.09		$1.05		$0.80

a Included under "Undistributed."
b Dressed stone included under rough stone.

Limestone sold in the United States in 1919—Continued.

State.	Number of plants.	Flux.		Sugar factories.		Glass works.		Paper mills.		Agriculture.		Other.		Total.	
		Quantity (long tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (approximate short tons).	Value.
Alabama	15	667,342	$914,116							(a)	(a)	(a)	(a)	859,030	$1,090,065
Arizona	5	59,567	55,118											162,000	140,846
Arkansas	2									(a)	(a)			(a)	(a)
California	20	36,953	78,165	44,090	$81,236	(a)	(a)			19,733	$74,311	33,549	$113,127	170,220	409,082
Colorado	16	372,378	380,043	75,762	152,162							(a)	(a)	493,200	532,973
Connecticut	2	(a)	(a)											(a)	(a)
Florida	5									5,780	10,198	(a)	(a)	111,240	133,747
Georgia	6	(a)	(a)							19,763	47,479	11,232	56,292	89,420	213,968
Idaho	6	(a)	(a)	26,180	43,652									100,420	155,716
Illinois	49	667,982	384,283			(a)	(a)			323,663	339,469	67,602	67,962	4,959,420	3,735,401
Indiana	82	154,921	130,796	13,182	15,613	35,685	$53,528			68,480	76,818	12,990	20,822	1,634,950	4,945,903
Iowa	29	(a)	(a)	(a)	(a)					46,452	31,354	(a)	(a)	513,030	508,606
Kansas	41									(a)	(a)	(a)	(a)	680,400	860,851
Kentucky	69	15,646	18,513							31,467	59,147	(a)	(a)	1,200,610	1,357,618
Louisiana	1													(a)	(a)
Maine	4							10,475	$22,903	(a)	(a)			23,230	52,856
Maryland	18	155, 836	137,615					(a)	(a)	(a)	(a)			352,450	397,905
Massachusetts	5	(a)	(a)							(a)	(a)	(a)	(a)	53,560	269,718
Michigan	18	3,585,440	1,857,686	(a)	(a)			41,458	45,706	(a)	(a)	1,578,494	891,491	7,186,760	3,797,522
Minnesota	17	(a)	(a)	(a)	(a)					(a)	(a)	(a)	(a)	215,490	379,852
Mississippi	1									(a)	(a)			(a)	(a)
Missouri	87	52,300	68,779	(a)	(a)	44,006	68,778	(a)	(a)	6,957	10,177	42,164	71,837	1,115,490	1,759,029
Nontana	8	149,966	119,620	(a)	(a)									205,190	159,079
Nebraska	8	(a)	(a)	(a)	(a)					(a)	(a)	(a)	(a)	203,460	280,602
Mevada	1			(a)	(a)							(a)	(a)	(a)	(a)
New Jersey	14	284,038	346,108							44,636	142,890			374,080	506,193
New Mexico	1			(a)	(a)									(a)	(a)
New York	63	421,815	506,049					(a)	(a)	97,145	231,371	547,615	545,905	3,392,950	4,406,721
North Carolina	4	(a)	(a)							46,045	106,405	(a)	(a)	69,220	133,198
Ohio	107	2,784,183	2,483,841			19,346	25,068			76,010	78,891	479,650	502,317	7,703,180	6,415,233
Oklahoma	15									(a)	(a)	(a)	(a)	659,450	656,843
Oregon	4									(a)	(a)			35,760	68,013
Pennsylvania	241	7,607,131	9,547,016			53,509	100,316	(a)	(a)	65,612	243,529	122,002	229,843	10,665,500	12,640,411
Porto Rico	17	(a)	(a)											67,000	101,186
Rhode Island	1	(a)	(a)							(a)	(a)			(a)	(a)
South Dakota	4			(a)	(a)									17,750	23,989
Tennessee	31	120,679	125,731							19,678	30,814	(a)	(a)	630,300	689,597

Texas	13	2, 268	2, 177			(a)	(a)			(a)	(a)	(a)	(a)	548, 000	453, 113
Utah	11	151, 679	138, 630	84, 169	143, 989									315, 310	329, 150
Vermont	10	413	639					(a)	(a)	(a)	(a)			38, 900	103, 858
Virginia	43	246, 267	293, 972							55, 582	126, 895			1, 446, 870	1, 454, 989
Washington	4	7, 966	11, 255	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	23, 750	45, 957
West Virginia	25	1, 305, 568	1, 576, 010					(a)	(a)	50, 710	121, 618	(a)	(a)	1, 971, 170	2, 228, 209
Wisconsin	61	52, 115	52, 210	(a)	(a)			5, 822	5, 822	9, 878	18, 294	36, 730	77, 185	1, 141, 490	1, 246, 837
Wyoming	8			104, 169	185, 909									104, 170	185, 909
Undistributed		26, 433	43, 302	156, 283	199, 351	13, 560	30, 777	34, 666	55, 218	405, 323	659, 800	148, 073	333, 010	225, 380	300, 956
	[illegible], 192	18, 928, 886	19, 271, 674	503, 835	821, 912	166, 106	278, 467	92, 421	129, 649	1, 392, 914	2, 409, 460	3, 080, 101	2, 909, 791	49, 759, 800	53, 171, 701
Average value			$1. 02		$1. 63		$1. 68		$1. 40		$1. 73		$0. 95		$1. 07

a Included under "Undistributed."

SANDSTONE.

Value of sandstone (including quartzite and bluestone) sold in the United States, 1915–1919.

State.	1915	1916	1917	1918	1919
Alabama	$30,432	$20,995	$17,098	$14,484	$33,852
Arizona	9,625	(a)	(a)	(a)	(a)
Arkansas	54,747	95,398	66,183	70,593	91,549
California	336,629	422,225	232,379	183,163	249,779
Colorado	52,487	53,902	90,646	81,226	47,464
Connecticut	(a)	(a)	(a)	(a)	44,914
Idaho	10,302	47,061	56,702	42,040	84,822
Illinois	43,307	40,343	42,304	(a)	(a)
Indiana	(a)	....	....	....	(a)
Iowa	(a)	(a)	(a)	....	....
Kansas	(a)	3,495	(a)	(a)	....
Kentucky	70,164	114,136	96,117	37,827	89,734
Maryland	11,038	6,003	(a)	(a)	(a)
Massachusetts	353,662	318,982	216,500	200,577	118,000
Michigan	(a)	21,449	(a)	(a)	24,413
Minnesota	173,995	186,179	81,717	(a)	62,512
Missouri	10,104	14,991	6,862	(a)	....
Montana	6,346	(a)	(a)	(a)	(a)
Nebraska	(a)	(a)	(a)	(a)	(a)
New Jersey	63,964	46,035	6,758	17,652	31,475
New Mexico	296,809	18,330	(a)	(a)	(a)
New York	[b] 1,000,523	[b] 714,558	[b] 760,582	[b] 325,351	[b] 384,516
North Carolina	27,544	(a)	228,048	288,681	(a)
Ohio	1,411,333	1,274,181	1,086,027	957,535	1,594,416
Oklahoma	2,525	24,229	5,096	(a)	(a)
Oregon	(a)	(a)	(a)	(a)	....
Pennsylvania	1,273,994	[b] 1,318,239	[b] 1,794,919	[b] 1,543,544	[b] 1,661,959
South Dakota	119,225	163,735	116,785	58,726	146,742
Tennessee	(a)	(a)	(a)	(a)	(a)
Texas	73,128	85,940	(a)	(a)	....
Utah	27,267	27,207	25,021	(a)	(a)
Virginia	178,775	66,217	34,058	47,309	28,654
Washington	(a)	(a)	(a)	45,368	(a)
West Virginia	124,929	48,416	52,543	65,740	42,409
Wisconsin	180,198	188,791	291,241	353,030	230,628
Wyoming	10,840	(a)	(a)	(a)	26,699
Undistributed	141,908	282,741	204,835	196,452	289,305
	6,095,800	5,603,778	5,512,421	4,529,298	5,283,842

[a] Included under "Undistributed."
[b] Includes bluestone.

Sandstone sold in the United States in 1918 and 1919.

Use.	1918		1919	
	Quantity.	Value.	Quantity.	Value.
Building stone ... cubic feet	973,990	$536,474	1,841,198	$1,131,734
Approximate equivalent in short tons	75,650	....	150,600	....
Paving blocks ... number	2,188,419	148,091	1,888,490	172,561
Approximate equivalent in short tons	21,900	....	20,720	....
Curbing ... cubic feet	531,952	298,971	1,131,425	647,102
Approximate equivalent in short tons	43,800	....	92,700	....
Flagging ... cubic feet	798,934	373,729	962,173	502,871
Approximate equivalent in short tons	65,900	....	78,870	....
Crushed stone ... short tons	882,831	1,050,106	1,179,213	1,432,842
Riprap ... do	356,784	305,308	214,629	262,869
Rubble ... do	105,022	107,958	92,000	149,425
Ganister ... do	1,297,874	1,688,334	783,504	974,326
Other ... do	8,355	20,327	11,034	10,112
Total (quantities approximate, in short tons)	2,858,100	4,529,298	2,623,270	5,283,842

Sandstone sold in the United States in 1918.

State.	Building.				Ganister.		Paving blocks.	
	Rough (rough blocks or rough sawed).		Dressed.					
	Quantity (cubic feet).	Value.	Quantity (cubic feet).	Value.	Quantity (short tons).	Value.	Number of blocks.	Value.
Alabama	(a)	(a)			(a)	(a)		
Arizona	(a)	(a)						
Arkansas								
California	(a)	(a)						
Colorado	b 33,677	b $7,558	(b)	(b)	43,051	$56,163		
Connecticut	(a)	(a)	(a)	(a)				
Idaho	b 50,732	b 40,955	(b)	(b)				
Illinois					(a)	(a)		
Kansas								
Kentucky	(c)	(c)	c 51,443	c $20,918				
Maryland					(a)	(a)		
Massachusetts								
Michigan	(a)	(a)						
Minnesota					(a)	(a)	(a)	(a)
Missouri	(a)	(a)						
Montana	(a)	(a)			(a)	(a)		
Nebraska								
New Jersey			(a)	(a)				
New Mexico								
New York	40,206	15,894	29,647	45,048	(a)	(a)	1,241,263	$84,408
North Carolina	(a)	(a)			(a)	(a)		
Ohio	b 486,983	b 292,480	(b)	(b)	48,019	102,447		
Oklahoma	(a)	(a)						
Oregon								
Pennsylvania	124,671	18,963	13,067	29,900	858,374	1,142,202	418,759	26,393
South Dakota			(a)	(a)	(a)	(a)		
Tennessee	(a)	(a)						
Texas								
Utah	(a)	(a)						
Virginia			(a)	(a)				
Washington	(a)	(a)					(a)	(a)
West Virginia					(a)	(a)		
Wisconsin	b 38,234	b 11,256	(b)	(b)	276,424	303,760	334,846	24,146
Wyoming								
Undistributed	101,720	43,471	3,610	10,031	72,006	83,762	193,551	13,144
	800,062	343,726	173,928	192,748	1,297,874	1,688,334	2,188,419	148,091

a Included under "Undistributed."
b Dressed stone included under rough stone.
c Rough stone included under dressed stone.

Sandstone sold in the United States in 1918—Continued.

State.	Curbing.		Flagging.		Rubble.		Riprap.	
	Quantity (cubic feet).	Value.	Quantity (cubic feet).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
Alabama							(a)	(a)
Arizona					(a)	(a)	(a)	(a)
Arkansas					(a)	(a)	40,480	$59,850
California			(a)	(a)	(a)	(a)	(a)	(a)
Colorado	(a)	(a)			3,047	$3,154	(a)	(a)
Connecticut								
Idaho					(a)	(a)		
Illinois								
Kansas			(a)	(a)			(a)	(a)
Kentucky			(a)	(a)	(a)	(a)	21,190	12,485
Maryland								
Massachusetts								
Michigan					(a)	(a)	(a)	(a)
Minnesota					(a)	(a)	(a)	(a)
Missouri								
Montana					(a)	(a)		
Nebraska					(a)	(a)	(a)	(a)
New Jersey					(a)	(a)	(a)	(a)
New Mexico					(a)	(a)		
New York	207,981	$131,940	43,512	$25,124	(a)	(a)	9,915	7,256
North Carolina					(a)	(a)	(a)	(a)
Ohio	305,571	155,994	717,312	327,767	6,837	6,458	66,508	46,472
Oklahoma								
Oregon							(a)	(a)
Pennsylvania	17,000	10,353	29,740	17,097	17,652	29,499	5,194	12,661
South Dakota					(a)	(a)	13,580	11,927
Tennessee					(a)	(a)		
Texas							(a)	(a)
Utah								
Virginia								
Washington					(a)	(a)	(a)	(a)
West Virginia	(a)	(a)			2,840	5,143	(a)	(a)
Wisconsin					1,370	921	21,211	9,666
Wyoming							(a)	(a)
Undistributed	1,400	684	8,370	3,741	73,276	62,783	178,706	144,991
	531,952	298,971	798,934	373,729	105,022	107,958	356,784	305,308

a Included under "Undistributed."

Sandstone sold in the United States in 1918—Continued.

State.	Crushed stone.						Other.		Total value.
	Road metal.		Railroad ballast.		Concrete.				
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	
Alabama							(a)	(a)	$14,484
Arizona									(a)
Arkansas	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	70,593
California	(a)	(a)	(a)	(a)	129,628	$104,022			183,163
Colorado					(a)	(a)	(a)	(a)	81,226
Connecticut									(a)
Idaho							(a)	(a)	42,040
Illinois	(a)	(a)							(a)
Kansas							(a)	(a)	(a)
Kentucky					(a)	(a)			37,827
Maryland									(a)
Massachusetts	(a)	(a)			61,545	144,577			200,577
Michigan	(a)	(a)					(a)	(a)	(a)
Minnesota					(a)	(a)			(a)
Missouri									(a)
Montana							(a)	(a)	(a)
Nebraska									(a)
New Jersey									17,652
New Mexico									(a)
New York	(a)	(a)	4,295	$3,222	(a)	(a)	(a)	(a)	325,351
North Carolina			(a)	(a)	(a)	(a)			288,681
Ohio	12,550	$13,050	(a)	(a)	(a)	(a)	5,552	$12,174	957,535
Oklahoma					(a)	(a)	(a)	(a)	(a)
Oregon									(a)
Pennsylvania	62,183	74,522	81,797	87,709	77,753	94,217	(a)	(a)	1,543,544
South Dakota	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	58,726
Tennessee									(a)
Texas					(a)	(a)			(a)
Utah									(a)
Virginia	(a)	(a)	(a)	(a)	(a)	(a)			47,309
Washington							(a)	(a)	45,368
West Virginia	12,500	19,400			6,200	6,300	(a)	(a)	65,740
Wisconsin	4,278	1,573			(a)	(a)	781	1,563	353,030
Wyoming					(a)	(a)			(a)
Undistributed	169,552	161,135	85,450	52,053	175,100	288,326	2,022	6,590	196,452
	261,063	269,680	171,542	142,984	450,226	637,442	8,355	20,327	4,529,298

a Included under "Undistributed."

Sandstone sold in the United States in 1919.

State.	Number of plants.	Building.				Ganister.		Paving blocks.		Curbing.		Flagging.	
		Rough.		Dressed.									
		Quantity (cubic feet).	Value.	Quantity (cubic feet).	Value.	Quantity (short tons).	Value.	Number of blocks.	Value.	Quantity (cubic feet).	Value.	Quantity (cubic feet).	Value.
Alabama	3					(a)	(a)						
Arizona	2												
Arkansas	6			(a)	(a)					(a)	(a)		
California	10	(a)	(a)										
Colorado	10	b 12,825	b $7,122	(b)	(b)	27,960	$32,815					1,390	$870
Connecticut	4	35,621	4,933										
Idaho	3	(c)	(c)	c 46,763	c $84,822								
Illinois	2					(a)	(a)						
Indiana	1												
Kentucky	5	(c)	(c)	c 120,925	c 84,312								
Maryland	2	(a)	(a)										
Massachusetts	3			(a)	(a)								
Michigan	4	(a)	(a)										
Minnesota	3												
Montana	2			(a)	(a)	(a)	(a)						
Nebraska	1			(a)	(a)								
New Jersey	4												
New Mexico	2	(a)	(a)										
New York	19	63,055	78,726	31,830	59,110			430,000	$33,266	238,234	$131,232	51,815	23,543
North Carolina	2					(a)	(a)						
Ohio	19	b 1,055,216	b 598,534	(b)	(b)	17,056	28,013			819,128	465,043	879,466	439,444
Oklahoma	2												
Pennsylvania	79	261,966	45,726	43,088	60,020	573,244	718,317	930,240	84,570	68,863	48,201	29,502	39,014
South Dakota	5	(a)	(a)			16,183	18,256	(a)	(a)				
Tennessee	2	(a)	(a)			(a)	(a)						
Utah	2	(a)	(a)					(a)	(a)				
Virginia	3	(a)	(a)										
Washington	1	(a)	(a)										
West Virginia	10	75,900	14,830			(a)	(a)			(a)	(a)		
Wisconsin	14	(c)	(c)	c 18,780	c 26,320	(a)	(a)	508,250	53,507				
Wyoming	3												
Undistributed		70,978	51,531	4,251	15,748	149,061	176,925	20,000	1,218	5,200	2,626		
	228	1,594,535	809,146	246,663	322,588	783,504	974,326	1,888,490	172,561	1,131,425	647,102	962,173	502,871
Average value			$0.51		$1.31		$1.24		d $91.38		$0.57		$0.52

a Included under "Undistributed." b Dressed stone included under rough stone. c Rough stone included under dressed stone. d Per M.

Sandstone sold in the United States in 1919—Continued.

State.	Number of plants.	Rubble.		Riprap.		Crushed stone. Road metal and concrete.		Crushed stone. Railroad ballast.		Other.		Total.	
		Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (approximate short tons).	Value.
Alabama	3	(a)	(a)									20,680	$33,852
Arizona	2			(a)	(a)							(a)	(a)
Arkansas	6			(a)	(a)	14,610	$24,668	(a)	(a)	(a)	(a)	43,320	91,549
California	10	(a)	(a)	(a)	(a)	223,147	212,531	(a)	(a)	(a)	(a)	271,740	249,779
Colorado	10	(a)	(a)	(a)	(a)	(a)	(a)					33,800	47,464
Connecticut	4					15,860	33,845	(a)	(a)			23,690	44,914
Idaho	3											3,610	84,822
Illinois	2					(a)	(a)					(a)	(a)
Indiana	1			(a)	(a)							(a)	(a)
Kentucky	5			4,800	$5,422							14,720	89,734
Maryland	2	(a)	(a)	(a)	(a)							(a)	(a)
Massachusetts	3					(a)	(a)					57,660	118,000
Michigan	4	(a)	(a)	(a)	(a)	(a)	(a)					19,640	24,413
Minnesota	3	150	$100			28,559	62,412					28,710	62,512
Montana	2	(a)	(a)							(a)	(a)	(a)	(a)
Nebraska	1			(a)	(a)							(a)	(a)
New Jersey	4	19,750	31,475									19,750	31,475
New Mexico	2							(a)	(a)			(a)	(a)
New York	19	(a)	(a)	6,373	4,980	21,531	51,797	(a)	(a)	(a)	(a)	65,050	384,516
North Carolina	2											(a)	(a)
Ohio	19	14,395	17,201	48,163	44,910			(a)	(a)	(a)	(a)	308,350	1,594,416
Oklahoma	2	(a)	(a)			(a)	(a)					(a)	(a)
Pennsylvania	79	41,881	81,981	25,490	67,123	239,652	340,358	165,475	$169,981	9,277	$6,668	1,098,290	1,661,959
South Dakota	5			6,163	6,073	96,860	120,668					119,360	146,742
Tennessee	2											(a)	(a)
Utah	2					(a)	(a)					(a)	(a)
Virginia	3					(a)	(a)	(a)	(a)			64,910	28,654
Washington	1			(a)	(a)							(a)	(a)
West Virginia	10	(a)	(a)	(a)	(a)	5,600	9,400					24,040	42,409
Wisconsin	14	3,291	3,784	(a)	(a)	9,728	12,103	12,917	11,537			143,400	230,628
Wyoming	3			122	176	13,752	26,523					13,870	26,699
Undistributed		12,533	14,884	123,518	134,185	181,954	242,222	149,568	114,797	1,757	3,444	248,680	289,305
	228	92,000	149,425	214,629	262,869	851,253	1,136,527	327,960	296,315	11,034	10,112	2,623,270	5,283,842
Average value			$1.62		$1.22		$1.34		$0.90		$0.92		$2.01

a Included under "Undistributed."

BLUESTONE.

Value of bluestone sold in New York and Pennsylvania in 1918 and 1919.

State.	Building stone.	Flagging.	Curbing.	Other uses.[a]	Total value.
1918.					
New York	$55,020	$25,084	$102,685	$8,891	$191,680
Pennsylvania	(b)	17,097	9,894	2,443	29,434
	55,020	42,181	112,579	11,334	221,114
1919.					
New York	136,374	23,542	82,511	6,581	249,008
Pennsylvania	(b)	38,912	30,138	840	69,890
	136,374	62,454	112,649	7,421	318,898

[a] Includes crushed stone, rubble, riprap, and unspecified; also building stone for Pennsylvania in 1918 and 1919.
[b] Included under "Other uses."

MISCELLANEOUS STONE.

Miscellaneous varieties of stone sold in the United States in 1918 and 1919.[a]

Use.	1918		1919	
	Quantity.	Value.	Quantity.	Value.
Building stone (rough and dressed) ... cubic feet	128,387	$38,979	428,200	$43,360
Approximate equivalent in short tons	10,000	...	33,240	...
Riprap and rubble ... short tons	20,857	12,945	95,486	98,983
Crushed stone ... do	743,292	738,486	979,230	1,481,250
Refractory stone ... do	36,446	114,611	22,450	60,695
Other ... do	34,144	68,013	60,134	236,615
	844,740	973,034	1,190,540	1,920,903

[a] Includes light-colored volcanic rocks, conglomerate, chert, cherty limestone, mica schist used for furnace lining, argillite, etc.

Miscellaneous varieties of stone sold in the United States in 1918.

State.	Building.		Riprap.		Crushed stone.						Other.		Total value.
					Road metal.		Railroad ballast.		Concrete.				
	Quantity (cubic feet).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	
Arizona							(a)	(a)	(a)	(a)			(a)
Arkansas					(a)	(a)			(a)	(a)			(a)
California			20,527	$12,625	22,390	$16,438	66,736	$31,561	73,025	$59,327			$119,951
Colorado	(a)	(a)									(a)	(a)	(a)
Florida									(a)	(a)			(a)
Idaho	(a)	(a)											(a)
Massachusetts	46,000	$10,583	330	320	76,421	96,363			121,404	159,824			267,090
Michigan					(a)	(a)							(a)
Missouri					(a)	(a)							(a)
New Hampshire											(a)	(a)	(a)
New Jersey	(a)	(a)					(a)	(a)	(a)	(a)	(a)	(a)	(a)
New York					(a)	(a)	(a)	(a)					(a)
North Carolina									(a)	(a)			(a)
Oregon							(a)	(a)					(a)
Pennsylvania	36,946	20,550			17,400	22,498	(a)	(a)	55,283	64,584	41,446	$149,611	265,243
Rhode Island					30,500	45,750			3,000	4,500			50,250
South Dakota					(a)	(a)							(a)
Virginia											(a)	(a)	(a)
Wisconsin					(a)	(a)					(a)	(a)	6,125
Undistributed	45,441	7,846			41,204	59,447	126,186	60,153	109,743	118,041	29,144	33,013	264,375
	128,387	38,979	20,857	12,945	187,915	240,496	192,922	91,714	362,455	406,276	70,590	182,624	973,034

a Included under "Undistributed."

Miscellaneous varieties of stone sold in the United States in 1919.

State.	Number of plants.	Building.		Riprap and rubble.		Crushed stone.				Other.		Total.	
						Road metal and concrete.		Railroad ballast.					
		Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (approximate, short tons).	Value.
Arizona	1					(a)	(a)					(a)	(a)
Arkansas	3					189, 724	$240, 057	(a)	(a)			259, 940	$330, 396
California	9	(a)	(a)	92, 222	$91, 998	192, 293	120, 467	(a)	(a)	(a)	(a)	285, 740	214, 692
Florida	1					(a)	(a)					(a)	(a)
Georgia	1									(a)	(a)	(a)	(a)
Idaho	2	(a)	(a)									(a)	(a)
Massachusetts	8			(a)	(a)	249, 944	503, 490	(a)	(a)			291, 110	586, 846
New Jersey	1	(a)	(a)			(a)	(a)					(a)	(a)
New York	3					24, 620	30, 848			(a)	(a)	33, 590	100, 775
Oregon	1	(a)	(a)									(a)	(a)
Pennsylvania	20	30, 650	$36, 627	(a)	(a)	71, 746	92, 896	(a)	(a)	33, 804	$139, 883	148, 300	284, 063
Rhode Island	5	(a)	(a)			76, 691	207, 532					76, 990	207, 732
South Dakota	1					(a)	(a)					(a)	(a)
Undistributed		2, 590	6, 733	3, 264	6, 985	52, 898	103, 843	121, 314	$182, 117	48, 780	157, 427	94, 870	196, 399
	56	b 33, 240	43, 360	95, 486	98, 983	857, 916	1, 299, 133	121, 314	182, 117	82, 584	297, 310	1, 190, 540	1, 920, 903

a Included under "Undistributed."
b Approximately 428,200 cubic feet.

CRUSHED STONE.

Crushed stone sold in the United States in 1918 and 1919.

1918.

	Road metal.		Railroad ballast.		Concrete.		Total.		Average value per ton.
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	
Granite	677, 292	$799, 720	371, 900	$330, 222	1, 020, 281	$1, 453, 507	2, 069, 473	$2, 583, 449	$1. 25
Basalt and related rocks (trap rock)	2, 484, 840	2, 882, 274	1, 023, 440	1, 104, 047	3, 048, 608	3, 319, 847	6, 556, 888	7, 306, 168	1. 11
Limestone	6, 085, 337	5, 177, 501	5, 509, 911	3, 901, 682	7, 525, 610	7, 194, 001	19, 120, 858	16, 273, 184	. 85
Sandstone	261, 063	269, 680	171, 542	142, 984	450, 226	637, 442	882, 831	1, 050, 106	1. 19
Miscellaneous	187, 915	240, 496	192, 922	91, 714	362, 455	406, 276	743, 292	738, 486	. 99
	9, 696, 447	9, 369, 671	7, 269, 715	5, 570, 649	12, 407, 180	13, 011, 073	29, 373, 342	27, 951, 393	.....
Average value per ton	....	$0. 97	....	$0. 77	....	$1. 05	....	$0. 95	.....

1919.

	Road metal and concrete.		Railroad ballast.		Total.		Average value per ton.
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	
Granite	2, 123, 073	$2, 854, 655	577, 001	$445, 625	2, 700, 074	$3, 300, 280	$1. 22
Basalt and related rocks (trap rock)	6, 079, 097	7, 375, 921	973, 779	1, 105, 687	7, 052, 876	8, 481, 608	1. 20
Limestone	16, 956, 886	17, 887, 168	4, 805, 060	3, 822, 038	21, 761, 946	21, 709, 206	1. 00
Sandstone	851, 253	1, 136, 527	327, 960	296, 315	1, 179, 213	1, 432, 842	1. 22
Miscellaneous	857, 916	1, 299, 133	121, 314	182, 117	979, 230	1, 481, 250	1. 51
	26, 868, 225	30, 553, 404	6, 805, 114	5, 851, 782	33, 673, 339	36, 405, 186	......
Average value per ton	....	$1. 14	....	$0. 86	....	$1. 08	......

ARTIFICIAL GAS AND BY-PRODUCTS IN 1917-18.

By R. S. McBride.

MUNICIPAL GAS SUPPLY, AN ENGINEERING AND CHEMICAL-RESOURCE PROBLEM.

Municipal fuel supply is one of the greatest problems of modern urban life; it is the last link in the chain which connects the user of heat, light, and power with the natural resources supplying fuel and energy. Gas and electricity, companion agencies in this service, are of constantly increasing importance. The public-utility aspects of these services are usually most conspicuous, for rates and the quality of service rendered are most in the public eye. However, these public-service industries are also of great economic significance, especially the gas industry, which furnishes not only gas as a source of heat, light, and power, but also the by-products of gas manufacture—coke, tar, ammonia, light oils, retort carbon, and lampblack—which are resources of great importance as raw materials for the chemical industry. It is this economic significance and the industrial application of these products that lend particular importance to the following discussion.

SCOPE OF THIS REPORT.

This report attempts to give all the basic data not only for artificial gas but also for the by-products of its manufacture. These by-products are really mineral resources, for they represent raw materials for chemical industry only partly manufactured in the processing of the coal.

The data that have been supplied by the gas companies of the country are summarized in the form in which they are submitted; these data have also been analyzed in the effort to show average and extreme conditions of operation for various types and sizes of gas plants. Thus the industry can hope to find in many particulars standards of operating practice or operating efficiency by which to judge the general performance of the industry, and each operator will find a basis for comparison of his own results with those obtained by other operators of similar plants.

The report deals with artificial gas made by coal-gas, carbureted water-gas, and oil-gas processes and with supplies of mixtures of these gases. In parts of the report are included, for the sake of comparison, data for natural-gas and coke-oven operations. However, in general, natural gas and coke-oven gas are not discussed here, as a full report on each of them is found in other chapters of Mineral Resources.[1]

[1] Sievers, E. G., Natural gas and natural-gas gasoline; and Lesher, C. E., Coke and by-products; U. S. Geol. Survey Mineral Resources, 1918, pt. 2.

Practically all of the output of coal-gas, water-gas, and oil-gas plants goes into public-utility municipal supplies. However, the total for these three kinds of gas does not completely represent the public-utility gas service in the United States, as a considerable quantity of coke-oven gas is also so used. In this report only incidental reference can be made to the public-utility aspects of the matter. It should be borne in mind that the prices of gas sold for public-utility supply are much higher than those usually charged for the gas sold by coke-oven companies, for the sale of coke-oven gas is usually a wholesale transaction. The higher price of the city supply represents, however, more than a charge for the gas itself, because the companies that supply public-utility service distribute their product over wide areas and maintain many facilities that contribute to the service of their customers but that are not essential to the supply of fuel gas from coke ovens to large industrial consumers or to the gas companies themselves. These companies, in fact, often purchase coke-oven gas for distribution and resale as a public-utility supply.

This report does not include any discussion of producer, blast-furnace, acetylene, Pintsch, or other industrial gases, which seldom form an important part of the municipal gas supply.

The summaries of data for gas and by-products are given on several bases and thus permit consideration by product, by State or other subdivision of the country, by class of company, or otherwise, as may seem most significant and feasible. The effort has been made not only to serve the gas industry and those interested in public-utility gas supply, but also to furnish data for an intelligent study both of coal by-products as furnished by gas companies and of the general fuel-engineering facts of greatest importance connected therewith.

The trends of industrial development are briefly discussed at various points in this report, but the data for most satisfactory treatment of the industry as a whole will not be available for some months. Therefore it is reserved for the report of the calendar year 1920 to give a more complete discussion of the engineering development now in progress. In that report it will be possible to consider the changes in practice which occurred just before, during, and just after the war period.

ACKNOWLEDGMENTS.

The data for this report were gathered by C. E. Lesher, who for a number of years was in charge of these investigations for the United States Geological Survey. The scant time available for their study and analysis during the war period prevented the completion of the reports at that time, and it was not until 1921 that opportunity was afforded for complete compilation and editing of the data. The author makes grateful acknowledgment of the preliminary work done by Mr. Lesher, and wishes to express also special appreciation of the statistical studies of these data made by Mrs. Helen L. Bennit, of the United States Geological Survey, under whose immediate supervision all the statistical work has been done.

UNITS OF MEASUREMENT.

The standard commercial unit for measuring gas in the United States is 1,000 cubic feet, represented in this report by the abbreviation M. The coal used in gas manufacture is usually reported in tons—anthracite in gross tons of 2,240 pounds; bituminous coal in net tons of 2,000 pounds. Statistics of coke in this report are also expressed in net tons.

SUMMARY OF DATA.

In Table 1 are presented the salient data concerning the operations of gas companies during 1918. These data afford a general summary for the latest year for which complete information is available, but give by no means a complete idea of the scope of the statistics included elsewhere in this report.

TABLE 1a.—*Salient figures of the artificial gas industry, 1918.*

Gas produced (M):	
Coal gas	48,486,546
Water gas	193,046,980
Oil gas	19,871,797
Coke-oven gas	385,035,154
	646,440,477
Gas sold (M):	
Coal gas	42,659,487
Water gas	175,597,423
Oil gas	16,684,157
Coke-oven gas	158,358,479
	393,299,546
Average price per M of gas sold:	
Coal gas	$1.00
Water gas	.89
Oil gas	.94
Coke-oven gas	.09
Average percentage of gas unaccounted for at all plants (coal, water, and oil gas)	12.7
Annual per capita consumption of artificial gas, including coke-oven gas (cubic feet)	3,683
Number of active gas plants:	
Coal gas	250
Water gas	431
Oil gas	81
Coke-oven gas	60
Coal and water gas	150
Coal and oil gas	3
Water and oil gas	3
	978
Average sales of gas per plant per annum (M):	
Coal gas	105,855
Water gas	300,681
Oil gas	191,772
Coke-oven gas	2,639,308
Fuels used in gas manufacture:	
Bituminous coal (net tons):	
Coal and water gas	5,031,614
Coke ovens	36,867,721
Anthracite (gross tons)	1,730,029
Oil (gallons)	841,928,218
Average yield of coal gas per ton of coal carbonized (M)	9.8
Solid fuel used per M of water gas produced, average (pounds)	35.8
Oil used per M of water gas produced, average (gallons)	3.6
Oil used per M of oil gas produced, average (gallons)	7.8
Coke sold, by coal-gas plants:	
Quantity (net tons)	1,813,740
Average price per ton	$7.70
Average yield of coke per ton of coal carbonized in coal-gas plants (per cent)	64.0
Tar produced (gallons):	
Coal gas	52,694,826
Water gas and oil gas	100,985,156
Coke-oven gas	263,299,470
	416,979,452
Average yield of coal-gas tar per ton of coal carbonized (gallons)	10.6
Average yield of water-gas tar per gallon of oil consumed (gallons)	0.146
Ammonia (sulphate equivalent) produced (pounds):	
Coal gas	59,348,144
Coke oven	697,308,770
	756,656,914
Crude light oil produced (gallons):	
Coal gas	5,729,629
Water gas	11,909,702
Coal and water gas	4,230,908
Oil gas	21,494
Coke-oven gas	87,222,450
	109,114,183
Retort carbon produced at coal-gas, water-gas, and coke-oven gas plants (pounds)	4,034,621
Lampblack produced at oil-gas plants (pounds)	262,022,000
Drip and holder oils produced at coal-gas and water-gas plants (gallons)	3,663,779
Naphthalene produced at coal-gas, water-gas, and coke-oven gas plants, crude and refined (pounds)	17,057,180
Value of products of the coal-gas, water-gas, and oil-gas industry:	
Gas sold	$214,031,123
By-products sold	26,248,245
	240,279,368
Value of products of the by-product coke industry:	
Coke	$193,018,785
Gas sold	13,699,515
Other by-products sold	60,902,943
	267,621,243
Total value of sales of products of artificial-gas industries, excluding by-product coke	$314,881,826

TABLE 1b.—*Summary of output of gas and by-products from artificial-gas plants in the United States, 1918.*

Product.	Production.	Sales.	
		Quantity.	Value.
Gas:	*M.*	*M.*	
Coal gas	48,486,546	42,659,487	$42,846,964
Water gas	193,046,980	175,597,423	155,426,672
Oil gas	19,871,797	16,684,157	15,757,487
Coke-oven gas	385,035,154	158,358,479	13,699,515
	646,440,477	393,299,546	227,730,638
Coke:	*Net tons.*	*Net tons.*	
Coal gas	3,180,535	1,813,740	13,963,232
Coke-oven	25,997,580	(*a*)	(*a*)
	29,178,115	....	....
Tar:	*Gallons.*	*Gallons.*	
Coal gas	52,694,826	47,727,839	1,863,580
Water gas	100,268,434	54,733,478	1,789,898
Oil gas	716,722	550,006	15,967
Coke-oven gas	263,299,470	200,233,002	6,364,972
	416,979,452	303,244,325	10,034,417
Ammonia (sulphate equivalent):	*Pounds.*	*Pounds.*	
Coal gas	59,348,144	56,900,464	1,453,070
Coke-oven gas	697,308,770	669,287,568	26,442,951
	756,656,914	726,188,032	27,896,021
Crude light oil and derived products:	*Gallons.*	*Gallons.*	
Coal gas	5,729,629	2,032,883	1,457,972
Water gas	11,909,702	4,613,751	3,830,392
Coal and water gas	4,230,908	2,229,535	1,220,138
Oil gas	21,494	20,376	4,274
Coke-oven gas	87,222,450	59,564,376	25,688,446
	109,114,183	68,460,921	32,201,222
Drip or holder oils:	*Gallons.*	*Gallons.*	
Coal gas	179,614	176,289	42,949
Water gas	3,484,165	3,430,232	455,949
	3,663,779	3,606,521	498,898
Naphthalene (crude and refined):	*Pounds.*	*Pounds.*	
Coal gas	429,798	392,997	10,675
Water gas	539,884	503,083	3,607
Coke-oven gas	16,087,498	15,890,447	650,229
	17,057,180	16,786,527	664,511
Retort carbon:	*Pounds.*	*Pounds.*	
Coal gas	2,202,853	2,014,961	13,275
Water gas	521,748	501,723	2,230
Coke-oven gas	1,310,020	1,310,020	2,732
	4,034,621	3,826,704	18,237
	Pounds.	*Pounds.*	
Lampblack: Oil gas	262,022,000	[b] 35,355,000	95,211
Miscellaneous by-products:			
Coal and water gas	....	....	25,826
Coke-oven	....	....	1,753,613
	....	....	1,779,439
Total value of sales of gas and by-products:			
Coal-gas, water-gas, and oil-gas plants	....	....	240,279,368
By-product coke ovens, excluding coke	....	....	74,602,458
			314,881,826

[a] Sales of coke from by-product ovens not comparable, as 90 per cent of the production is used by the operator. The total value of the coke produced including estimates for coke consumed in associated iron furnaces, but not sold, was $193,018,785.
[b] In addition, lampblack used for briquets, 80,124,000 pounds.

MAGNITUDE AND DEVELOPMENT OF THE GAS INDUSTRY.

The quantity and value of the artificial gas sold in the United States are given in Table 2, which shows for the last 20 years the more important facts regarding the four principal sources of gas supply. These data are also shown graphically in figure 18. The most striking development during the 20 years is clearly in coke-oven gas, for the volume of this gas sold in 1918 was about fifty times that sold in 1898. Oil gas, water gas, and coal gas have all increased in

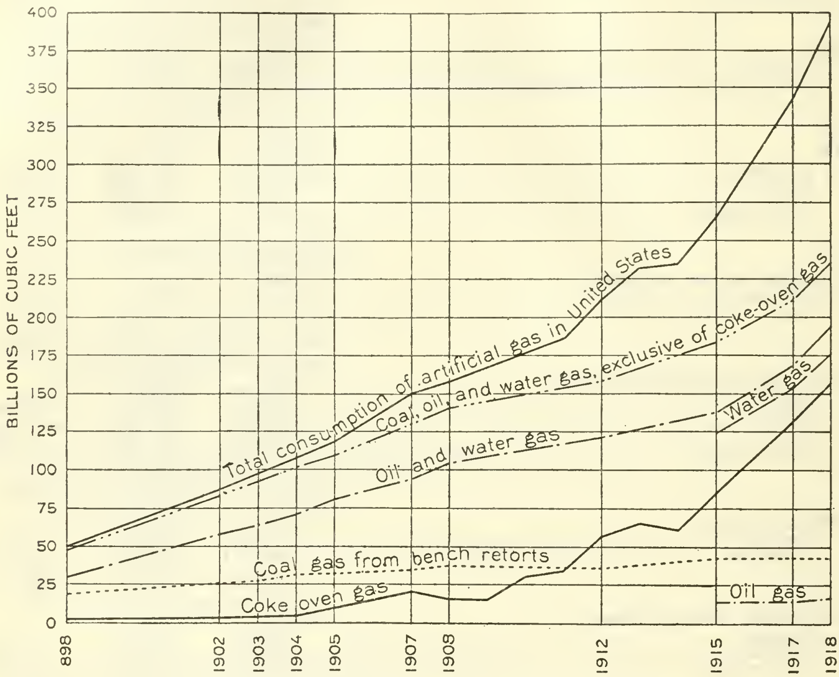

FIGURE 18.—Artificial gas sold in the United States, 1898–1918.

sales during the same period, but not so greatly. Sales of oil gas were about thirty times as great in 1918 as in 1898, of water gas about six times, and of coal gas barely two and a half times. It is more difficult to appraise the increase in the value of the gas sold, as very inadequate data are available for the earlier years. However, it is shown that the value of coal gas in 1918 was almost exactly double the value in 1898; and it appears that the value of all four kinds together was probably at least four times as much in 1918 as in 1898.

TABLE 2.—*Artificial gas sold in the United States, by kinds, 1898–1918.*

Year.	Coal gas.		Water gas.		Oil gas.	
	Quantity (M).	Value.	Quantity (M).	Value.	Quantity (M).	Value.
1898	18,431,201	$21,502,295	a 30,418,987	(b)	a 497,016	(b)
1902	25,069,000	c 29,342,881	(b)	(b)	(b)	(b)
1903	25,670,000	c 30,315,776	(b)	(b)	(b)	(b)
1904	30,109,449	c 32,090,998	(b)	(b)	(b)	(b)
1905	30,722,279	c 32,937,456	d 77,412,025	d $78,072,500	(d)	(d)
1907	34,302,956	33,331,465	d 94,634,620	d 90,173,112	(d)	(d)
1908	37,355,886	34,670,418	d 103,347,497	d 96,343,221	(d)	(d)
1912	35,202,124	32,031,367	d 122,697,796	d 111,600,841	(d)	(d)
1915	43,747,432	40,257,108	124,129,569	112,281,956	13,971,333	$12,668,169
1917	42,927,728	38,324,113	153,457,318	131,876,065	14,739,508	13,470,911
1918	42,659,487	42,846,964	175,597,423	155,426,672	16,684,157	15,757,487

Year.	Coke-oven gas.[e]		Total.	
	Quantity (M).	Value.	Quantity (M).	Value.
1898	3,620,673	(b)	52,967,877	....
1902	4,010,074	(c)	29,079,074	$29,342,881
1903	5,379,462	(c)	31,049,462	30,315,776
1904	4,705,542	(c)	34,814,991	32,090,998
1905	9,731,936	(c)	117,866,240	111,009,956
1907	20,516,731	$3,130,839	149,454,307	126,635,416
1908	16,205,925	2,557,483	156,909,308	133,571,122
1912	54,491,248	4,650,517	212,391,168	148,282,725
1915	84,355,914	8,624,899	266,204,248	173,832,132
1917	131,026,575	11,360,335	342,151,129	195,031,424
1918	158,358,479	13,699,515	393,299,546	227,730,638

a Figures of production.
b Statistics not available.
c Value of coke-oven gas included with coal gas.
d Figures for oil gas included with water gas.
e Includes only surplus gas sold.

For consideration of the more recent changes the data of Table 3 are the most convenient. This table presents figures of production as well as of sales and also indicates the quantity of gas unaccounted for or wasted. These last figures are discussed later in this report.

TABLE 3.—*Artificial gas produced and sold in 1915, 1917, and 1918, by kinds.*

Kind.	Year.	Production (M).	Sales.		Unaccounted for (M).
			Quantity (M).	Value.	
Coal	1915	47,638,905	43,747,432	$40,257,108	3,891,473
	1917	47,525,148	42,927,728	38,324,113	4,597,420
	1918	48,486,546	42,659,487	42,846,964	5,827,059
Water	1915	136,333,318	124,129,569	112,281,956	12,203,749
	1917	174,357,536	153,457,318	131,876,065	20,900,218
	1918	193,046,980	175,597,423	155,426,672	17,449,557
Oil	1915	16,035,105	13,971,333	12,668,169	2,063,772
	1917	17,552,855	14,739,508	13,470,911	2,813,347
	1918	19,871,797	16,684,157	15,757,487	3,187,640
Coke-oven	1915	213,667,614	84,355,914	8,624,899	6,139,827
	1917	337,728,251	131,026,575	11,360,335	18,113,074
	1918	385,035,154	158,358,479	13,699,515	15,800,363
Total artificial	1915	413,674,942	266,204,248	173,832,132	24,298,821
	1917	577,163,790	342,151,129	195,031,424	46,424,059
	1918	646,440,477	393,299,546	227,730,638	42,264,619
Natural gas	1915	628,578,842	628,578,842	101,312,381	....
	1917	795,110,376	795,110,376	142,089,334	....
	1918	721,000,959	721,000,959	153,553,560	....
Grand total	1915	1,042,253,784	894,783,090	275,144,513	24,298,821
	1917	1,372,274,166	1,137,261,505	337,120,758	46,424,059
	1918	1,367,441,436	1,114,300,505	381,284,198	42,264,619

It is of interest to compare these figures for 1918, which have been gathered by the Geological Survey, with the estimates of operations for 1919, recently issued by the American Gas Association.[2] This association estimates the production of artificial gas in 1919 as follows: Carbureted water gas, 180 billion cubic feet; coal gas, 65.2 billion cubic feet; oil gas, 26.1 billion cubic feet; other gases, including coke-oven gas distributed by public utilities, 51 billion cubic feet; total, 322.3 billion cubic feet. This total for 1919 is less than half the total production for 1918 as shown by the Survey studies. However, the Survey figures include all the sales by coke-oven companies, many of which are sales for industrial purposes not properly classed as public-utility service.

The American Gas Association's summary of operations shows strikingly the magnitude of the artificial-gas industry in other particulars. It is estimated in the report cited that 4,600 cities, towns, and villages, including a population of more than 43,000,000 persons, are served by this industry. The customers of the gas companies aggregate about 8,500,000 and are supplied through mains more than 68,000 miles in total length. The Gas Association estimates that more than 71,000 persons and an investment of more than $4,000,000,000 are employed in this public-utility service.

The development of the gas industry during the World War, as shown in Table 3, is most striking in coke-oven gas. The output of coke-oven gas in 1918 was nearly double that of 1915. This was the natural result of the tremendous increase in requirements for metallurgical coke and the various by-products, such as ammonia and light oils, which are most efficiently produced from coal by coke-oven processes. It is probable that this rapid increase in supply of gas from coke ovens will be even more conspicuously shown in the report for 1920, as many of the industrial developments in this field were not completed until after the signing of the armistice. In fact, some of the war projects did not reach the operating stage until early in 1920.

So far as coal gas is concerned there has been little increase in output during recent years, and the increases in output of oil gas and water gas, although amounting to about 20 and 40 per cent, respectively, between 1915 and 1918, have been much less than in the output of coke-oven gas. The changes in value of gas sold during this period are more or less proportionate to the changes in quantity sold. The value reported here is almost invariably that determined by sales at prices fixed by public regulation, and in a large majority of instances these prices were not changed by the regulating authorities sufficiently to have any material effect on the aggregate figures here presented. This subject of the price of gas is discussed more fully in a later section of this report.

The data for 1917 and 1918 are presented by States in Tables 4 and 5. These tables show also the quantity of gas unaccounted for (difference between production and sales) and the average price per thousand cubic feet. These two items are discussed in greater detail in a later section. In the use of these and subsequent tables care should be exercised in discriminating between figures of production and figures of sales. This is more important for artificial gas than

[2] Am. Gas Assoc. Monthly, December, 1920.

for most other fuels or mineral products, because the "unaccounted for" gas represents a considerable percentage, even in the best modern practice.

TABLE 4.—*Artificial gas produced and sold in the United States in 1917, by States.*

[Including coke-oven gas.]

State.	Number of plants producing.	Production (M).	Sales.			Unaccounted for (M).
			Quantity (M).	Value.	Average price per M.	
Alabama	21	45,575,801	14,467,616	$1,658,001	$0.11	4,741,983
Arizona	9	289,186	258,412	413,700	1.60	30,774
Arkansas and Oklahoma	4	52,200	45,384	51,594	1.14	6,816
California	55	15,382,623	12,911,672	11,344,485	.88	2,470,951
Colorado	12	1,985,189	1,785,047	1,396,575	.78	200,142
Connecticut	29	6,021,869	5,504,141	5,454,677	.99	517,728
Delaware	6	745,085	669,641	632,318	.94	75,444
District of Columbia and Maryland	17	12,238,455	10,702,584	5,158,037	.48	644,553
Florida	16	981,411	882,067	1,131,523	1.28	99,344
Georgia	18	1,834,907	1,677,632	1,747,027	1.04	157,275
Idaho	3	92,929	83,826	126,257	1.51	9,103
Illinois	88	64,655,011	40,961,382	22,940,197	.56	4,154,380
Indiana	53	54,250,109	28,022,093	5,510,651	.20	1,537,024
Iowa	63	4,049,873	3,710,418	3,750,412	1.01	339,455
Kansas	7	115,562	104,537	131,239	1.26	11,025
Kentucky	10	8,400,618	4,294,599	334,159	.08	31,507
Louisiana	3	1,617,838	1,488,517	1,505,448	1.01	129,321
Maine	12	694,882	635,838	738,361	1.16	59,044
Massachusetts	70	24,448,210	19,034,012	14,420,276	.76	922,539
Michigan	77	24,559,349	13,102,278	7,293,561	.56	3,517,799
Minnesota	22	12,861,044	8,164,655	4,337,679	.53	870,893
Mississippi	9	231,105	171,432	218,745	1.28	59,673
Missouri	25	11,391,428	9,024,701	6,772,260	.75	504,491
Montana	6	249,493	211,453	339,352	1.60	38,040
Nebraska	17	1,630,078	1,528,518	1,634,296	1.07	101,560
Nevada	4	72,007	59,553	105,029	1.76	12,454
New Hampshire	12	760,824	697,045	804,173	1.15	63,779
New Jersey	34	24,109,147	17,145,974	13,445,832	.78	2,874,647
New Mexico and Wyoming	4	66,435	54,197	75,707	1.40	12,238
New York	98	79,855,470	58,970,761	44,477,695	.75	7,991,600
North Carolina	22	712,272	614,568	752,646	1.22	97,704
North Dakota	6	213,989	185,866	239,704	1.29	28,123
Ohio	24	55,452,672	24,888,287	1,984,766	.08	5,196,586
Oregon	10	1,854,186	1,549,607	1,604,637	1.04	304,579
Pennsylvania	95	82,381,832	37,248,111	17,722,630	.48	6,391,220
Rhode Island	7	2,938,647	2,772,908	2,490,285	.90	165,739
South Carolina	9	510,401	446,270	511,774	1.15	64,131
South Dakota	10	303,126	272,761	370,638	1.36	30,365
Tennessee	12	2,170,113	1,349,702	1,329,405	.99	501,411
Texas	22	2,167,572	1,914,387	2,140,530	1.12	253,185
Utah	4	557,419	491,156	438,882	.89	66,263
Vermont	10	272,727	242,298	314,182	1.30	30,429
Virginia	22	2,347,344	2,114,750	2,033,379	.96	232,594
Washington	17	2,106,584	1,936,425	1,645,002	.85	170,159
West Virginia	6	7,367,927	2,967,261	264,532	.09	10,212
Wisconsin	42	16,588,841	6,786,787	3,239,166	.48	692,777
	1,122	577,163,790	342,151,129	195,031,424	.57	46,424,059

TABLE 5.—*Artificial gas produced and sold in the United States in 1918, by States.*

[Including coke-oven gas.]

State.	Number of plants producing.	Production (M).	Sales.			Unaccounted for (M).
			Quantity (M).	Value.	Average price per M.	
Alabama	21	45,687,951	16,444,475	$1,796,335	$0.11	1,896,889
Arizona	8	478,366	295,038	480,684	1.63	183,328
Arkansas, Louisiana and Oklahoma	6	122,824	104,698	141,751	1.35	18,126
California	54	16,779,097	14,105,255	13,242,140	.94	2,673,842
Colorado	14	5,722,217	3,525,678	1,632,508	.46	586,138
Connecticut	28	6,808,327	6,195,291	6,659,453	1.07	613,036
Delaware	6	860,452	754,370	804,137	1.07	106,082
District of Columbia and Maryland	16	19,291,102	11,764,858	7,534,289	.64	578,101
Florida	16	1,115,097	977,666	1,340,210	1.37	137,431
Georgia	18	2,170,943	1,951,304	2,050,297	1.05	219,639
Idaho	3	92,657	78,433	129,124	1.65	14,224
Illinois	84	66,553,065	41,611,240	23,729,695	.57	3,092,855
Indiana	53	58,912,920	30,780,904	5,885,540	.19	3,196,358
Iowa	68	4,250,715	3,909,402	4,243,626	1.09	341,313
Kansas	8	140,542	123,980	164,957	1.33	16,562
Kentucky	10	8,211,016	4,279,853	202,914	.05	37,564
Maine	12	791,949	702,593	902,647	1.28	89,356
Massachusetts	70	25,385,944	20,377,687	17,875,542	.88	1,624,257
Michigan	78	25,526,416	15,854,146	9,338,332	.59	1,269,099
Minnesota	25	14,020,752	8,578,614	3,557,029	.41	224,384
Mississippi	9	270,414	210,249	265,326	1.26	60,165
Missouri	25	11,844,529	8,732,546	6,782,666	.78	1,186,021
Montana	7	253,482	215,090	346,435	1.65	38,392
Nebraska	18	1,716,718	1,573,251	1,931,888	1.23	143,467
Nevada	4	66,669	55,383	100,887	1.82	11,286
New Hampshire	13	813,626	735,556	951,616	1.29	78,070
New Jersey	36	24,157,945	18,692,369	13,995,166	.75	1,855,225
New Mexico and Wyoming	4	70,021	60,112	88,116	1.47	9,909
New York	97	92,898,494	73,143,190	57,235,865	.78	6,395,186
North Carolina	22	795,197	672,065	949,267	1.41	123,132
North Dakota	6	236,098	174,354	314,578	1.80	61,744
Ohio	29	78,364,690	37,071,480	2,597,138	.07	5,612,435
Oregon	10	2,512,260	2,200,382	1,901,879	.86	311,878
Pennsylvania	94	87,485,018	40,005,978	20,675,457	.52	7,352,301
Rhode Island	7	3,102,283	2,972,695	3,134,701	1.05	129,588
South Carolina	10	662,282	584,075	754,469	1.29	78,207
South Dakota	10	306,990	271,884	420,614	1.55	35,106
Tennessee	10	2,190,841	1,578,819	1,169,727	.74	232,701
Texas	24	2,645,694	2,262,819	2,529,242	1.12	382,875
Utah	4	552,550	500,403	493,680	.99	52,147
Vermont	10	295,525	263,656	358,517	1.36	31,869
Virginia	22	2,583,339	2,329,338	2,271,133	.98	254,001
Washington	16	2,596,459	2,312,713	2,370,192	1.02	283,746
West Virginia	6	9,029,198	4,387,080	374,344	.09	5,627
Wisconsin	43	18,067,803	9,878,574	4,006,525	.40	620,957
	1,134	646,440,477	393,299,546	227,730,638	.58	42,264,619

KINDS OF GAS PRODUCED AND SOLD.

Although the total number of gas plants in the United States has not materially changed during recent years, as appears from the data in Table 6, it is evident that there has been a distinct tendency to increase the number of companies supplying mixed coal and water gas. About the same number of companies were supplying coal gas in 1918 as in 1915, but there was an increase of 27 in the plants that combined water-gas manufacture with coal-gas manufacture. The reasons for this increase are the smaller investment and the shorter time required for increasing plant capacity by adding water-gas equipment as compared with coal-gas equipment. During this period there were considerable demands made upon the gas companies for increased output, and many of these companies could meet the demands only by adding facilities for manufacturing water gas.

This tendency was encouraged also by the fact that water-gas plants can be operated with much less labor per unit of output than coal-gas plants, and during the World War an adequate supply of labor was, of course, difficult to obtain at gas works as well as elsewhere. However, it should not be inferred from this tendency that the production of carbureted water-gas may be expected to increase at the same rate during the next three to five years. Quite the contrary can be expected, for a new and serious factor has entered through the increasing cost and difficulty of procuring an adequate supply of oil for the manufacture of carbureted water gas. It may safely be prophesied, therefore, that the tendency will be away from carbureted water gas during the coming decade rather than toward a continuation of its increase.

TABLE 6.—*Artificial-gas plants in the United States, 1915 and 1918.*

	1915	1918
Coal-gas plants (only)	271	250
Coal-gas plants operated with water-gas plants	123	150
Coal-gas plants operated with oil-gas plants	2	3
	396	403
Water-gas plants (only)	430	431
Water-gas plants operated with coal-gas plants	123	150
Water-gas plants operated with oil-gas plants	....	3
	553	584
Oil-gas plants (only)	91	81
Oil-gas plants operated with coal-gas plants	2	3
Oil-gas plants operated with water-gas plants	....	3
	93	87
By-product coke-oven plants	41	60

The distribution of gas plants throughout the country is shown by Table 7, which gives for each State the number of artificial-gas plants reporting operations in 1918. The total number of plants does not necessarily represent either the total number of operating companies or the total number of works within the State, for a single company may operate several works, and a single works may supply gas for several distributing companies.

TABLE 7.—*Artificial-gas plants in the United States, 1918, by kinds of gas.*

State.	Coke-oven.	Coal gas.	Water gas.	Oil gas.	Coal gas and water gas.	Coal gas and oil gas.	Water gas and oil gas.	Total.
Alabama	5	6			5			16
Arizona				8				8
Arkansas					1			1
California		1		53				54
Colorado	1	4	3		3			11
Connecticut			16		6			22
Delaware		2	4					6
District of Columbia			2					2
Florida		1	13		1			15
Georgia		9	5		2			16
Idaho		3						3
Illinois	4	20	25		18			67
Indiana	6	19	12		8			45
Iowa		6	42		9		1	58
Kansas		1	5		1			7
Kentucky	1	8	1					10
Louisiana		1	1					2
Maine		6	4		1			11
Maryland	1	5	8					14
Massachusetts	1	12	19		19			51
Michigan	2	34	6		15	3		60
Minnesota	3	7	12	1	1			24
Mississippi		6	1		1			8
Missouri	1	7	14	1	1			24
Montana		2	2		1			5
Nebraska		1	17					18
Nevada				4				4
New Hampshire		2	6	1	1		1	11
New Jersey	2	3	29		1			35
New Mexico		1		1				2
New York	4	17	46		15			82
North Carolina		7	11		2			20
North Dakota		2	2		1			5
Ohio	13	8	5	1	1			28
Oklahoma					1			1
Oregon		3	1	6				10
Pennsylvania	10	9	66	1	4			90
Rhode Island			1		3			4
South Carolina		1	5		2			8
South Dakota		1	7		1			9
Tennessee	1	4	1		2			8
Texas		2	13	3	2		1	21
Utah		2			1			3
Vermont		1	7		1			9
Virginia		4	2		8			14
Washington	1	5	2		4			12
West Virginia	2	2	2					6
Wisconsin	2	13	13	1	7			36
Wyoming		2						2
	60	250	431	81	150	3	3	978

The total number of companies reported as operating has not materially changed during recent years. In the older, more densely settled States there has been a decrease in the number of manufacturing plants by a consolidation or affiliation of distributing companies that draw their gas supply from a single works.

The increase in number resulting from the establishment of new plants in the smaller towns, especially in the younger or more sparsely settled States, has been largely offset by a decrease in the older, more densely settled States, resulting from the consolidation of distributing companies that draw their gas supply from a single works.

The tendency for manufactured gas to replace natural gas as a municipal supply in districts where natural gas is available apparently has not yet become appreciable, although doubtless with the rapid diminution of the natural-gas supply this tendency will become important during the coming decade.

It is of great interest to compare this tabulation of gas-manufacturing plants (Table 7) with the tabulation of the gas-distributing companies of the country prepared by the American Gas Association (Tables 8 and 9). In general there are a few more distributing companies in each State than manufacturing works, and there are a few more companies distributing each kind of gas than are reported as manufacturing it. This results from the fact that in many places a single works supplies gas for two or more distribution systems.

TABLE 8.—*Number of companies distributing artificial gas in 1919, by States.*[3]

[Estimates by American Gas Association.]

Alabama	12	Maine	13	Oregon	11
Arizona	10	Maryland	13	Pennsylvania	83
Arkansas	1	Massachusetts	62	Rhode Island	8
California	59	Michigan	58	South Carolina	8
Colorado	10	Minnesota	24	South Dakota	9
Connecticut	25	Mississippi	8	Tennessee	8
Delaware	6	Missouri	24	Texas	19
District of Columbia	2	Montana	4	Utah	3
Florida	17	Nebraska	19	Vermont	9
Georgia	16	Nevada	3	Virginia	16
Hawaii	2	New Hampshire	12	Washington	14
Idaho	3	New Jersey	39	Wisconsin	39
Illinois	66	New Mexico	2	West Virginia	3
Indiana	41	New York	97	Wyoming	2
Iowa	56	North Carolina	20		
Kansas	6	North Dakota	5		[4] 1,000
Kentucky	9	Ohio	18		
Louisiana	5	Oklahoma	1		

TABLE 9.—*Number of companies distributing artificial gas in 1919, by kinds of gas.*[5]

[Estimates by American Gas Association.]

Water gas exclusively	435
Coal gas exclusively	247
Coal and water gas mixed	168
Oil gas	101
Coke-oven gas exclusively	23
Coke-oven mixed with other gas	18
Oil and coal mixed	5
Uncertain	3
	1,000

Tables 10 to 13 give for each kind of gas a full report, by States, for the years 1915, 1917, and 1918. (No data were gathered during 1916.) In a few States the number of companies reporting production is less than three, and in order to avoid disclosing individual operations such States are combined in geographic groups.

[3] Where a producing company sells its product to another company for distribution to the public, only the distributing company is counted.

[4] Includes 43 municipal plants supplying artificial gas to the public and 24 coke-oven plants selling gas to distributing companies.

[5] Where a producing company sells its gas to another company for distribution to the public, only the distributing company is included.

TABLE 10.—*Coal gas produced and sold in the United States in 1915, 1917, and 1918, by States.*

State.	Number of plants producing.	Gas produced (M).	Gas sold.			Gas unaccounted for.	
			Quantity (M).	Value.	Average price per M.	Quantity (M).	Percentage of total produced
1915.							
Alabama	11	920,282	700,550	$747,587	$1.07	219,732	23.9
California, New Mexico and Wyoming	3	40,966	33,571	47,651	1.42	7,395	18.1
Colorado	6	1,241,028	1,114,720	897,300	.80	126,308	10.2
Connecticut	9	1,544,694	1,469,954	1,403,556	.95	74,740	4.8
Delaware, Florida, South Carolina, Vermont, and West Virginia	8	369,764	326,718	395,975	1.21	43,046	11.6
District of Columbia and Maryland	7	383,678	321,228	314,180	.98	62,450	16.3
Georgia	10	731,058	683,277	799,190	1.17	47,781	6.5
Idaho	3	78,702	73,161	122,064	1.53	5,541	7.0
Illinois	36	2,363,304	2,162,620	2,177,831	1.01	200,684	8.5
Indiana	26	1,459,512	1,315,835	1,312,111	1.00	143,677	9.8
Iowa	12	601,700	545,793	567,137	1.04	55,907	9.3
Kansas, North Dakota, and South Dakota	6	196,130	173,614	235,261	1.36	22,516	11.5
Kentucky	9	136,780	114,261	122,612	1.07	22,519	16.5
Louisiana and Texas	3	130,423	112,735	146,270	1.30	17,688	13.6
Maine	6	360,736	315,092	359,714	1.14	45,644	12.7
Massachusetts	32	5,841,499	5,527,794	4,847,885	.88	313,705	5.4
Michigan	50	6,371,003	5,862,042	5,033,718	.86	508,961	8.0
Minnesota	7	878,077	824,221	687,492	.83	53,856	6.1
Mississippi	6	126,108	103,139	130,183	1.26	22,969	18.2
Missouri	9	3,438,166	3,249,282	2,621,959	.81	188,884	5.5
Montana	3	102,306	85,452	136,674	1.33	16,854	16.5
New Hampshire	4	139,291	126,655	159,058	1.26	12,636	9.1
New Jersey	7	1,044,634	963,245	912,606	.95	81,389	7.8
New York	34	8,347,116	8,035,240	6,839,006	.85	311,876	3.7
North Carolina	9	399,401	345,707	442,449	1.28	53,694	13.4
Ohio	10	923,374	820,583	670,730	.82	102,791	11.1
Oklahoma	3	55,438	48,446	56,561	1.17	6,992	12.6
Oregon	3	33,260	29,521	50,579	1.71	3,739	11.2
Pennsylvania	13	2,588,615	2,106,090	2,139,810	1.02	482,525	18.6
Rhode Island	3	1,139,513	1,068,440	954,818	.89	71,073	6.2
Tennessee	6	651,249	563,489	575,338	1.02	87,760	13.5
Utah	3	477,853	395,454	366,506	.93	82,399	17.2
Virginia	11	870,716	759,843	765,444	1.01	110,873	12.7
Washington	9	1,259,320	1,155,195	1,252,603	1.08	104,125	8.3
Wisconsin	19	2,393,209	2,214,465	1,965,250	.89	178,744	7.5
	396	47,638,905	43,747,432	40,257,108	.92	3,891,473	8.2
1917.							
Alabama	11	873,705	739,509	749,530	1.01	134,196	15.4
Arkansas, Louisiana, and Oklahoma	3	55,205	49,331	63,520	1.29	5,874	10.6
California, New Mexico, and Wyoming	4	57,633	47,018	64,053	1.36	10,615	18.4
Colorado	6	1,520,610	1,373,765	1,065,539	.78	146,845	9.7
Connecticut	7	1,418,242	1,302,021	1,246,645	.96	116,221	8.2
Delaware, Vermont, and West Virginia	6	107,054	95,095	128,663	1.35	11,959	11.2
District of Columbia and Maryland	6	155,641	126,923	147,770	1.16	28,718	18.5
Florida and South Carolina	4	370,958	309,368	357,361	1.16	61,590	16.6
Georgia	11	728,748	657,360	703,940	1.07	71,388	9.8
Idaho	3	92,929	83,826	126,257	1.51	9,103	9.8
Illinois	39	2,641,430	2,319,796	2,284,654	.98	321,634	12.2
Indiana	27	1,683,164	1,499,469	1,440,450	.96	183,695	10.9
Iowa	11	591,845	528,639	520,327	.98	63,206	10.7
Kansas, Nebraska, and South Dakota	5	82,989	75,718	101,716	1.34	7,271	8.8
Kentucky	8	135,603	114,879	125,740	1.09	20,724	15.3
Maine	7	459,477	413,062	472,245	1.14	46,415	10.1
Massachusetts	31	5,999,509	5,573,567	4,948,485	.89	425,942	7.1
Michigan	52	7,014,732	6,406,931	5,381,004	.84	607,801	8.7
Minnesota	8	988,358	933,490	750,893	.80	54,868	5.6
Mississippi	7	159,424	120,764	148,599	1.23	38,660	24.2
Missouri	9	4,539,976	4,242,672	3,127,736	.74	297,304	6.5
Montana	3	135,237	107,879	187,477	1.74	27,358	20.2

TABLE 10.—*Coal gas produced and sold in the United States in 1915, 1917, and 1918, by States*—Continued.

State.	Number of plants producing.	Gas produced (M).	Gas sold.			Gas unaccounted for.	
			Quantity (M).	Value.	Average price per M.	Quantity (M).	Percentage of total produced
1917—Continued.							
New Hampshire	3	132,794	122,903	$162,111	$1.32	9,891	7.4
New Jersey	5	724,662	637,891	597,118	.94	86,771	12.0
New York	33	6,223,949	5,777,449	4,297,773	.74	446,500	7.2
North Carolina	9	520,125	443,829	523,605	1.18	76,296	14.7
North Dakota	3	187,659	160,846	204,152	1.27	26,813	14.3
Ohio	8	284,218	249,051	272,570	1.09	35,167	12.4
Oregon	3	39,444	35,286	60,952	1.73	4,158	10.5
Pennsylvania	14	2,588,909	2,373,501	2,305,740	.97	215,408	8.3
Rhode Island	3	1,109,538	1,029,314	922,671	.90	80,224	7.2
Tennessee	7	696,048	602,479	590,962	.98	93,569	13.4
Texas	3	160,755	146,626	180,847	1.23	14,129	8.8
Utah	3	433,656	383,170	348,188	.91	50,486	11.6
Virginia	12	1,011,001	905,601	919,983	1.02	105,400	10.4
Washington	9	856,016	749,978	862,045	1.15	106,038	12.4
Wisconsin	19	2,743,905	2,188,722	1,932,792	.88	555,183	20.2
	402	47,525,148	42,927,728	38,324,113	.89	4,597,420	9.7
1918.							
Alabama	11	781,437	636,710	661,820	1.04	144,727	18.5
Arkansas, Louisiana, and Oklahoma	3	74,523	63,453	81,363	1.28	11,070	14.9
California, New Mexico, and Wyoming	4	59,780	52,692	74,985	1.42	7,088	11.9
Colorado	7	1,655,731	1,458,430	1,227,938	.84	197,301	11.9
Connecticut	6	1,381,215	1,285,782	1,354,690	1.05	95,433	6.9
Delaware, Vermont, and West Virginia	6	110,610	97,879	140,596	1.44	12,731	11.5
District of Columbia and Maryland	5	98,342	81,204	118,785	1.46	17,138	17.4
Florida and South Carolina	5	419,429	355,770	462,228	1.30	63,659	15.2
Georgia	11	847,714	746,015	790,926	1.06	101,699	12.0
Idaho	3	92,657	78,433	129,124	1.65	14,224	15.3
Illinois	37	2,660,186	2,286,734	2,392,038	1.05	373,452	14.0
Indiana	27	1,668,828	1,431,337	1,429,624	1.00	237,491	14.2
Iowa	15	775,991	699,860	770,741	1.10	76,131	9.8
Kansas, Nebraska, and South Dakota	5	79,562	67,746	96,171	1.42	11,816	14.9
Kentucky	8	139,063	115,456	133,171	1.15	23,607	17.0
Maine	7	379,057	325,353	431,431	1.33	53,704	14.2
Massachusetts	31	5,749,292	5,388,115	5,640,203	1.05	361,177	6.3
Michigan	52	6,985,722	6,345,491	5,763,127	.91	640,231	9.2
Minnesota	8	1,054,690	984,043	918,606	.93	70,647	6.7
Mississippi	7	191,749	148,740	180,606	1.21	43,009	22.4
Missouri	8	4,758,170	4,068,189	3,006,193	.74	689,981	14.5
Montana	4	156,304	125,754	215,480	1.71	30,550	19.5
New Hampshire	3	141,428	127,371	185,860	1.46	14,057	9.9
New Jersey	4	262,345	227,942	249,295	1.09	34,403	13.1
New York	32	7,937,874	6,752,097	7,183,094	1.06	1,185,777	14.9
North Carolina	9	510,282	430,246	595,268	1.38	80,036	15.7
North Dakota	3	208,987	149,120	273,107	1.83	59,867	28.6
Ohio	9	303,441	248,893	288,207	1.16	54,548	18.0
Oregon	3	41,231	36,477	63,460	1.74	4,754	11.5
Pennsylvania	13	2,141,931	1,844,865	1,904,048	1.03	297,066	13.9
Rhode Island	3	639,315	613,340	643,016	1.05	25,975	4.1
Tennessee	6	593,354	509,967	453,913	.89	83,387	14.1
Texas	4	200,658	185,363	230,371	1.24	15,295	7.6
Utah	3	459,780	418,408	414,534	.99	41,372	8.3
Virginia	12	1,039,234	939,277	947,868	1.01	99,957	9.6
Washington	9	1,051,184	920,395	1,149,296	1.25	130,789	12.4
Wisconsin	20	2,835,450	2,412,540	2,245,781	.93	422,910	14.9
	403	48,486,546	42,659,487	42,846,964	1.00	5,827,059	12.0

TABLE 11.—*Water gas produced and sold in the United States in 1915, 1917, and 1918, by States.*

State.	Number of plants producing.	Gas produced (M).	Gas sold.			Gas unaccounted for.	
			Quantity (M).	Value.	Average price per M.	Quantity (M).	Percentage of total produced
1915.							
Alabama	3	174,828	118,402	$118,811	$1.00	56,426	32.3
Arkansas, Louisiana, Mississippi, and Oklahoma	6	1,408,320	1,298,104	1,392,215	1.07	110,216	7.8
California, Oregon, and Utah	4	731,078	606,971	540,874	.89	124,107	17.0
Colorado	6	484,223	446,496	357,651	.80	37,727	7.8
Connecticut	19	3,162,835	2,960,863	3,014,162	1.02	201,972	6.4
Delaware	5	571,554	508,445	492,056	.97	63,109	11.0
District of Columbia and Maryland	9	5,878,366	5,497,663	4,584,967	.83	380,703	6.5
Florida	13	539,428	504,596	736,705	1.46	34,832	6.5
Georgia	6	850,861	796,490	892,932	1.12	54,371	6.4
Illinois	40	21,411,816	19,963,203	16,887,480	.85	1,448,613	6.8
Indiana	15	1,697,775	1,551,421	1,485,971	.96	146,354	8.6
Iowa	50	2,864,696	2,699,452	2,778,457	1.03	165,244	5.8
Kansas	5	56,190	48,553	65,784	1.35	7,637	13.6
Kentucky and West Virginia	4	143,608	107,072	101,786	.95	36,536	25.4
Maine	4	231,543	207,754	243,572	1.17	23,789	10.3
Massachusetts	35	8,287,306	7,906,829	6,921,775	.88	380,477	4.6
Michigan	17	1,692,762	1,562,242	1,214,140	.78	130,520	7.7
Minnesota	9	3,550,815	3,338,831	2,715,552	.81	211,984	6.0
Missouri	14	2,816,988	2,636,691	2,238,254	.85	180,297	6.4
Montana	3	70,542	65,987	93,958	1.42	4,555	6.5
Nebraska	18	1,358,010	1,291,725	1,444,252	1.12	66,285	4.9
New Hampshire	8	523,284	467,593	544,333	1.16	55,691	10.6
New Jersey	26	11,970,196	10,218,331	9,555,335	.94	1,751,865	14.6
New York	63	46,939,337	42,542,557	36,286,939	.85	4,396,780	9.4
North Carolina	11	134,099	113,343	154,406	1.36	20,756	15.5
North Dakota	3	25,406	25,248	40,352	1.60	158	0.6
Ohio	7	314,167	278,518	211,321	.76	35,649	11.3
Pennsylvania	70	12,648,668	11,186,356	11,469,138	1.03	1,462,312	11.5
Rhode Island	4	525,433	486,102	520,299	1.07	39,331	7.5
South Carolina	7	386,195	348,735	424,389	1.22	37,460	9.7
South Dakota	8	224,880	207,753	294,949	1.42	17,127	7.6
Tennessee	3	504,405	465,956	465,956	1.00	38,449	7.6
Texas	17	1,593,583	1,413,462	1,622,795	1.15	180,121	11.3
Vermont	7	181,280	164,541	217,220	1.32	16,739	9.2
Virginia	10	974,904	842,008	822,879	.98	132,896	13.6
Washington	5	662,133	599,413	611,716	1.02	62,720	9.5
Wisconsin	18	741,804	651,863	718,575	1.10	89,941	12.1
	552	136,333,318	124,129,569	112,281,956	.90	12,203,749	9.0
1917.							
Alabama	5	279,739	245,496	234,580	.96	34,243	12.2
Arkansas, Louisiana, Mississippi and Oklahoma	5	1,676,940	1,526,238	1,554,182	1.02	150,702	9.0
California, Oregon and Utah	3	225,364	198,831	178,255	.90	26,533	11.8
Colorado	6	464,579	411,282	331,036	.80	53,297	11.5
Connecticut	22	4,603,627	4,202,120	4,208,032	1.00	401,507	8.7
Delaware	4	735,759	660,630	621,302	.94	75,129	10.2
District of Columbia and Maryland	10	7,079,276	6,474,348	4,725,375	.73	604,928	8.5
Florida	14	680,707	628,718	847,417	1.35	51,989	7.6
Georgia	7	1,106,159	1,020,272	1,043,087	1.02	85,887	7.8
Illinois	45	28,249,979	25,045,851	19,554,401	.78	3,204,128	11.3
Indiana	20	2,439,820	2,223,605	1,869,466	.84	216,215	8.9
Iowa	51	3,455,141	3,179,531	3,227,282	1.02	275,610	8.0
Kansas	5	63,973	58,007	71,566	1.23	5,966	9.3
Kentucky and West Virginia	3	77,748	64,578	80,025	1.24	13,170	16.9
Maine	5	235,405	222,776	266,116	1.19	12,629	5.4
Massachusetts	38	11,059,971	10,563,374	8,686,827	.82	496,597	4.5
Michigan	23	4,714,565	2,144,728	1,646,498	.77	2,569,837	54.5
Minnesota	12	4,091,264	3,868,063	3,261,708	.84	223,201	5.5
Missouri	14	2,773,261	2,566,574	2,060,574	.80	206,687	7.5
Montana	3	114,256	103,574	151,875	1.47	10,682	9.3
Nebraska	16	1,620,878	1,519,879	1,622,954	1.07	100,999	6.2
New Hampshire	8	627,598	573,740	639,600	1.11	53,858	8.6
New Jersey	27	15,091,135	13,386,384	12,141,280	.91	1,704,751	11.3
New York	59	57,485,365	49,938,270	39,879,658	.80	7,547,095	13.1
North Carolina	13	192,147	170,739	229,041	1.34	21,408	11.1
North Dakota	3	26,330	25,020	35,552	1.42	1,310	5.0

TABLE 11.—*Water gas produced and sold in the United States in 1915, 1917, and 1918, by States*—Continued.

State.	Number of plants producing.	Gas produced (M).	Gas sold.			Gas unaccounted for.	
			Quantity (M).	Value.	Average price per M.	Quantity (M).	Percentage of total produced
1917—Continued.							
Ohio	6	431,323	338,563	$306,193	$0.90	92,760	21.5
Pennsylvania	69	15,792,148	14,008,345	14,213,585	1.01	1,783,803	11.3
Rhode Island	4	1,829,109	1,743,594	1,567,614	.90	85,515	4.7
South Carolina	7	440,147	390,251	438,519	1.12	49,896	11.3
South Dakota	8	280,926	252,212	339,937	1.35	28,714	10.2
Tennessee	4	836,065	710,420	736,603	1.04	125,645	15.0
Texas	16	1,963,810	1,728,516	1,909,314	1.10	235,294	12.0
Vermont	8	199,281	177,271	225,097	1.27	22,010	11.0
Virginia	10	1,336,343	1,209,149	1,113,396	.92	127,194	9.5
Washington	6	788,631	724,613	721,793	1.00	64,018	8.1
Wisconsin	20	1,288,767	1,151,756	1,136,325	.99	137,011	10.6
	579	174,357,536	153,457,318	131,876,065	.86	20,900,218	12.0
1918.							
Alabama	5	594,357	486,396	482,210	.99	107,961	18.2
Arkansas, Louisiana, Mississippi and Oklahoma	5	126,966	102,754	145,108	1.41	24,212	25.0
Colorado	6	478,211	477,104	396,619	.83	1,107	0.2
Connecticut	22	5,427,112	4,909,509	5,304,763	1.08	517,603	9.5
Delaware	4	851,126	745,359	793,121	1.06	105,767	12.4
District of Columbia and Maryland	10	10,055,419	9,494,456	7,210,551	.76	560,963	5.6
Florida	14	806,195	716,248	1,013,635	1.42	89,947	11.2
Georgia	7	1,323,229	1,205,289	1,259,371	1.05	117,940	8.9
Illinois	43	28,383,751	26,049,756	20,227,700	.78	2,333,995	8.2
Indiana	20	3,120,642	2,611,282	2,247,604	.86	509,360	16.3
Iowa	52	3,471,837	3,207,294	3,470,082	1.08	264,543	7.6
Kansas	6	90,887	79,880	106,210	1.33	11,007	12.1
Kentucky and West Virginia	3	80,395	63,467	95,171	1.50	16,928	21.1
Maine	5	412,892	377,240	471,216	1.25	35,652	8.6
Massachusetts	38	12,868,652	12,160,284	11,482,855	.94	708,368	5.5
Michigan	21	4,144,305	3,896,968	3,033,475	.78	247,337	6.0
Minnesota	13	2,536,877	2,491,264	2,032,058	.82	45,613	1.8
Missouri	15	3,122,493	2,626,461	2,309,476	.88	496,032	15.9
Montana, Oregon, and Utah	5	219,063	198,185	244,926	1.24	20,878	9.5
Nebraska	17	1,708,077	1,565,551	1,920,269	1.23	142,526	8.3
New Hampshire	8	660,723	597,801	746,978	1.25	62,922	9.5
New Jersey	30	15,064,627	13,243,805	12,811,536	.97	1,820,822	12.1
New York	61	66,968,260	61,758,851	49,529,817	.80	5,209,409	7.8
North Carolina	13	284,915	241,819	353,999	1.46	43,096	15.1
North Dakota	3	27,111	25,234	41,471	1.64	1,877	6.9
Ohio	6	207,352	175,257	191,602	1.09	32,095	15.5
Pennsylvania	70	18,842,972	16,124,817	16,938,479	1.05	2,718,155	14.4
Rhode Island	4	2,462,968	2,359,355	2,491,685	1.06	103,613	4.2
South Carolina	7	551,755	489,723	618,816	1.26	62,032	11.2
South Dakota	8	285,724	255,938	394,809	1.54	29,786	10.4
Tennessee	3	921,362	772,048	676,217	.88	149,314	16.2
Texas	16	2,388,464	2,028,781	2,236,995	1.10	359,683	15.1
Vermont	8	220,182	198,073	259,456	1.31	22,109	10.0
Virginia	10	1,544,105	1,390,061	1,323,265	.95	154,044	10.0
Washington	6	1,078,385	953,093	1,074,914	1.13	125,292	11.6
Wisconsin	20	1,715,589	1,518,020	1,490,213	.98	197,569	11.5
	584	193,046,980	175,597,423	155,426,672	.89	17,449,557	9.0

TABLE 12.—*Oil gas produced and sold in the United States in 1915, 1917, and 1918, by States.*

State.	Number of plants producing.	Gas produced (M).	Gas sold.			Gas unaccounted for.	
			Quantity (M).	Value.	Average price per M.	Quantity (M).	Percentage of total produced
1915.							
Arizona	7	165,140	157,000	$252,985	$1.61	8,140	4.9
California	62	14,095,041	12,278,118	10,902,167	.89	1,816,923	12.9
Connecticut, Massachusetts, and New Hampshire	4	82,505	75,670	103,842	1.37	6,835	8.3
Illinois, Michigan, Minnesota, Ohio, and Wisconsin	6	14,185	13,149	22,408	1.70	1,036	7.3
Louisiana, Missouri, New Mexico, and Texas	5	42,031	36,507	53,826	1.47	5,524	13.1
Nevada	3	49,363	43,201	89,787	2.08	6,162	12.5
Oregon	6	1,586,840	1,367,688	1,243,154	.91	219,152	13.8
	93	16,035,105	13,971,333	12,668,169	.91	2,063,772	12.9
1917.							
Arizona	9	289,186	258,412	413,700	1.60	30,774	10.6
California	53	15,309,969	12,848,242	11,286,575	.88	2,461,727	16.1
Indiana, Iowa, Ohio, and Wisconsin	4	17,431	15,650	22,505	1.44	1,781	10.2
Louisiana, Missouri, and New Mexico	3	24,576	21,879	30,139	1.38	2,697	11.0
Nevada and Washington	5	72,870	60,313	105,956	1.76	12,557	17.2
New Hampshire, New York, and Pennsylvania	3	11,721	10,561	51,882	4.91	1,160	9.9
Oregon	6	1,784,095	1,485,206	1,509,785	1.02	298,889	16.8
Texas	3	43,007	39,245	50,369	1.28	3,762	8.7
	86	17,552,855	14,739,508	13,470,911	.91	2,813,347	16.0
1918.							
Arizona	8	478,366	295,038	480,684	1.63	183,328	38.3
California	53	16,777,938	14,104,207	13,238,733	.94	2,673,731	15.9
Iowa, Minnesota, Missouri, and Wisconsin	4	14,026	12,651	22,411	1.77	1,375	9.8
Michigan	3	1,805	1,423	2,071	1.46	382	21.2
Nevada	4	66,669	55,383	100,887	1.82	11,286	16.9
New Hampshire, Ohio, and Pennsylvania	4	23,107	21,261	30,693	1.44	1,846	8.0
New Mexico and Texas	5	67,972	57,143	78,414	1.37	10,829	15.9
Oregon	6	2,441,914	2,137,051	1,803,594	.84	304,863	12.5
	87	19,871,797	16,684,157	15,757,487	.94	3,187,640	16.0

TABLE 13.—*Coke-oven gas produced and sold in the United States in 1915, 1917, and 1918, by States.*

State.	Number of plants producing.	Gas produced (M).	Gas used in process (M).	Gas sold.			Unaccounted for (M).
				Quantity (M).	Value.	Average price per M.	
1915.							
Alabama	4	35,120,074	20,550,141	13,490,740	$462,842	$0.03	1,079,193
Illinois	4	26,416,867	13,535,605	12,285,324	1,220,354	.10	595,938
Indiana	3	41,845,886	19,220,187	20,614,337	1,941,740	.09	2,011,362
Kentucky	1	3,832,179	1,895,645	1,936,534	77,461	.04	....
Maryland	1	4,685,646	2,210,369	2,453,474	(a)	(a)	21,803
Massachusetts	1	6,655,544	3,735,960	2,919,584	(a)	(a)	....
Minnesota	2	1,349,983	781,808	568,175	188,009	.33	....
New Jersey	1	2,973,938	1,014,153	1,959,785	(a)	(a)	....
New York	3	8,972,061	6,807,716	2,164,345	138,426	.06	....
Ohio	3	10,251,929	4,868,537	3,783,236	199,789	.05	1,600,156

[a] Included in combined States.

TABLE 13.—*Coke-oven gas produced and sold in the United States in 1915, 1917, and 1918, by States*—Continued.

State.	Number of plants producing.	Gas produced (M).	Gas used in process (M).	Gas sold. Quantity (M).	Gas sold. Value.	Gas sold. Average price per M.	Unaccounted for (M).
1915—Contd.							
Pennsylvania	9	48,396,030	33,862,518	14,215,164	$1,254,678	$0.09	318,348
Tennessee	1	224,540	193,138	31,402	1,515	.05	....
Washington	1	501,407	250,703	250,704	79,807	.32	....
West Virginia	1	2,012,278	1,881,051	131,227	5,249	.04	....
Michigan, Missouri, Wisconsin	6	20,429,252	12,364,342	7,551,883	a 3,055,029	a.21	513,027
	41	213,667,614	123,171,873	84,355,914	8,624,899	.10	6,139,827
1917.							
Alabama	5	44,422,357	26,366,202	13,482,611	673,891	.05	4,573,544
Illinois	4	33,763,602	19,539,249	13,595,735	1,101,142	.08	628,618
Indiana	5	50,125,497	24,690,992	24,297,400	2,198,581	.09	1,137,105
Kentucky	1	8,215,939	4,074,512	4,141,427	165,160	.04	....
Maryland	1	5,003,538	891,318	4,101,313	(b)	(b)	10,907
Massachusetts	1	7,388,730	4,491,659	2,897,071	(b)	(b)	....
Minnesota	2	7,781,422	3,825,496	3,363,102	325,078	.10	592,824
New Jersey	2	8,293,350	4,088,526	3,121,699	(b)	(b)	1,083,125
New York	5	16,137,492	12,890,109	3,247,383	255,220	.08	....
Ohio	9	54,729,281	25,367,799	24,293,373	1,399,433	.06	5,068,109
Pennsylvania	11	63,998,150	38,742,501	20,863,765	1,198,929	.06	4,391,884
Tennessee	1	638,000	319,000	36,803	1,840	.05	282,197
Washington	1	461,074	....	461,074	60,237	.13	....
West Virginia	2	7,314,973	4,390,454	2,919,919	199,204	.07	4,600
Michigan, Missouri, Wisconsin	5	29,454,846	18,910,785	10,203,900	a 3,781,620	a.19	340,161
	55	337,728,251	188,588,602	131,026,575	11,360,335	.09	18,113,074
1918.							
Alabama	5	44,312,157	27,346,587	15,321,369	652,305	.04	1,644,201
Colorado	1	3,588,275	1,610,401	1,590,144	(b)	(b)	387,730
Illinois	4	35,509,128	21,848,970	13,274,750	1,109,957	.08	385,408
Indiana	6	54,123,450	24,935,658	26,738,285	2,208,312	.08	2,449,507
Kentucky	1	8,021,323	3,893,599	4,127,724	18,875	.05	....
Maryland	1	9,137,341	6,948,143	2,189,198	(b)	(b)	....
Massachusetts	1	6,768,000	3,384,000	2,829,288	(b)	(b)	554,712
Minnesota	3	10,428,585	5,217,764	5,102,957	605,915	.12	107,864
New Jersey	2	8,830,973	3,610,351	5,220,622	(b)	(b)	....
New York	4	17,992,360	13,360,118	4,632,242	522,954	.11	....
Ohio	13	77,844,890	35,680,775	36,638,953	2,109,790	.06	5,525,162
Pennsylvania	10	66,497,490	40,126,614	22,033,796	1,828,554	.08	4,337,080
Tennessee	1	676,125	379,321	296,804	39,597	.13	....
Washington	1	466,890	....	439,225	145,982	.33	27,665
West Virginia	2	8,973,492	4,636,491	4,337,001	299,522	.07	....
Michigan, Missouri, Wisconsin	5	31,864,675	17,897,520	13,586,121	a 4,157,752	a.16	381,034
	60	385,035,154	210,876,312	158,358,479	13,699,515	.09	15,800,363

a Includes also Maryland, Massachusetts, and New Jersey, with Colorado additional in 1918.
b Included in combined States.

CAPACITY OF GAS PLANTS.

The number of gas plants has not materially changed during recent years, but the total production and sales of gas have increased considerably. It is obvious, therefore, that the average sales per plant must have increased. This fact is brought out strikingly in Table 14, which shows the number of plants and the average sales per plant for each kind of gas during the period of 20 years from 1898 to 1918, so far as data are available. (See also fig. 19.) There has been a notable increase in the average for both water gas and oil gas, continuing up to the latest years for which figures are available, and a considerable increase in the average for coke-oven gas. In coal gas, however, the increase in sales per plant which was marked during the first 15 years of the present century has not continued, and the average in 1918 was less than in 1915 or 1917. Probably this fact is partly the result of war conditions which precluded the increase of coal gas installations because of the greater cost per unit of capacity, the longer time required for installation, and the greater seriousness of labor problems. Furthermore, poor coal, inefficient labor, and depreciation in plant, which could not be cared for because repairs were especially difficult and expensive during war times, all contributed to decrease the output from the old coal-gas plants.

There was an increase of about 40 per cent in the average sales per plant for coke-oven gas between 1912 and 1918. This was the result of an increase in the size of plants as well as of the growing tendency to sell surplus gas rather than to use it freely, or even wastefully, in the coke-oven operations. This figure will probably

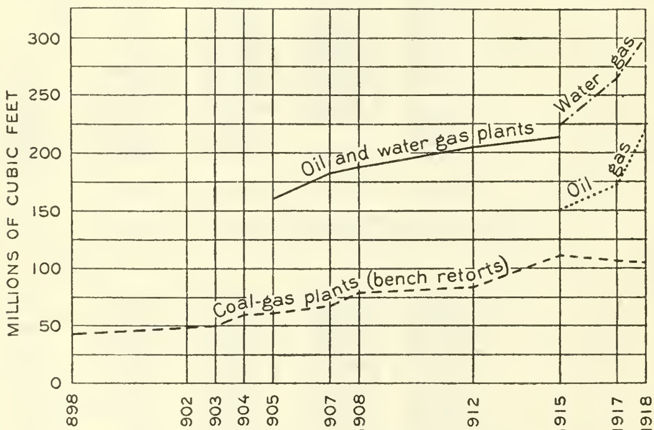

FIGURE 19.—Artificial gas sold per plant in the United States, 1898–1918.

continue to increase indefinitely. With the rising price of oil, an increase is also again to be expected in the average size of coal-gas plant and therefore in the average sales per plant, for coal gas does not require oil as a raw material. Whether the average sales of water gas and oil gas per plant will correspondingly decrease is not by any means certain, as the replacement of existing water-gas and oil-gas equipment by coal-gas facilities can not proceed as rapidly as might be expected on considering only the relative thermal efficiency of the processes. The difficulty in procuring capital and the high cost per unit of plant capacity for coal gas still tend to encourage extensions of water-gas and oil-gas plants. Furthermore, with the gradual decrease in the average heating value of the gas supplied, which is taking place generally throughout the country, the volume of sales per plant is tending to increase, even though there may be no material change in population served.

Table 14 also brings out strikingly the fact that the average coal-gas plant is much smaller than either the average oil-gas plant or the average water-gas plant and that each of these in turn is very much smaller than the average coke-oven plant. This difference is the result of the fact that only coal-gas plants have been regarded as suitable for many small towns. It is impracticable to install a very small water-gas or oil-gas machine, and therefore when the output required has been unusually small, a coal-gas plant has generally been chosen. On the other hand, coke-oven gas plants are almost always chosen where coke in large quantities is the principal product required. Under these circumstances the quantity of gas to be produced is a secondary factor. The quantity of gas produced per unit of coke made is large, hence the large average sales of coke-oven gas for each plant. If all the gas were sold instead of part of it being used in coking or other plant operations, the contrast between sales per plant of coke-oven gas and other types of gas would be even more striking.

TABLE 14.—*Number and average sales per plant for each kind of gas, 1898–1918.*

Year.	Coke-oven gas.		Coal gas.		Water gas.		Oil gas.		Total.	
	Number of plants.	Average sales per plant (M).	Number of plants.	Average sales per plant (M).	Number of plants.	Average sales per plant (M).	Number of plants.	Average sales per plant (M).	Number of plants.	Average sales per plant (M).
1898.....	(a)	(a)	433	42,566	(a)	(a)	(a)	(a)	....	....
1902.....	(a)	(a)	522	48,024	(a)	(a)	(a)	(a)	....	....
1903.....	(a)	(a)	514	49,942	(a)	(a)	(a)	(a)	....	....
1904.....	(a)	(a)	514	58,579	(a)	(a)	(a)	(a)	....	....
1905.....	(a)	(a)	508	60,477	b 477	b 162,289	(b)	(b)	....	....
1907.....	(a)	(a)	493	69,580	b 520	b 181,990	(b)	(b)	....	....
1908.....	(a)	(a)	482	77,502	b 552	b 187,224	(b)	(b)	....	....
1912.....	29	1,879,009	424	83,024	b 604	b 203,142	(b)	(b)	1,057	200,938
1915.....	41	2,057,461	396	110,473	552	224,872	93	150,229	1,082	246,030
1917.....	55	2,382,302	402	106,785	579	265,039	86	171,390	1,122	304,948
1918.....	60	2,639,308	403	105,855	584	300,681	87	191,772	1,134	346,825

a Statistics not available.
b Figures for oil gas included with water gas.

GAS UNACCOUNTED FOR.

In the manufacture and distribution of gas there are leakages and uses of gas which are not accurately measurable and which amount to a considerable percentage of the total gas produced. In general the difference between production and sales is considered as a total and called "unaccounted for." This includes the gas used by the company itself, the decrease in volume due to change in temperature, the actual leakage during distribution, and the net losses, if any, due to inaccuracy of meters. In Tables 10–13 the quantity of gas unaccounted for, by kinds of gas and by States, has been indicated. The magnitude of this loss as shown in Table 2 is rather appalling, but by no means all of it is unavoidable.

To show in what classes the percentage of gas unaccounted for is the largest a comparison of percentages according to the size of the plant is presented in Table 15. In this table and in similar tables throughout this report, all the plants supplying coal, water, or oil gas are grouped according to their sales, as follows: Class A, plants selling less than 20 million cubic feet of gas a year; B, 20 to 50 million; C, 50 to 100 million; D, 100 to 200 million; E, 200 to 500 million; F, 500 to 1,000 million; G, more than 1,000 million. The minimum, maximum, and average percentage unaccounted for, reported by the plants in each of these groups, together with the number of plants so reporting, are shown, and the number of plants reporting different percentages of unaccounted for gas are reported by groups. From this tabulation the following facts are evident:

Very few plants claim to have less than 5 per cent of their gas unaccounted for, and often it is doubtful whether the estimates have been accurately made when so small a percentage as this is reported.

The vast majority of plants report between 5 and 15 per cent of their production as unaccounted for, being about equally divided between the group reporting between 5 and 10 per cent and the group reporting between 10 and 15 per cent.

The number of plants reporting large percentages of gas unaccounted for is greater among small plants than among large plants, and the average percentage of gas unaccounted for by small plants is decidedly larger than the percentage reported by the larger operators.

Although the average large plant does not report as much gas unaccounted for as the average small plant, yet some large plants report almost twice as much as the average small plant.

In considering the gas unaccounted for, local conditions must be taken into account, and no definite conclusions regarding any particular locality can be reached without careful consideration of the length of the distribution system relative to the quantity of gas sold, the age and condition of the distribution system, and many other factors of engineering significance.

The fact that more than 26,000,000,000 cubic feet of gas was reported as unaccounted for by coal, water, and oil gas companies in 1918 can be better understood by remembering that these companies distributed gas through more than 68,000 miles of mains and service pipes to more than 6,000,000 buildings using more than 8,500,000 meters. There is no doubt that the average percentage of gas unaccounted for should in general be materially decreased, and this fortunate result will probably be possible during the coming few years if the conditions with respect to labor supply become favorable. However, there is a limit below which the cost of saving the gas unaccounted for may be greater than the value of the gas saved. Because of this fact it is generally stated that a company can not afford to attempt, under ordinary conditions of distribution, to maintain its system in a condition better than that which corresponds to a proportion of gas unaccounted for amounting to 7 or 8 per cent.

TABLE 15.—*Number of coal, water, and oil gas plants reporting different percentages of gas unaccounted for, 1918, by size of plant.*

	A. 1-20,000 M.	B. 20,000-50,000 M.	C. 50,000-100,000 M.	D. 100,000-200,000 M.
Total sales of gas by all coal, water, and oil gas plants (M).	4,377,073	8,245,525	9,340,761	10,616,777
Number of plants reporting gas unaccounted for [a]	430	257	134	74
Minimum percentage reported	0.4	2.5	0.4	2.0
Maximum percentage reported	52.0	46.5	40.7	26.2
Average percentage reported	13.3	13.7	12.3	12.2
Number of plants reporting less than 5 per cent	45	16	8	2
Number of plants reporting 5-9.9 per cent	136	72	49	27
Number of plants reporting 10-14.9 per cent	101	68	39	23
Number of plants reporting 15-19.9 per cent	68	60	22	12
Number of plants reporting 20-24.9 per cent	42	23	9	8
Number of plants reporting 25 per cent or more	38	18	7	2

[a] Excludes a small number of plants for which reports were incomplete or otherwise defective.

TABLE 15.—*Number of coal, water, and oil gas plants reporting different percentages of gas unaccounted for, 1918, by size of plant*—Continued.

	E. 200,000–500,000 M.	F. 500,000–1,000,000 M.	G. 1,000,000 M. and over.	Total.
Total sales of gas by all coal, water, and oil gas plants (M)	27,395,047	20,171,972	154,793,912	234,941,067
Number of plants reporting gas unaccounted for[a]	83	30	40	1,048
Minimum percentage reported	1.2	2.6	1.1	0.4
Maximum percentage reported	29.0	38.9	24.2	52.0
Average percentage reported	10.8	10.6	9.9	12.7
Number of plants reporting less than 5 per cent.	9	4	10	94
Number of plants reporting 5–9.9 per cent	27	11	11	333
Number of plants reporting 10–14.9 per cent	32	10	13	286
Number of plants reporting 15–19.9 per cent	9	2	4	177
Number of plants reporting 20–24.9 per cent	4	2	2	90
Number of plants reporting 25 per cent or more.	2	1	....	68

[a] Excludes a small number of plants for which reports were incomplete or otherwise defective.

UTILIZATION OF GAS.

As in previous years, the gas companies were asked to estimate the quantity of gas sold for use in illumination, as domestic fuel, and as industrial fuel. Many companies, however, have not been able to submit such estimates. It has been assumed for these companies that the same percentage went to each class of use as was reported by other companies in the same part of the country. The data are given in Table 16.

TABLE 16.—*Artificial gas sold in the United States, 1898–1918, by uses.*

[Coal, water, oil, and coke-oven gas.]

Year.	Illuminating purposes.		Fuel.		Total (M).
	Quantity (M).	Percentage of total.	Quantity (M).	Percentage of total.	
1898[a]	15,955,149	86.6	2,476,052	13.4	18,431,201
1902	23,401,319	80.5	5,677,755	19.5	29,079,074
1903	22,953,793	73.9	8,095,669	26.1	31,049,462
1904	25,864,097	74.3	8,950,894	25.7	34,814,991
1905	86,349,641	73.3	31,516,599	26.7	117,866,240
1907	102,088,386	68.3	47,365,921	31.7	149,454,307
1908	109,290,116	69.7	47,619,192	30.3	156,909,308
1912	100,000,321	47.1	112,390,847	52.9	212,391,168
1915	80,796,873	30.4	185,407,375	69.6	266,204,248
1917[b]	80,141,649	23.4	262,006,480	76.6	342,151,129
1918[b]	234,874,890	59.7	158,424,656	40.3	393,299,546

[a] Coal gas only.
[b] Except for coke-oven gas the figures of distribution shown do not represent actual reports from operators, but are "spread" totals based on the proportions shown by operators who reported distribution. The actual figures reported, exclusive of coke-oven gas, are as follows: 1917, for illuminating purposes, 16,305,122 M; for domestic fuel, 39,311,224 M; and for industrial fuel, 9,658,236 M; 1918, for illuminating and household purposes, 75,769,465 M; and for industrial fuel, 12,811,197 M.

The data shown in Table 16 for 1898–1915 indicate a constantly decreasing percentage of the gas used for "illuminating" purposes. However, it is doubtful whether these figures can be taken as having precisely the significance that they appear to have for apparently many gas companies have reported as "illuminating" all gas sold to household customers and have reported as "fuel" only the gas sold to industrial customers. A more accurate estimate was possible for 1917, as gas sold for illuminating and other household uses was separately reported. As shown in the footnote to Table 16, the three principal classes of use were separately reported by a large number of companies, but the total of the industrial and the domestic fuel uses has been included for this year under the heading "Fuel," thus making these figures comparable with those for previous years.

In using the data in Table 16 and those given below from the estimates of the American Gas Association it should be remembered that at best it is only possible to estimate for any locality the quantity of gas which goes to each of the several uses, and apparently many of the estimates have not been as carefully made as might be desired. It can safely be assumed, however, that there has been a constantly increasing application of gas for industrial fuel and also for domestic

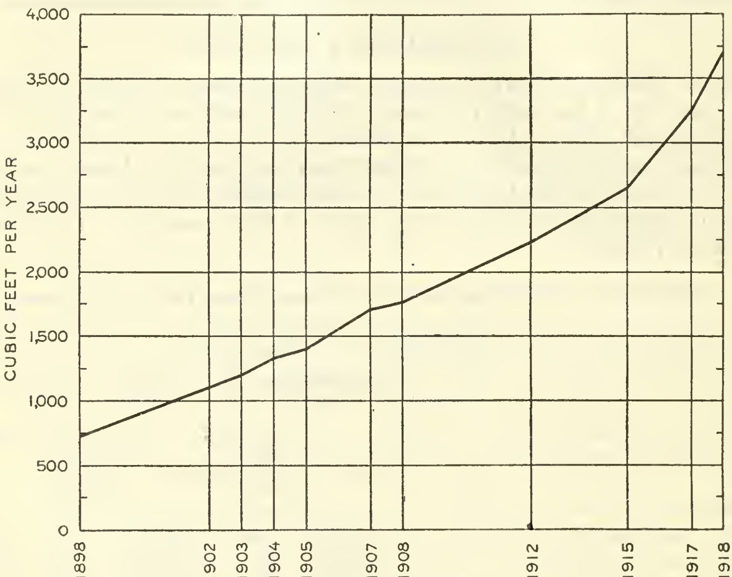

FIGURE 20.—Artificial gas sold per capita in the United States, 1898-1918.

fuel (fuel for cooking, heating water, and similar household operations). The quantity as well as the percentage of the gas used for illumination has decreased somewhat during recent years. It appears, however, that during the period 1900–1910 there was some increase in the quantity of gas thus applied, though probably the percentage decreased, as even larger increases were occurring simultaneously in the field of industrial and domestic fuel.

The estimates of sales of artificial gas in 1919, recently published by the American Gas Association, are as follows: For illumination, 22 per cent; for domestic uses other than illumination, 50 per cent; for industrial operations, 23 per cent. These estimates are based on the assumption of 300,000,000,000 cubic feet of gas sold during the year. It is believed that they are more carefully made than those furnished by the large number of operators who have attempted an estimate for the Survey.

In connection with these estimates as to the uses of gas the number of gas appliances installed is interesting. The American Gas Association estimates that 6,400,000 domestic cooking appliances are in use, approximately 1,300,000 water heaters, nearly 900,000 space heaters, and almost 10,000,000 incandescent mantle burners for illumination, in addition to the gas "arc" lamps or street lamps, which are separately classified. The same estimates indicate that 7,600 hotels, 2,300 clubs, 74,000 restaurants, and 2,000 other institutions are using gas equipment for part or all of their cooking operations. In view of these facts it seems very probable that the large percentages estimated by the association for domestic and industrial use are fully justified.

The consumption of gas in the United States has not only increased in total quantity but has also increased materially per capita during the last 20 years, as is shown in Table 17 and figure 20. From these data it is evident that over five times as much gas was used per capita in 1918 as in 1898, amounting to the surprising average of 3,683 cubic feet per person for the entire population of the country.

TABLE 17.—*Per capita consumption and average price of gas, 1898–1918.*

Year.	Per capita consumption in the United States.	Average price per M.				
		Coke-oven gas.	Coal gas.	Water gas.	Oil gas.	Total average.
	Cubic feet.					
1898	726		$1.17			
1902	1,098	$1.01				
1903	1,192	.98				
1904	1,330	.92				
1905	1,402	.81		$1.01		$0.94
1907	1,712	$0.15	.97	.95		.85
1908	1,764	.16	.93	.93		.85
1912	2,226	.09	.91	.91		.70
1915	2,648	.10	.92	$0.90	$0.91	.65
1917	3,254	.09	.89	.86	.91	.57
1918	3,683	.09	1.00	.89	.94	.58

PRICE OF GAS.

In Tables 4 and 5 is stated the average price of the gas sold. These data show rather surprising variations from an average of 8 cents per M in some States to $1.76 per M in others. In the States where a fairly low average price is reported this is invariably the result of including considerable quantities of coke-oven gas, for which the price at the ovens is reported instead of the price delivered as public-utility supplies, as for coal gas, water gas, and oil gas. The extent to which the lower price of coke-oven gas has an influence may best be judged from the data given in Table 17, where the average price is given for each kind of gas separately. (See also fig. 21.) It will be noted that coke-oven gas commonly sells for 9 or 10 cents per M whereas coal gas, water gas, and oil gas are sold at an average for the whole country of 90 cents, or more recently 90 cents to $1. This fact is also brought out in Tables 10–13, where the average value of gas of each kind is given for each State for 1915, 1917, and 1918.

In considering the price of gas it is especially important to keep in mind the size of the plant manufacturing it. Most small plants incur costs materially greater per M of gas sold than large plants. To bring out the extent to which this is true the plants have been grouped by size, as in Table 15, and the number of plants of each group selling gas at various average prices is shown in Table 18. Some large plants charge more per M than some small plants, but the average large plant receives less per M than the average small plant. For example, class A plants, selling 20 million cubic feet of gas or less a year each, received an average of $1.48 per M in 1918, class B plants, selling 20 to 50 million cubic feet per year each, received an average of $1.32 per M; and so on to class G plants, selling more than 1,000 million cubic feet of gas a year each, which received an average of only 84 cents per M. From the same table the number of plants in each price group can also be noted, and it is evident from this grouping that there are few plants receiving income near either the maximum or the minimum reported for their respective groups, although the range of average income within each group is considerable.

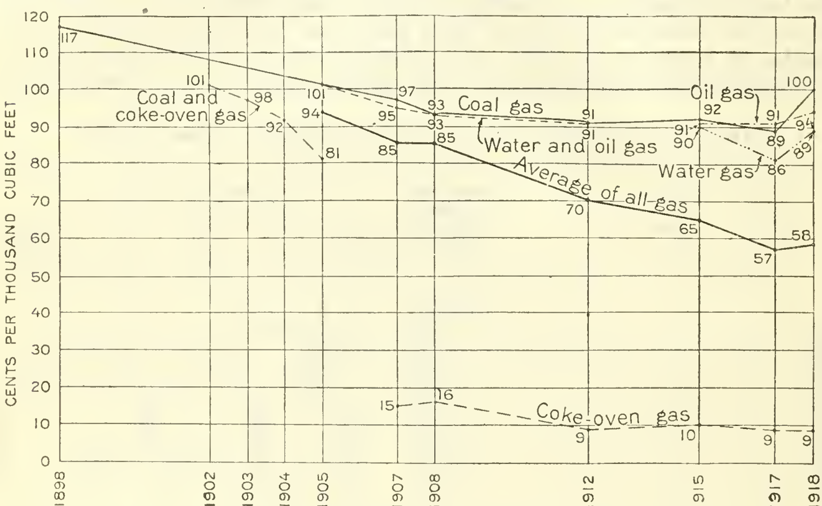

FIGURE 21.—Average price of artificial gas sold in the United States, 1898–1918.

TABLE 18.—*Number of coal, water, and oil gas plants reporting average price of gas in 1918, by size of plant and by price groups.*

	A. 1–20,000 M.	B. 20,000–50,000 M.	C. 50,000–100,000 M.	D. 100,000–200,000 M.
Total sales of gas by all coal, water, and oil gas plants (M)	4,377,073	8,245,525	9,340,761	10,616,777
Total number of plants reporting price [a]	442	257	134	75
Price per M cubic feet:				
Minimum	$0.48	$0.71	$0.71	$0.55
Maximum	5.56	2.37	1.92	2.39
Average	1.48	1.32	1.22	1.11
Number of plants selling gas at—				
Less than $0.60 per M cubic feet	1			1
$0.60–$0.69				
$0.70–$0.79	3	2	1	2
$0.80–$0.89	3	4	8	7
$0.90–$0.99	18	9	13	10
$1.00–$1.09	22	24	22	18
$1.10–$1.19	20	40	24	16
$1.20–$1.29	47	46	23	13
$1.30–$1.39	56	38	16	3
$1.40–$1.49	72	32	15	3
$1.50–$1.74	133	53	11	1
$1.75–$1.99	47	6	1	
$2.00–$2.49	15	3		1
$2.50–$2.99	3			
$3.00 or more	2			

[a] Excludes a small number of plants for which reports were incomplete or otherwise defective.

TABLE 18.—*Number of coal, water, and oil gas plants reporting average price of gas in 1918, by size of plant and by price groups*—Continued.

	E. 200,000–500,000 M.	F. 500,000–1,000,000 M.	G. 1,000,000 M and over.	Total.
Total sales of gas by all coal, water, and oil gas plants (M)	27,395,047	20,171,972	154,793,912	234,941,067
Total number of plants reporting price [a]	86	32	42	1,068
Price per M cubic feet:				
Minimum	$0.66	$0.69	$0.62	$0.48
Maximum	1.55	1.27	1.14	5.56
Average	1.03	.97	.84	1.31
Number of plants selling gas at—				
Less than $0.60 per M cubic feet				2
$0.60–$0.69	2	1	6	9
$0.70–$0.79	3	2	9	22
$0.80–$0.89	9	4	12	47
$0.90–$0.99	26	11	9	96
$1.00–$1.09	21	10	5	122
$1.10–$1.19	12	4	1	117
$1.20–$1.29	6			135
$1.30–$1.39	5			118
$1.40–$1.49	1			123
$1.50–$1.74	1			199
$1.75–$1.99				54
$2.00–$2.49				19
$2.50–$2.99				3
$3.00 or more				2

[a] Excludes a small number of plants for which reports were incomplete or otherwise defective.

In using the figures given in any of the tables showing average price of gas it should be remembered that there have been many changes in price schedules during the last four or five years and that such changes continue to occur frequently. Any accurate estimate of current prices is therefore difficult. Of course it is wholly out of the question to say that the price of gas in any community should be approximately a certain amount simply because other companies of the same size and apparently working under similar conditions charge that amount. Local conditions as to the cost of fuel, number of customers, number of miles of mains, and other factors affect the proper average price fully as much as the kind of gas or the size of the undertaking.

MATERIALS USED IN MAKING GAS.

In the manufacture of coal gas practically no other fuel is used except bituminous coal. A few companies scattered throughout the country use also a small quantity of cannel coal, benzol, gasoline, or other oil for enriching this gas. As shown in Table 19, the use of oil of any sort has decreased very much since 1915, only 8 per cent as much oil being used in 1917 as in 1915 for the enrichment of coal gas. The decrease is due to the high price of the oil and the tendency of local authorities to permit companies to supply gas of somewhat lower candlepower and heating value than formerly, thus making the use of enriching oil unnecessary.

The quantity of bituminous coal used in the manufacture of coal gas in 1917 and 1918 increased slightly, as compared with 1915, though there was slightly less gas made during the two later years. In other words, there has been a tendency to produce somewhat less gas per ton of coal carbonized than was possible in 1915. In 1915 the average yield per ton of coal used was 10.25 M, but in 1917 and 1918 the average was only 9.77 M, a decrease in output efficiency of 0.48 M per ton or about 4.6 per cent. This doubtless was the result of poorer coal, less efficient labor, and the difficulty in maintaining plant facilities in as good condition as prior to the war. Whether or not a return to the higher efficiency can be effected will depend on many factors, but it is probable that the yield of gas per ton of coal will increase materially as more local authorities permit the supply of gas of lower average heating value, as they are tending to do at present.

TABLE 19.—*Fuels used in the manufacture of coal gas in 1915, 1917, and 1918, by States.*

State.	1915		1917		1918	
	Bituminous coal (net tons).	Oil (gallons).	Bituminous coal (net tons).	Oil (gallons).	Bituminous coal (net tons).	Oil (gallons).
Alabama	74,551	300	90,886	300	80,477	
Colorado	101,540		122,494		130,634	
Connecticut	[a] 152,925	[b] 376,671	[a] 140,850	1,500	132,305	
Georgia	73,786	100	78,927		87,531	
Idaho	6,930		8,171		8,256	
Illinois	208,671	51,235	275,597	500	297,605	
Indiana	150,587		168,403		178,648	
Iowa	60,555		62,267	[c] 410	80,675	
Kentucky	14,111		14,759	500	14,272	
Maine	36,093		44,877		38,079	
Massachusetts	[a] 559,044	[b] 347,173	[a] 571,823	3,079	[a] 571,970	
Michigan	629,492	3,334	737,874	1,002	733,853	50
Minnesota	84,164		99,959		104,232	
Mississippi	12,596		15,907		19,095	
Missouri	[a] 383,361	[c] 100	565,464		596,988	255,473
Montana	8,951		[a] 12,069		14,065	
New Hampshire	14,914		14,710		15,603	
New Jersey	[a] 99,968		125,730		24,072	
New York	[a] 828,974	[b] 362,337	[a] 639,903	3,354	[a] 726,439	27,883
North Carolina	38,173		[a] 47,633	953	50,215	
Ohio	95,572		30,665		35,902	
Oregon	3,387		3,961		3,928	
Pennsylvania	231,160	6,266	260,743	32,000	[a] 214,009	
Rhode Island	112,802		114,423		64,552	
Tennessee	62,162	[b] 156,219	71,128	[b] 48,629	61,897	
Utah	35,002		35,331		38,629	
Virginia	90,801		111,534		114,672	
Washington	119,438	600	87,285		98,287	
Wisconsin	[a] 237,293		[a] 287,010		305,918	
Northeastern States: Delaware, District of Columbia, Maryland, and Vermont	47,276		26,948		20,368	
Southeastern States: Florida, South Carolina, and West Virginia	28,704	10,143	42,841	14,400	43,708	8,059
Northwestern States: Kansas, Nebraska, North Dakota, South Dakota, and Wyoming	22,155		28,760		29,065	
Southwestern, and Western States: Arkansas, California, Louisiana, New Mexico, Oklahoma, and Texas	19,964		22,661		30,723	
	[d] 4,645,102	[e] 1,314,478	[d] 4,961,593	[e] 106,627	[d] 4,966,672	291,465

[a] Includes a small quantity of cannel coal.
[b] Includes a small quantity of benzol.
[c] Gasoline.
[d] Includes 307 tons of cannel coal in 1915; 1,296 tons in 1917; and 927 tons in 1918.
[e] Includes 53,805 gallons of benzol in 1915, and 39,729 gallons in 1917.

The yield of gas per ton of coal depends also on the skill of the management. It is to be expected, therefore, that large plants will show better operating efficiency than small plants. That this is the fact is clearly demonstrated in Table 20, where the plants are grouped by size as before and by the average yield of gas per ton of coal carbonized. Some of the very small plants in class A and class B report high yields; but the yield reported is estimated by many of these operators because they do not have the facilities for accurate measurement, and it is therefore likely that fewer companies are making the large yield of gas per ton of coal reported than would appear from these figures. The group averages, however, are very significant, showing a distinct tendency to larger average yields by the larger plants. Moreover, it will be noted that practically none of the plants making 50 million cubic feet or more report less than 7 M per ton of coal. Less than 7 M per ton is probably an inexcusably low yield in any plant, and only in very small plants would such a yield be allowed to continue even for a single year without correction of conditions. In fact, less than 9 M per ton is seldom found in medium or large works, as will be noted from the reports summarized in this table.

Table 20.—*Number of plants reporting yields of coal gas, by size of plant and average yield per ton of coal carbonized.*

	A. 1–20,000 M.	B. 20,000–50,000 M.	C. 50,000–100,000 M.	D. 100,000–200,000 M.
Total sales of gas by coal-gas plants ......M..	1,501,169	4,057,995	4,664,570	4,182,702
Number of plants reporting yield	135	126	68	30
Gas produced per ton of coal, in M:				
Minimum	4.1	6.9	7.2	6.7
Maximum	13.1	13.4	10.6	13.0
Average	9.0	9.8	9.8	9.8
Number of plants producing—				
Less than 7 M per ton	16	1	....	1
7–7.99 M	13	8	3	....
8–8.99 M	29	19	8	3
9–9.99 M	34	45	23	12
10 M or more	43	53	34	14

	E. 200,000–500,000 M.	F. 500,000–1,000,000 M.	G. 1,000,000 M or over.	Total.
Total sales of gas by coal-gas plants ......M..	9,180,896	5,046,679	14,025,476	42,659,487
Number of plants reporting yield	29	8	7	403
Gas produced per ton of coal, in M:				
Minimum	7.7	8.9	7.9	4.1
Maximum	12.3	10.7	12.0	13.4
Average	9.9	10.0	10.2	9.5
Number of plants producing—				
Less than 7 M per ton	....	....	....	18
7–7.99 M	1	....	1	26
8–8.99 M	4	1	....	64
9–9.99 M	10	2	2	128
10 M or more	14	5	4	167

For the manufacture of water gas, until very recently only anthracite or coke has been used as the solid fuel, together with certain types of petroleum oil called "gas oil." During the World War, owing to the shortage of coke and anthracite, a decided tendency to use bituminous coal in the manufacture of water gas became evident. Nearly 8,000 tons of bituminous coal was used for making water gas in 1917, and approximately 65,000 tons in 1918.

The advantage of using bituminous coal is twofold. In the first place, it is cheaper per ton than anthracite or coke in many if not in most parts of the country. In the second place, its use permits the manufacture of carbureted water gas of requisite quality with less oil per M than would otherwise be necessary. The investigations made jointly by the United States Bureau of Mines and the State of Illinois have been particularly useful to gas engineers in this development.[6]

During the four years 1915–1918 there was a constant increase in the demand for water gas, as pointed out earlier in the discussion. Most of the increase in supply was accomplished by increasing the quantity of anthracite used for water-gas manufacture. In 1918 more than twice as much anthracite was used for this purpose as in 1915, whereas the coke used increased less than 10 per cent. This tendency to use anthracite rather than coke to care for the increasing output is not surprising in view of the very large demand for coke of all qualities and the great difficulty in supplying it during the war.

The total quantity of oil used in 1917 and again in 1918 was greater than that required during 1915, but so much more gas was made that the average quantity of oil used per M of carbureted water gas produced was less. The average quantity of oil used in 1915 approximated 4.06 gallons per M of carbureted water gas, in 1917 slightly less than 3.9 gallons, and in 1918 only 3.6 gallons. This reduction in the oil used for water-gas manufacture would have been even greater if it had not been necessary to maintain the oil supplies for some of the larger carbureted water gas plants in order that the toluol produced from the gas should be sufficient for urgent war needs.

With a decrease in oil used per M of gas produced there is almost always an increase in the quantity of solid fuel necessary per M. The relative increase in solid fuel depends in part, however, on the quality of the gas to be made. In 1915 an average of 33.18 pounds of coal or coke was used per M of gas made, in 1917 the average was 35.70 pounds, and in 1918 it was 35.78 pounds. During the same period there was a tendency to decrease the average heating value required of the gas companies, and this permitted the use of somewhat smaller quantities of solid fuel per M of gas than would otherwise have been necessary.

This fact should be kept in mind when considering that the quantity of solid fuel per M increased only about 2½ pounds between 1915 and 1918, while the quantity of oil per M was decreasing 0.46 gallon, a ratio of 5.4 pounds of coal for each gallon of oil. Under ordinary circumstances the increase in coal per M is more nearly 8 pounds for each decrease of 1 gallon in oil.

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[6] Water-gas manufacture with central district bituminous coal as generator fuel: Illinois Geol. Survey Buls. 22 and 24.

TABLE 21.—*Fuels used in the manufacture of water gas in 1915, 1917, and 1918, by States.*

State.	1915			1917				1918			
	Anthracite (gross tons).	Coke (net tons).	Oil (gallons).	Bituminous (net tons.)	Anthracite gross (tons).	Coke (net tons).	Oil (gallons).	Bituminous (net tons).	Anthracite (gross tons).	Coke (net tons).	Oil (gallons).
Alabama		3,644	594,608			4,297	936,674			9,705	2,104,691
California, Oregon, and Utah		a 18,642	4,413,712	2,195		2,850	860,534			b 2,393	b 412,170
Colorado	684	7,401	1,464,962		1,032	7,574	1,307,782	1,056		8,648	1,655,866
Connecticut	30,955	17,923	11,472,308		55,683	17,240	16,250,328	1,899	74,419	15,921	17,339,470
Delaware	9,111	167	1,921,820		12,313	202	2,518,284		13,676	107	3,043,389
District of Columbia and Maryland	78,730	10,772	22,087,021	335	103,952	1,712	24,920,585	1,644	155,225	2	33,708,231
Florida	2,326	8,042	1,911,404	188	2,437	9,778	2,087,471		1,890	15,763	2,784,231
Georgia		12,219	3,023,750	227	81	18,647	3,868,704		317	24,016	4,555,326
Idaho											
Illinois	240	344,103	96,025,978	1,171	170,802	360,935	130,145,011	20,523	130,560	401,032	111,055,073
Indiana		25,220	5,528,244			48,975	8,431,190	390		55,029	8,727,779
Iowa	773	49,304	10,532,611	859	2,363	59,053	12,559,105	581	1,224	62,367	12,094,127
Kansas	108	1,128	225,806		60	1,211	234,156	476	10	1,700	381,096
Kentucky and West Virginia		3,105	550,621		517	1,230	275,719		426	1,624	274,807
Louisiana, Mississippi, Arkansas, and Oklahoma		28,643	5,677,306			27,533	5,776,793			2,940	482,143
Maine	1,481	2,457	806,525		3,797	1,762	818,834		3,418	3,488	1,304,940
Massachusetts	14,227	129,732	27,615,751		33,315	179,074	33,012,834	1,012	84,616	163,412	38,008,338
Michigan	161	31,589	6,091,913		325	86,792	16,486,953	36	280	71,216	14,214,189
Minnesota		54,717	13,783,252	56	14,353	54,746	15,554,372		2,561	42,045	9,846,634
Missouri		45,043	10,613,569	529	280	50,392	9,959,681	2,479		54,492	10,941,320
Montana		1,339	253,029			1,879	329,357			1,806	291,384
Nebraska		20,325	5,069,992			26,579	6,088,636	198	138	28,557	6,045,747
New Hampshire	3,643	5,449	1,805,937	67	3,962	8,400	2,141,058		5,095	7,793	2,150,960
New Jersey	111,214	73,991	43,869,583	202	195,298	45,621	55,960,192	5,954	226,839	23,796	55,965,463
New York	523,559	171,798	202,151,388		706,421	159,145	230,506,051	14,167	773,443	172,385	241,597,588
North Carolina	428	2,636	526,500		1,325	3,920	749,024		782	5,709	1,042,607
North Dakota		513	77,446			615	67,863			628	61,181
Ohio		6,717	1,316,661			6,061	1,810,416			4,860	891,960
Pennsylvania	44,269	149,976	51,816,505		156,896	114,591	69,097,671	4,644	228,629	98,220	68,498,622
Rhode Island	3,807	4,893	1,833,813		14,848	15,992	6,102,287	400	18,431	23,707	8,423,113
South Carolina		6,498	1,477,531	672	19	8,475	1,545,303		217	9,738	1,890,497
South Dakota	300	4,498	867,816	224	447	5,070	923,951	249	88	5,432	976,856
Tennessee		8,350	1,985,375		869	13,980	2,743,571	5,840		11,576	2,679,859
Texas	818	25,625	5,561,573	445		34,018	6,520,396		1,413	41,288	7,792,680
Vermont	3,213	152	657,161	118	3,852	200	688,193		4,850	140	775,730
Virginia	118	12,905	3,894,876		434	24,800	5,460,096		577	27,292	6,153,424
Washington		14,538	2,887,055			18,292	3,344,379			22,989	4,387,643
Wisconsin	354	14,172	2,844,561	527	624	26,532	4,537,183	3,394	905	29,907	4,864,829
	830,519	1,318,226	553,237,963	7,815	1,486,305	1,448,173	684,620,637	64,942	1,730,029	1,451,723	687,423,963

a Includes 5,200 tons of lampblack.

b Oregon and Utah only.

The quantity of solid fuel used in the manufacture of water gas varies widely, even in plants of the same size. It depends somewhat upon the quality of the fuel, but more upon the skill of the operators of the machines and the management of the plant. In Table 22 are given for the size groups of plants the quantity of solid fuel used in the production of carbureted water gas. By this tabulation the large influence of size of plant upon efficiency is most strikingly set forth.

TABLE 22.—*Solid fuel used per M of carbureted water gas manufactured in 1918, by size of plant and by efficiency groups.*

	A. 1-20,000 M.	B. 20,000-50,000 M.	C. 50,000-100,000 M.	D. 100,000-200,000 M.
Total sales of gas by water-gas plants....M..	2,479,767	3,690,017	4,037,795	5,956,703
Number of plants reporting sales[a]	256	116	58	42
Pounds of fuel used per M of gas produced:				
Minimum	17	19	29	22
Maximum	161	84	141	63
Average	62.9	48.1	43.6	39.6
Number of plants using—				
Less than 30 pounds per M	6	4	1	4
30-34 pounds	7	4	8	7
35-39 pounds	7	14	16	13
40-44 pounds	36	26	15	8
45-49 pounds	30	21	6	5
50-54 pounds	30	16	7	3
55-59 pounds	17	14	2	....
60-69 pounds	42	13	1	2
70-89 pounds	47	4	1	....
90-119 pounds	27	....	....	....
120 pounds or more	7	....	1	....

	E. 200,000-500,000 M.	F. 500,000-1,000,000 M.	G. 1,000,000 M or over.	Total.
Total sales of gas by water-gas plants....M..	16,862,175	15,125,293	127,445,673	175,597,423
Number of plants reporting sales[a]	52	24	31	579
Pounds of fuel used per M of gas produced:				
Minimum	29	28	26	17
Maximum	56	50	49	161
Average	36.9	36.6	34.3	51.4
Number of plants using—				
Less than 30 pounds per M	2	1	6	24
30-34 pounds	14	9	11	60
35-39 pounds	22	8	9	89
40-44 pounds	11	4	4	104
45-49 pounds	2	1	1	66
50-54 pounds	....	1	....	57
55-59 pounds	1	....	....	34
60-69 pounds	....	....	....	58
70-89 pounds	....	....	....	52
90-119 pounds	....	....	....	27
120 pounds or more	....	....	....	8

[a] Excludes a small number of plants for which reports were incomplete or otherwise defective.

It is evident that in larger operations more than 45 pounds of solid fuel per M of gas is seldom reported, but for small plants and those of medium size the average is as high as this, and for class A plants (those manufacturing less than 20,000,000 cubic feet per year) it is even higher. In the smaller plants the large quantity of solid fuel used is often necessary because the generating equipment is operated only a few hours each day, and much solid fuel is consumed by maintaining a fire during nonoperating periods. Where the plant is generally operated 24 hours a day it is seldom necessary to use more than 50 or 60 pounds of generator fuel per M of gas produced, but with the smaller plants the average is higher than this, and many of them report 100 pounds or more per M.

The oil efficiencies for the several size groups of plants are summarized in Table 23. The variation in quantity of oil used per M of gas between plants is notably greater with small operations than with large, but the general average for all plants of any one size group varies little from the general averages for other groups. In fact, if reliable estimates for every plant had been available it is probable that no group would have shown an average beyond the limits of 3.5 to 4 gallons per M, although of course numerous individual plants report materially greater and materially smaller quantities of oil used. Nevertheless, the vast majority of plants have in the years under discussion used between 3 and 4.5 gallons per M.

TABLE 23.—*Oil used for manufacture of carbureted water gas in 1918, by size of plant and by quantity of oil.*

	A. 1-20,000 M.	B. 20,000-50,000 M.	C. 50,000-100,000 M.	D. 100 000-200,000 M.
Total sales of gas by water-gas plants.....M..	2,479,767	3,690,017	4,037,795	5,956,703
Number of plants reporting oil used [a]	258	116	58	42
Gallons of oil used per M of gas produced:				
Minimum	1.6	2.0	2.7	2.4
Maximum	9.7	5.7	4.9	4.8
Average	4.0	3.5	3.5	3.4
Number of plants using—				
Less than 2 gallons of oil per M of gas	2	....	....	....
2.0-2.9 gallons	20	10	8	5
3.0-3.4 gallons	52	44	26	21
3.5-3.9 gallons	66	40	13	13
4.0-4.4 gallons	62	15	9	2
4.5-4.9 gallons	24	4	2	1
5.0 gallons or more	32	3	....	....

	E. 200,000-500,000 M.	F. 500,000-1,000,000 M.	G. 1,000,000 M or over.	Total.
Total sales of gas by water-gas plants.....M..	16,862,175	15,125,293	127,445,673	175,597,423
Number of plants reporting oil used [a]	52	24	31	581
Gallons of oil used per M of gas produced:				
Minimum	1.9	1.9	2.8	1.6
Maximum	8.7	4.0	4.5	9.7
Average	3.5	3.3	3.6	3.7
Number of plants using—				
Less than 2 gallons of oil per M of gas	1	1	....	4
2.0-2.9 gallons	7	4	4	58
3.0-3.4 gallons	22	10	8	183
3.5-3.9 gallons	11	8	15	166
4.0-4.4 gallons	8	1	3	100
4.5-4.9 gallons	2	....	1	34
5.0 gallons or more	1	....	....	36

[a] Excludes a small number of plants for which reports were incomplete or otherwise defective.

More oil was used in the production of oil gas in 1918 than in 1915 or 1917, as shown in Table 24, but not much more than was used in 1912. The quantity of gas made during the later years, however, was materially greater, so that the quantity of oil used per M of gas made decreased materially. In 1915 an average of 8.5 gallons per M was used; in 1917 and 1918 it was 7.8 gallons. This decrease in average consumption of oil per M of gas represents the natural result of decreasing average quality of the gas produced. The decrease in quality occurred during the war period as a consequence of administrative permits granted by State and municipal officials throughout the country.

TABLE 24.—*Oil used in the production of oil gas in 1912, 1915, 1917, and 1918, by States in gallons.*

State.	1912	1915	1917	1918
Arizona	2,816,776	1,825,764	2,812,900	3,425,801
California	[a] 128,311,597	118,400,146	117,100,441	127,601,352
Nevada	315,260	503,133	702,135	649,266
Oregon and Washington	14,269,051	[b] 14,263,719	15,874,433	[b] 21,496,159
Texas	251,200	231,700	426,162	523,868
Northeastern group [c]	118,100	831,700	129,940	149,200
South Central group [d]	728,568	189,308	238,500	177,062
North Central group [e]	925,800	157,250	200,363	190,082
	147,736,352	136,402,720	137,484,874	154,212,790

[a] Includes oil used for a small quantity of water gas.
[b] Oregon only.
[c] Includes in 1912, New York and Pennsylvania; in 1915, Connecticut, Massachusetts, and New Hampshire; in 1917, New Hampshire, New York, and Pennsylvania; in 1918, New Hampshire and Pennsylvania.
[d] Includes in 1912, Louisiana, New Mexico, and Oklahoma; in 1915 and 1917, Louisiana, Missouri, and New Mexico; in 1918, Missouri and New Mexico.
[e] Includes in 1912, Illinois, Iowa, Michigan, Minnesota, Ohio, South Dakota, and Wisconsin; in 1915, Illinois, Michigan, Minnesota, Ohio, and Wisconsin; in 1917, Indiana, Iowa, Ohio, and Wisconsin; in 1918, Iowa, Michigan, Minnesota, Ohio, and Wisconsin.

In Table 25 is shown by size of plant the consumption of oil per M of oil gas manufactured. In the manufacture of oil gas no solid fuel is used, and therefore a higher efficiency can naturally be expected for large plants. The average consumption per M of gas made decreases materially from the smaller to the larger size groups. In fact, among the larger plants none report as great oil consumption per M as is reported by most of even the best-operated smaller plants. Even the smaller oil-gas plants, however, have less excuse for excessive oil consumption than exists in the manufacture of water gas. Very few plants of any size reported more than 11 gallons of oil required per M of oil gas made.

TABLE 25.—*Oil used per M of oil gas manufactured in 1918, by size of plant and by efficiency groups.*

	A. 1–20,000 M.	B. 20,000–50,000 M.	C. 50,000–100,000 M.	D. 100,000–200,000 M.
Total sales of gas by oil-gas plants M	396,137	497,513	638,396	477,372
Number of plants reporting	48	16	9	3
Gallons of oil used per M of gas produced:				
Minimum	4.5	8.9	8.1	8.0
Maximum	15.9	12.5	15.8	11.0
Average	10.5	10.3	10.5	9.0
Number of plants using—				
Less than 6 gallons of oil per M of gas	2			
6–7.9 gallons	3			
8–8.9 gallons	2	1	3	2
9–9.9 gallons	8	5	1	
10–10.9 gallons	15	7	2	
11–11.9 gallons	8	2	1	1
12–14.9 gallons	9	1	1	
15 gallons or more	1		1	

TABLE 25.—*Oil used per M of oil gas manufactured in 1918, by size of plant and by efficiency groups*—Continued.

	E. 200,000-500,000 M.	F. 500,000-1,000,000 M.	G. 1,000,000 M and over.	Total.
Total sales of gas by oil-gas plants..........M..	1,351,976	....	13,322,763	16,684,157
Number of plants reporting..........	5	....	5	86
Gallons of oil used per M of gas produced:				
Minimum..........	4.4	....	7.0	4.4
Maximum..........	8.6	....	8.8	15.9
Average..........	7.2	....	7.6	10.0
Number of plants using—				
Less than 6 gallons of oil per M of gas......	1	....	....	3
6-7.9 gallons..........	2	....	4	9
8-8.9 gallons..........	2	....	1	11
9-9.9 gallons..........	....	....	....	14
10-10.9 gallons..........	....	....	....	24
11-11.9 gallons..........	....	....	....	12
12-14.9 gallons..........	....	....	....	11
15 gallons or more..........	....	....	....	2

BY-PRODUCTS OF GAS MANUFACTURE.

All modern processes of making gas yield by-products, and in many processes the value of the by-products is as great as the value of the gas itself. The manufacture of coal gas is not commercially feasible unless the by-products are produced efficiently and can be marketed under favorable conditions. The relative value of the several by-products can be seen in the general summary of data (Table 1), which shows that coke, coal-gas tar, water-gas tar, ammonia, and other by-products reach total values in the millions of dollars. Even the output of retort carbon and lampblack must be measured in hundreds of thousands of dollars, although these are minor by-products in practically all gas works.

In fixing prices for artificial gas it is observable that the "net holder cost" of the gas is very small indeed. This measure of cost represents the total expenditure for operations, less the income from the sales of by-products, divided by the output of gas. In other words, it represents the net operating expense of the plant considered only as a gas-manufacturing establishment. To this net holder cost must be added, of course, the proper charges for taxes, depreciation, amortization, and interest upon the plant investment, before the actual total cost for supplying the gas at the works is ascertained; and of course also the expenses of distribution, commercial department, and management, as well as the interest upon the distribution system, must be added in calculating the total proper charge for the gas supplied the customer. Although the holder cost may be small, especially in a coal-gas works, the capital charges resulting from a large investment in such works are very considerable. If it were not possible to obtain the income from by-products to offset the operating expense in whole or in part, the sum of the operating expense and of this group of capital charges would make the gas prohibitively high.

The principal by-products of gas works are coke, tar, ammonia (in one or more forms), retort carbon and lampblack, light oils, and naphthalene. All kinds of gas plants produce tar, but coke and ammonia are produced only in coal-gas plants. Retort carbon and lampblack and also light oils may be recovered at works of almost any type. Only relatively few plants, however, recover the retort carbon, light oils, and naphthalene in salable quantities; hence they are all minor products for the country as a whole.

COKE.

The production and sales of coke manufactured at coal-gas plants in the United States are shown in Table 26. Where three or more gas plants of this type are operating in a State a separate total is given; where a smaller number of plants are found, the States are combined by geographic groups.

TABLE 26.—*Coke produced and sold from coal-gas plants in 1915, 1917, and 1918.*

State.	Number of plants producing.	Production (net tons).	Sales.		
			Quantity (net tons).	Value.	Average price per ton.
1915.					
Alabama		45,315	29,552	$96,806	$3.28
California, Montana, New Mexico, and Wyoming		5,630	4,377	32,998	7.54
Colorado		63,618	53,659	145,900	2.72
Connecticut		90,327	36,552	142,927	3.91
Delaware, Florida, South Carolina, and West Virginia		19,414	9,421	37,678	4.00
District of Columbia and Maryland		23,170	11,121	50,338	4.53
Georgia		45,880	24,007	91,998	3.83
Idaho		4,226	3,179	18,820	5.92
Illinois		155,226	115,326	438,389	3.80
Indiana		97,386	47,933	179,624	3.75
Iowa		34,525	23,426	128,448	5.48
Kansas, North Dakota, and South Dakota		11,519	7,609	47,927	6.30
Kentucky		6,944	2,446	6,437	2.63
Louisiana, Oklahoma, and Texas		11,307	5,834	29,510	5.06
Maine		16,771	10,894	62,972	5.78
Massachusetts		334,686	175,226	857,726	4.89
Michigan		416,901	286,505	1,319,637	4.61
Minnesota		52,835	8,004	47,660	5.95
Mississippi		6,117	4,615	15,615	3.38
Missouri		243,617	84,932	325,325	3.83
New Hampshire		8,764	5,977	30,331	5.07
New Jersey		62,877	10,728	42,147	3.93
New York		543,406	283,284	1,077,573	3.80
North Carolina		52,005	11,981	52,290	4.36
Ohio		60,104	48,442	199,222	4.11
Oregon		1,999	1,250	6,115	4.89
Pennsylvania		150,464	125,283	653,223	5.21
Rhode Island and Vermont		22,111	8,111	34,273	4.23
Tennessee		39,153	26,742	73,500	2.75
Utah		21,651	11,580	55,074	4.76
Virginia		51,432	23,012	97,995	4.26
Washington		81,045	36,746	191,345	5.21
Wisconsin		160,501	124,798	608,554	4.88
		2,940,926	1,662,552	7,198,377	4.33
1917.					
Alabama	11	57,832	36,926	134,678	3.65
Arkansas, Louisiana, and Oklahoma	3	2,863	1,354	7,384	5.45
California, New Mexico, and Wyoming	3	1,933	1,950	8,144	4.18
Colorado	6	91,349	54,332	302,046	5.56
Connecticut	7	83,065	46,115	368,666	7.99
Delaware and West Virginia	3	1,663	1,040	5,721	5.50
District of Columbia and Maryland	6	11,030	6,165	30,166	4.89
Florida and South Carolina	3	24,403	20,338	96,302	4.74
Georgia	9	52,776	15,968	75,211	4.71
Idaho	3	5,135	3,254	24,138	7.42
Illinois	33	169,280	117,737	782,709	6.65
Indiana	27	108,275	76,738	458,956	5.98
Iowa	10	35,313	20,139	169,136	8.40
Kansas, Nebraska, and South Dakota	5	5,084	3,620	23,725	6.55
Kentucky	8	6,207	4,155	20,672	4.98
Maine	7	27,977	18,029	129,245	7.17
Massachusetts	30	389,040	195,030	1,160,764	5.95
Michigan	52	466,308	336,879	1,711,682	5.08

TABLE 26.—*Coke produced and sold from coal-gas plants in 1915, 1917, and 1918*—Con.

State.	Number of plants producing.	Production (net tons).	Sales.		
			Quantity (net tons).	Value.	Average price per ton.
1917—Continued.					
Minnesota	8	63,359	13,640	102,554	$7.52
Mississippi	7	9,746	5,651	31,188	5.52
Missouri	8	338,493	305,558	2,073,921	6.79
Montana	3	7,000	5,749	44,063	7.66
New Hampshire	3	7,993	5,353	44,478	8.31
New Jersey	5	46,592	8,510	50,359	5.92
New York	32	428,027	169,932	861,317	5.07
North Carolina	9	30,260	20,520	114,478	5.58
North Dakota	3	11,628	8,325	58,169	6.99
Ohio	6	12,687	7,608	47,632	6.26
Oregon	3	2,407	1,124	8,923	7.94
Pennsylvania	13	141,407	121,439	533,305	4.39
Rhode Island and Vermont	5	77,338	24,322	170,420	7.01
Tennessee	7	43,466	23,113	122,706	5.31
Texas	3	8,878	5,305	31,461	5.93
Utah	3	21,339	10,181	58,048	5.70
Virginia	12	62,906	19,861	114,898	5.79
Washington	9	52,015	18,846	109,371	5.80
Wisconsin	17	189,892	122,442	867,057	7.08
	382	3,094,966	1,857,248	10,953,693	5.90
1918.					
Alabama	11	49,172	23,415	134,832	5.76
Arkansas, Louisiana, and Oklahoma	3	5,101	3,486	22,070	6.33
California, New Mexico, and Wyoming	3	2,859	1,529	4,869	2.53
Colorado	7	93,617	48,882	306,114	6.26
Connecticut	6	91,480	35,215	393,915	11.19
Delaware and West Virginia	3	1,665	1,014	6,536	6.45
Florida and South Carolina	3	26,045	18,147	130,165	7.17
Georgia	11	53,772	13,780	87,626	6.36
Idaho	3	4,966	2,234	12,008	5.38
Illinois	37	177,915	133,050	1,057,253	7.95
Indiana	27	114,706	87,005	599,801	6.89
Iowa	15	49,924	26,003	229,754	8.84
Kansas, Nebraska, and South Dakota	5	4,547	2,493	18,424	7.39
Kentucky	8	8,396	5,940	31,936	5.38
Maine	7	21,671	9,189	71,085	7.74
Maryland	5	6,902	3,894	21,298	5.47
Massachusetts	31	390,073	165,011	1,066,674	6.46
Michigan	52	469,558	337,184	2,543,271	7.54
Minnesota	8	67,450	17,157	147,132	8.58
Mississippi	7	10,026	7,519	44,610	5.93
Missouri	7	357,973	324,679	3,165,464	9.75
Montana	4	8,139	3,159	24,664	7.81
New Hampshire	3	9,087	6,048	57,557	9.57
New Jersey	4	15,528	10,226	57,982	5.62
New York	30	502,223	172,395	1,063,879	6.17
North Carolina	9	33,169	19,287	133,873	6.94
North Dakota	3	12,377	8,040	61,715	7.68
Ohio	8	19,335	13,234	97,605	7.38
Oregon	3	2,416	961	6,541	6.80
Pennsylvania	13	113,191	99,196	625,931	6.31
Rhode Island and Vermont	5	46,345	14,887	117,792	7.91
Tennessee	6	41,934	22,439	126,482	5.64
Texas	4	10,914	3,685	26,701	7.25
Utah	3	23,241	7,416	40,165	5.42
Virginia	12	70,547	13,207	72,867	5.52
Washington	9	58,389	13,927	85,828	6.16
Wisconsin	19	205,882	138,807	1,268,813	9.14
	394	3,180,535	1,813,740	13,963,232	7.70

The total production of coke in coal-gas plants is considerable, but both the quantity and the value of the coke sold are much smaller than those of coke made in coke-oven plants. The quantity of coke sold in 1918 from coal-gas works using retorts was only 1,800,000 tons, valued at approximately $14,000,000, but in the same year 25,997,580 tons of coke was made in coke ovens and represented a value at the plant of $193,018,785.

The quantity of coke produced in coal-gas works has been steadily increasing for many years, and it is to be expected that this increase will continue. The rate of increase, however, will probably be somewhat retarded by the use in very large works of coke-oven rather than coal-gas retorts, as the oven lends itself to large-scale operations somewhat more satisfactorily, labor cost and some features of by-product recovery being considered. The rate of increase may also be affected by the development of certain special types of coal-gas retorts, notably the vertical retort, which promises to be an increasingly important factor in the future of city gas manufacture. The principal limitations upon the increase in coal-gas plants will probably be the difficulty in procuring adequate capital for new installations and the difficulty of disposing of large quantities of "gas-house" coke.

The yield of coke per ton of coal carbonized in the gas works varies greatly; it depends in part on the quality of the coal and the processes of carbonization but more largely on the skill of the management. As might be expected, small gas works do not recover so large a percentage of coke from the coal as large works. This fact is strikingly brought out in the data of Table 27, which gives for each size group of gas works the maximum, minimum, and average yield of coke from the coal, and the number of plants reporting yields within the different efficiency groups. Commonly 55 to 70 per cent of the coal is recovered as coke, but in all size groups there are a few plants that fall outside these limits, both above and below. The average yield for each group, except the smallest, is between 60 and 70 per cent. This represents approximately the percentage of fixed carbon and ash in coal typical of that used in these works, or, in other words, it corresponds with the theoretical quantity of material which should be left if the coal could be so treated as just to eliminate all the moisture and volatile matter. The coke as obtained in the works, however, still contains some volatile constituents which tend to make the percentage yield higher than could be expected in theory; but this volatile matter is more or less offset by the losses of coke that result from spillage and from the partial combustion of the coke when it is drawn hot from the retorts.

TABLE 27.—*Percentage yield of coke from coal carbonized in coal-gas plants in 1918, by size of plant and by efficiency groups.*

	A. 1–20,000 M.	B. 20,000–50,000 M.	C. 50,000–100,000 M.	D. 100,000–200,000 M.
Total sales of gas by coal-gas plants	1,501,169	4,057,995	4,664,570	4,182,702
Number of plants producing coke [a]	124	124	68	30
Percentage yield of coke from coal:				
Minimum	18.5	24.3	37.0	49.5
Maximum	[b] 91.7	81.4	76.8	[b] 93.5
Average	58.6	60.4	63.8	65.5
Number of plants recovering—				
Less than 30 per cent	1	1		
30–39.9 per cent	9	3	1	
40–44.9 per cent	3	3	1	
45–49.9 per cent	7	6	1	1
50–54.9 per cent	14	8	5	1
55–59.9 per cent	25	17	6	2
60–64.9 per cent	32	37	26	8
65–69.9 per cent	21	36	19	13
70–74.9 per cent	6	8	8	2
75–79.9 per cent	3	3	1	1
80 per cent or more	3	2		2

[a] Excludes a small number of plants for which reports were incomplete or otherwise defective.
[b] Improbable, but so reported.

TABLE 27.—*Percentage yield of coke from coal carbonized in coal-gas plants in 1918, by size of plant and by efficiency groups*—Continued.

	E. 200,000–500,000 M.	F. 500,000–1,000,000 M.	G. 1,000,000 M and over.	Total.
Total sales of gas by coal-gas plants ... M..	9,180,896	5,046,679	14,025,476	42,659,487
Number of plants producing coke [a]	29	8	7	390
Percentage yield of coke from coal:				
Minimum	50.7	65.0	49.8	18.5
Maximum	[b] 86.3	74.3	75.0	[b] 93.5
Average	64.8	68.8	66.3	61.2
Number of plants recovering—				
Less than 30 per cent				2
30–39.9 per cent				13
40–44.9 per cent				7
45–49.9 per cent			1	16
50–54.9 per cent	3			31
55–59.9 per cent	3			53
60–64.9 per cent	8		2	113
65–69.9 per cent	11	5	1	106
70–74.9 per cent	3	3	2	32
75–79.9 per cent			1	9
80 per cent or more	1			8

[a] Excludes a small number of plants for which reports were incomplete or otherwise defective.
[b] Improbable, but so reported.

The coke made at gas works is in part consumed in the plants for heating the retorts. Thus the sales of coke are only approximately 60 per cent of the production. Some of the coke made in coal-gas works is used for the manufacture of water gas in works affiliated with the coal-gas plant. This practice is particularly notable in large city operations where a mixed gas is supplied to the public. The coal-gas coke that is sold finds a market for domestic and industrial uses of various sorts and is more or less in competition with anthracite. In this respect gas-works coke is quite in contrast with the output of coke ovens, the major portion of which is used for metallurgical operations.

The variation in the price of coke made by coal-gas works is shown in the summary of sales by States (Table 26) and also in Table 28, where the average prices obtained are shown by size of plant. The striking variation in price from $2.75 to more than $19 a ton represents the result of many influences, including the quality of the coke and the conditions in the locality where it is produced. As might be expected, the average price of the coke sold does not vary greatly with the size of the plant; geographic conditions are of much greater consequence. The table shows the price of the coke at the plant. The price to the customer at the point of delivery would generally be much higher, being more nearly comparable with the price of the corresponding sizes of anthracite in the same locality.

The influence of war-time conditions on the price of fuel is clearly evident by comparison of the average prices of coke for 1915, 1917, and 1918. The average increased from $4.33 a ton in 1915 to $7.70 a ton in 1918.

As pointed out above, the development of coal-gas manufacture in this country, as well as the use of by-product coke ovens for city gas manufacture, is to a considerable extent dependent on developing adequate markets for the coke. With the demand for anthracite increasing and the supply decreasing there will doubtless be a gradual increase in the use of coke as a substitute for anthracite. As a result, we may expect a change in the habits of consumers of domestic fuel as they learn how to use coke efficiently for household purposes.

TABLE 28.—*Average price of coke sold from coal-gas works in 1918, by size of plant and by price groups.*

	A. 1–20,000 M.	B. 20,000–50,000 M.	C. 50,000–100,000 M.	D. 100,000–200,000 M.	E. 200,000–500,000 M.	F. 500,000–1,000,000 M.	G. 1,000,000 M and over.	Total.
Total sales of gas by coal-gas plants.....M..	1,501,169	4,057,995	4,664,570	4,182,702	9,180,896	5,046,679	14,025,476	42,659,487
Number of plants selling coke [a]	119	122	65	28	29	7	7	377
Average price per ton of coke sold:								
Minimum	$2.80	$2.24	$4.42	$4.00	$2.75	$4.50	$4.28	$2.75
Maximum	19.13	16.15	13.08	13.54	18.59	10.52	9.80	19.13
Average	7.00	7.01	7.68	7.84	8.02	6.76	6.90	7.25
Number of plants receiving—								
Less than $3.00 a ton	1	4	.....	.....	1	.....	.....	6
$3.00–$3.99	5	2	.....	.....	.....	.....	.....	7
$4.00–$4.99	10	8	4	2	2	1	1	28
$5.00–$5.99	19	18	5	4	4	2	1	53
$6.00–$6.99	26	26	14	4	4	2	3	79
$7.00–$7.99	23	30	14	7	5	1	.....	80
$8.00–$8.99	19	23	16	4	6	.....	.....	68
$9.00–$9.99	7	5	6	3	2	.....	2	25
$10.00–$10.99	6	1	3	2	.....	1	.....	13
$11.00–$11.99	.....	3	.....	.....	2	.....	.....	5
$12.00 or more	3	2	3	2	3	.....	.....	13

[a] Excludes a small number of plants for which reports were incomplete or otherwise defective.

TAR.

The production of tar at coal-gas works was an appreciable factor in the coal-tar business in 1917 and 1918, but the output at the gas works was materially less than that from coke-oven operations. For example, in 1918 only about 53,000,000 gallons of tar was made at coal-gas works, whereas more than 260,000,000 gallons was produced at coke ovens.

The output of coal-gas tar for 1917 and 1918 is reported in Tables 29 and 30. The data in these tables show that the average price of the tar varied widely throughout the country, but the average for the country as a whole was in each year slightly greater than in previous years. The average in 1915 was 2.8 cents a gallon, including coke-oven tar; in 1917, 3.3 cents; and in 1918, 3.9 cents. The total sales of coal-gas and coke-oven tar in 1918 were 248,000 000 gallons, valued at $8,000,000; in contrast with a total of 186,000,000 gallons, valued at only $5,000,000, in 1915.

As shown in Table 30 the sales of tar from coal-gas works represent approximately 90 per cent of the total production. Most of the tar sold goes to the distiller, but a little is sold for fuel. The tar consumed in the gas plant, representing approximately 10 per cent unaccounted for by sales, is used mostly for fuel, especially under boilers, but the value of coal tar for other purposes is so great that to burn it as a fuel is usually an economic waste. Some of the tar not reported as sold is refined by the gas works where it is produced, but this is believed to be a very small percentage of the total.

TABLE 29.—*Tar sold from coal-gas plants in 1917, by States.*

State.	Number of plants reporting sales.	Quantity (gallons).	Value.	Average price per gallon.
Alabama	11	902,362	$29,695	$0.033
Arkansas, Louisiana, Oklahoma, and Texas	5	195,278	13,157	.067
California, New Mexico, and Wyoming	3	44,824	1,620	.036
Colorado	6	1,355,007	45,069	.033
Connecticut	7	1,121,608	44,633	.040
District of Columbia and Maryland	6	175,790	6,135	.035
Delaware and West Virginia	3	13,546	984	.073
Florida and South Carolina	3	57,201	3,558	.062
Georgia	9	339,978	16,518	.049
Idaho	3	91,059	4,121	.045
Illinois	31	4,081,796	120,462	.030
Indiana	25	1,770,965	62,701	.035
Iowa	11	391,711	19,893	.051
Kansas and Nebraska	3	54,106	2,081	.038
Kentucky	8	45,637	5,253	.115
Maine	7	496,568	17,479	.035
Massachusetts	30	6,527,469	224,744	.034
Michigan	52	8,796,551	276,304	.031
Minnesota	8	1,391,858	40,575	.029
Mississippi	9	221,873	9,079	.041
Missouri	5	5,006,467	199,130	.040
Montana	3	151,253	11,973	.079
New Hampshire	3	183,600	5,641	.031
New Jersey	5	786,713	25,237	.032
New York	30	7,769,515	243,620	.031
North Carolina	9	231,367	11,395	.049
North Dakota and South Dakota	4	151,259	4,998	.033
Ohio	6	220,870	9,316	.042
Oregon	3	43,429	2,835	.065
Pennsylvania	12	1,684,467	27,889	.017
Rhode Island and Vermont	4	1,503,090	48,340	.032
Tennessee	7	766,099	29,099	.038
Utah	3	332,539	14,980	.045
Virginia	12	1,029,511	38,151	.037
Washington	9	1,114,265	49,713	.045
Wisconsin	17	4,268,782	107,948	.025
	372	53,318,413	1,774,326	.033

TABLE 30.—*Tar produced and sold from coal-gas plants in 1918, by States.*

State.	Number of plants reporting production.	Production (gallons).	Sales.		
			Quantity (gallons).	Value.	Average price per gallon.
Alabama	11	790,460	714,814	$25,327	$0.035
Arkansas, Louisiana, Oklahoma, and New Mexico	4	107,781	103,253	5,778	.056
Colorado	7	1,447,946	1,446,423	90,231	.062
Connecticut	6	1,549,078	852,412	44,154	.052
Delaware and West Virginia	3	28,381	24,637	1,295	.053
Florida and South Carolina	3	369,166	337,286	13,292	.039
Georgia	11	852,970	597,595	25,325	.042
Idaho	3	55,572	47,460	2,741	.058
Illinois	37	3,069,109	3,059,369	108,905	.036
Indiana	27	1,942,980	1,788,957	68,360	.038
Iowa	14	638,842	531,372	36,045	.068
Kansas and Nebraska	3	55,221	48,390	1,700	.035
Kentucky	8	137,179	124,628	5,995	.048
Maine	7	410,387	396,662	14,708	.037
Maryland	5	91,701	98,047	5,391	.055
Massachusetts	31	6,684,234	5,724,832	221,364	.039
Michigan	51	7,562,047	7,339,512	227,223	.031
Minnesota	8	1,142,202	1,076,771	39,153	.036
Mississippi	6	145,626	148,292	6,345	.043
Missouri	7	5,116,059	5,369,609	205,305	.038
Montana	4	155,609	150,344	3,219	.021
New Hampshire	3	162,610	162,610	6,936	.043
New Jersey	4	322,065	309,265	16,442	.053
New York	30	8,803,751	8,221,955	342,984	.042
North Carolina	9	472,334	486,550	17,075	.035
North Dakota	3	249,693	231,631	7,201	.031
Ohio	8	324,044	283,849	12,544	.044
Oregon	3	34,782	24,310	1,977	.081
Pennsylvania	13	2,454,645	480,945	19,190	.040
Rhode Island and Vermont	4	776,583	802,771	29,162	.036
South Dakota and Wyoming	4	50,788	27,011	1,084	.040
Tennessee	6	641,156	607,155	18,126	.030
Texas	4	211,926	207,923	15,875	.076
Utah	3	409,466	354,448	14,644	.041
Virginia	12	1,016,504	983,404	33,282	.034
Washington	9	1,087,751	1,167,232	54,394	.047
Wisconsin	18	3,324,178	3,396,115	120,808	.036
	389	52,694,826	47,727,839	1,863,580	.039

The value of the tar varies considerably, but as shown in Table 31 it is usually between 3 and 4 cents a gallon, regardless of the size of the works. In considering this table it should be borne in mind that the quality of the tar is as much a factor in the price that it will command as any other influence. If the light oils have been removed or if the plant has been so operated as to make the percentage of light oils in the tar unusually low, the tar does not command as high a price as otherwise; but the value of these light oils is so great that if they can be sold separately the income from them more than offsets the loss in value incurred by removing them from the tar. Other factors affecting the value of the tar are the local demand for tar products and for liquid fuels and the characteristics of the tar—for example, the quantity of free carbon it contains.

TABLE 31.—*Average prices realized for coal tar sold by coal-gas plants in 1918, by size of plant and by price group.*

	A. 1-20,000 M.	B. 20,000-50,000 M.	C. 50,000-100,000 M.	D. 100,000-200,000 M.	E. 200,000-500,000 M.	F. 500,000-1,000,000 M.	G. 1,000,000 M and over.	Total.
Total sales of gas by coal-gas plants.....M..	1,501,169	4,057,995	4,664,570	4,182,702	9,180,896	5,046,679	14,025,476	42,659,487
Number of plants selling tar [a]	119	121	67	29	29	8	6	379
Average price per gallon of tar sold:								
Minimum	$0.015	$0.020	$0.010	$0.026	$0.020	$0.027	$0.024	$0.015
Maximum	.150	.100	.195	.070	.096	.140	.065	.195
Average	.050	.040	.040	.030	.040	.040	.041	.044
Number of plants receiving—								
$0.01-$0.019 per gallon	2		2					4
.02- .029	7	9	4	2	2	3	1	28
.03- .039	40	56	35	11	19	2	2	165
.04- .049	22	31	16	11	5	2	2	89
.05- .059	12	14	3	2	1			32
.06- .079	14	10	3	2	1		1	31
.08- .099	5		1	1	1			8
.10 or more	17	1	3			1		22

[a] Excludes a small number of plants for which reports were incomplete or otherwise defective.

The average yield of tar in coal-gas works of different sizes is shown in Table 32, where plants are grouped according to size, as for other products. As might be expected, the recovery of tar in very small works is slightly lower than in larger plants, but works above a certain minimum size are almost invariably so operated as not only to eliminate all the tar from the gas but also to recover it completely. The yield per ton of coal carbonized for all the size groups from B to G is therefore substantially the same.

TABLE 32.—*Yield of coal-gas tar per ton of coal consumed in 1918, by size of plant and by efficiency groups.*

	A. 1-20,000 M.	B. 20,000-50,000 M.	C. 50,000-100,000 M.	D. 100,000-200,000 M.
Total sales of gas by coal-gas plants.....M..	1,501,169	4,057,995	4,664,570	4,182,702
Number of plants producing tar [a]	120	123	67	29
Gallons of tar per ton of coal consumed:				
Minimum	2.0	5.3	5.8	8.4
Maximum	26.3	15.4	15.9	14.1
Average	9.6	11.0	11.1	11.0
Number of plants recovering—				
Less than 5 gallons per ton	7			
5-5.9 gallons	5	1	1	
6-6.9 gallons	4	7	1	
7-7.9 gallons	10	7	1	
8-8.9 gallons	16	8	4	3
9-9.9 gallons	20	13	8	2
10-10.9 gallons	27	32	19	9
11-11.9 gallons	12	23	11	8
12 gallons or more	19	32	22	7

[a] Excludes a small number of plants for which reports were incomplete or otherwise defective.

TABLE 32.—*Yield of coal-gas tar per ton of coal consumed in 1918, by size of plant and by efficiency groups*—Continued.

	E. 200,000–500,000 M.	F. 500,000–1,000,000 M.	G. 1,000,000 M and over.	Total.
Total sales of gas by coal-gas plants........M..	9,180,896	5,046,679	14,025,476	42,659,487
Number of plants producing tar [a]	29	8	7	383
Gallons of tar per ton of coal consumed:				
Minimum	8.5	10.3	8.5	2.0
Maximum	14.0	14.9	13.1	26.3
Average	10.7	11.9	11.1	10.6
Number of plants recovering—				
Less than 5 gallons per ton	....	....	....	7
5–5.9 gallons	....	....	....	7
6–6.9 gallons	....	....	....	12
7–7.9 gallons	....	....	....	18
8–8.9 gallons	1	....	1	33
9–9.9 gallons	5	....	....	48
10–10.9 gallons	11	3	1	102
11–11.9 gallons	7	2	4	67
12 gallons or more	5	3	1	89

[a] Excludes a small number of plants for which reports were incomplete or otherwise defective.

The irregularities in the reports of tar production are probably due in some measure to the difficulty of estimating the quantities of tar in stock at various times. A stock of tar representing the production of weeks or even months may be on hand at the beginning or end of a year, and some error in estimating this stock makes an apparent discrepancy in the reports of average production for the previous and the subsequent periods. This condition probably accounts for many reports of less than 7 or more than 12 gallons of tar per ton of coal consumed.

The yield of tar varies more with the kind of coal, the process of treatment, and the care in collection than it does with the size of the plant. The average yield appears to be about 10 gallons of tar per ton of coal. Some of the newer processes give higher yields, and with the increasing demands for liquid fuels of all sorts there is also a tendency for more complete recovery and sale of this valuable by-product. Where the tar, as often in the past, was simply recovered as a boiler fuel for use in the gas works itself the efficiency in collection and the quality of the tar were of secondary importance; but this situation is fast changing.

In the manufacture of water gas some of the oil used for carbureting the gas is not completely "cracked" and therefore appears in and is removed from the crude gas as tar. But this tar is very different from coal-gas tar, and its quality varies widely with the methods of operating the water-gas machine. The results reported for 1917 and 1918 from water-gas plants throughout the country are summarized in Tables 33 and 34.

TABLE 33.—*Tar sold from water-gas plants in 1917, by States.*

State.	Number of plants.	Quantity (gallons)	Value.	Average price per gallon (cents).
Alabama, Arkansas, Louisiana, and Oklahoma	4	1,092,178	$24,751	2.3
Colorado	3	99,619	3,052	3.1
Connecticut	7	435,812	15,895	3.6
Delaware, District of Columbia, and Maryland	5	2,215,000	73,758	3.3
Florida	4	128,012	4,633	3.6
Georgia	3	131,053	4,444	3.4
Illinois	11	23,068,644	278,325	1.2
Indiana	8	1,253,207	31,774	2.5
Iowa	17	1,271,077	35,860	2.8
Kansas and Minnesota	3	327,154	11,393	3.5
Kentucky, Ohio, and Tennessee	4	458,548	10,833	2.4
Maine, New Hampshire, Rhode Island, and Vermont	6	56,773	1,384	2.4
Massachusetts	16	1,840,971	46,105	2.5
Michigan	3	605,388	15,120	2.5
Missouri	9	900,873	35,056	3.9
Montana, North Dakota, South Dakota, and Oregon	5	20,405	2,037	10.0
Nebraska	10	1,180,714	35,689	3.0
New Jersey	11	3,529,990	86,494	2.5
New York	24	9,658,868	313,503	3.2
North Carolina	4	15,443	785	5.1
Pennsylvania	23	9,338,643	167,558	1.8
South Carolina	4	251,804	8,688	3.5
Texas	8	157,140	6,382	4.1
Virginia	7	712,638	21,541	3.0
Washington	4	498,010	16,406	3.3
Wisconsin	5	285,244	7,217	2.5
	208	59,533,208	1,258,683	2.1

TABLE 34.—*Tar produced and sold from water-gas plants in 1918, by States.*

State.	Number of plants producing.	Production (gallons).	Sales.		Average price per gallon (cents).
			Quantity (gallons).	Value.	
Alabama and Louisiana	3	178,377	158,377	$5,876	3.7
Colorado	3	171,068	63,070	3,120	4.9
Connecticut	13	1,996,224	502,321	17,408	3.5
Delaware, District of Columbia, and Maryland	9	5,257,213	2,504,273	105,669	4.2
Florida	6	362,045	152,946	8,911	5 8
Georgia	3	581,702	392,307	17,476	4.5
Illinois	18	20,562,402	17,921,985	496,806	2.8
Indiana	11	1,087,556	973,720	27,143	2.8
Iowa	22	1,132,997	1,104,645	44,120	4.0
Kansas and Utah	3	72,999	72,999	2,224	3.0
Kentucky, Ohio, Tennessee, and West Virginia	6	418,515	367,227	11,426	3.1
Maine and New Hampshire	5	182,090	127,696	3,536	2.8
Massachusetts	22	5,631,661	2,095,525	105,610	5.0
Michigan	12	2,108,728	2,674,036	74,142	2.8
Minnesota	4	1,611,516	1,353,695	47,802	3.5
Missouri	10	1,103,936	1,406,404	46,567	3.3
Montana and North Dakota	4	43,871	13,300	555	4.2
Nebraska	7	692,011	591,774	25,180	4.3
New Jersey	15	4,345,709	3,009,059	104,558	3.5
New York	38	39,412,723	6,947,819	366,482	5.3
North Carolina	6	63,000	21,950	1,071	4.9
Pennsylvania	33	8,779,602	10,070,618	202,544	2.0
Rhode Island	3	1,417,118	107,149	2,912	2.7
South Carolina	3	246,357	199,212	7,213	3.6
South Dakota	3	41,000	15,401	651	4.2
Texas	6	937,062	68,210	3,786	5.6
Virginia	9	754,195	747,729	21,507	2.9
Washington	4	699,261	649,063	24,804	3.8
Wisconsin	7	377,496	420,968	10,799	2.6
	288	100,268,434	54,733,478	1,789,898	3.3

It is evident from Table 34 that nearly half of the water-gas tar produced is not sold, but is used by the gas works, generally as boiler fuel. The sales in 1918 were less than in 1917, although greater than in 1915, the latest previous year for which reports were made. This decrease was probably the result of the general conditions of fuel supply in the country, which made it difficult to get boiler fuel of any type at a reasonable price. As a result much of the water-gas tar that might have otherwise been sold was used in the works for boiler fuel in place of bituminous coal, which was not readily available or was unusually expensive. Whenever steam coal is high priced or hard to get, less water-gas tar will be sold, because the manufacturer will prefer to retain it for use in his own boiler plant. That the tar was in demand during 1918 is evident from the marked increase in average price from 2.1 cents a gallon in 1917 to 3.3 cents in 1918. In 1915 the average price of tar sold by water-gas and oil-gas plants (about 51,000,000 gallons, valued at $1,120,000) was 2.2 cents a gallon.

The yield of water-gas tar shown in Table 35 is computed in terms of gallons of tar produced per gallon of oil used. The yield increases steadily with increasing size of plant, although of course there are wide variations within each size group. The average price obtained for the tar in the very small works is also notably lower than that obtained in the medium or large plants, but between these two classes there is no great disparity of price. Practically all of this tar sold is used for fuel, although some of it is worked up for road oil and other tar products. The price obtained for water-gas tar is therefore more affected by the markets for liquid fuel than that of coal-gas tar.

TABLE 35.—*Yield of tar from water-gas plants and average prices obtained in 1918, by size of plant.*

	A. 1-20,000 M.	B. 20,000-50,000 M.	C. 50,000-100,000 M.	D. 100,000-200,000 M.	E. 200,000-500,000 M.	F. 500,000-1,000,000 M.	G. 1,000,000 M and over.	Total.
Number of plants reporting production of tar [a]	49	50	46	31	46	24	31	277
Recovery per gallon of oil consumed (gallons):								
Minimum	0.002	0.01	0.01	0.038	0.002	0.017	0.035	0.01
Maximum	.35	.295	.22	.22	.289	.294	.216	.35
Average	.08	.11	.11	.11	.12	.13	.14	.115
Number of plants reporting sales of tar	36	31	37	26	43	23	28	224
Average price obtained per gallon:								
Minimum	$0.015	$0.01	$0.02	$0.01	$0.018	$0.02	$0.022	$0.01
Maximum	.15	.15	.08	.113	.065	.31	.118	.15
Average	.02	.04	.04	.04	.04	.05	.05	.038

[a] Excludes a small number of plants for which reports were incomplete or otherwise defective.

In Table 36 are summarized the tar returns from all oil-gas plants for 1915, 1917, and 1918. Only 9 out of the 81 oil-gas works reported production of tar in 1918. Doubtless tar was produced at the other 72 plants, though perhaps not recovered separately. More commonly the tar and the lampblack, which are separated from the crude gas together, are not subsequently separated from each other but are either used as fuel under the boilers of the works or are briquetted or sold for fuel. In times of scarcity of fuel there is in oil-gas manufacture the same tendency as noted above for water-gas manufacture, namely, to burn the tar. This probably accounts for the fact that very few companies reported any production of oil-gas tar in 1918.

With so few producers reporting, the recorded price per gallon of oil-gas tar is not particularly significant. The figures given in Table 36 represent correctly, however, the order of magnitude of the price per gallon. This price would, of course, fluctuate considerably with the conditions of the liquid fuel market as well as with the demand for tar products.

TABLE 36.—*Tar produced and sold from oil-gas plants in 1915, 1917, and 1918.*

	1915	1917	1918
Number of plants reporting production	21		9
Production ... gallons	3,665,176		716,722
Yield (gallons of tar per gallon of oil used):			
Maximum [a]			.084
Average			.021
Sales:			
Quantity ... gallons	64,433	727,556	550,006
Value	$4,268	$32,682	$15,967
Price per gallon ... cents	6.6	4.5	2.9

[a] The reports range from zero up to the maximum.

RETORT CARBON AND LAMPBLACK.

In the production of water gas and coal gas a certain quantity of carbon is deposited in the form known as retort carbon. The quantity of this material produced and sold in 1915, 1917, and 1918 is shown in Table 37. Of the 100 plants reporting any production of retort carbon in 1918, nearly all are coal-gas plants, a few are coke ovens, and a few are water-gas plants.

TABLE 37.—*Retort carbon produced and sold from artificial-gas plants in 1915, 1917, and 1918.*

	Number of plants reporting sales.	Production (pounds).	Sales.		
			Quantity (pounds).	Value.	Average price per pound (cent).
1915.					
Coal-gas and water-gas plants	47	8,166,000	1,722,000	$9,873	0.57
1917.					
Coal-gas and water-gas plants	47	10,600,000	2,640,000	14,800	.56
1918.					
Coal-gas plants	90	2,202,853	2,014,961	13,275	.66
Water-gas plants	6	521,748	501,723	2,230	.44
Coke-oven plants	4	1,310,020	1,310,020	2,732	.21
	100	4,034,621	3,826,704	18,237	.48

In the manufacture of oil gas a considerable quantity of lampblack is produced by cracking the oil at high temperature and is separated from the crude gas by scrubbing with water. In Table 38 are shown data on this product for 1915, 1917, and 1918.

TABLE 38.—*Lampblack produced and sold from oil-gas plants in 1915, 1917, and 1918.*

	1915	1917	1918
Number of plants reporting production	21	21	29
Production.....pounds..	100,090,000	159,304,000	262,022,000
Used for lampblack briquets.....do....	....	83,252,000	80,124,000
Sales.....do....	52,918,000	62,410,000	35,355,000
Value of sales	$174,659	$169,425	$95,211
Average price obtained per pound.....cent..	0.33	0.27	0.27

The production for 1917 was 60 per cent greater than in 1915, and that for 1918 was 160 per cent greater than in 1915. About one-third of the product in 1918 was used at the works for the manufacture of lampblack briquets; about 13 per cent was sold, mainly for the manufacture of briquets or for use as fuel; and the remainder, more than half the total, was presumably used as fuel in the oil-gas works. In the territory where oil gas is made—that is, the far West and the Southwest—all forms of high-grade solid fuel are rare or very expensive, hence lampblack briquets afford a valuable substitute for anthracite or coke. To some extent lampblack also enters the chemical industries for further manufacture into various carbon products, but its large content of tar makes it less valuable for such uses than it might otherwise be. The presence of this tar, however, makes it well adapted to briquetting.

Two distinct views as to lampblack are held by oil-gas manufacturers. One group undertakes to make as large a quantity of lampblack as possible, regarding it as a valuable by-product which returns more to the producer than it costs. The second group undertakes to reduce the yield of lampblack to the lowest possible point, regarding this product as only a nuisance. Many local conditions affect both the cost of production and the value of this product, and it is not practicable to generalize as to the merits of the claims of these two groups, or to prophesy any tendency within the industry toward greater or lesser production of lampblack.

AMMONIA.

In Tables 39 and 40 are shown the production and sales of ammonia at coal-gas works in the United States during 1917 and 1918. A comparison of the figures for these years with those for earlier periods shows a slight increase in value from $1,330,000 in 1915 to $1,362,000 in 1917 and a somewhat larger increase to $1,453,000 in 1918. In the preparation of these tables all the ammonia produced has been computed as nearly as possible on the basis of pounds of ammonium sulphate. From some reports, however, the exact quantity or strength of liquor made could not be accurately estimated, and hence there is some uncertainty in State as well as in national totals. The wide fluctuation in the value of the product sold is also probably the result of uncertainty in estimate as to the actual quantity handled rather than to any great difference in market conditions. The uncertainty in these figures is of slight consequence, however, for the total yield of ammonia in coal-gas works is not valued at more than 6 or 8 per cent of the value of the ammonia produced at coke ovens during the corresponding period. For example, in 1918 the sales from coal-gas works are reported at approximately 57,000,000 pounds of sulphate equivalent, valued at less than $1,500,000, whereas coke-oven operators sold more than 669,000,000 pounds of ammonium sulphate equivalent with a total value in excess of $26,000,000. In gathering statistics for later years a somewhat different system of reporting will probably be used, and it is hoped that more complete data can be collected both as to the quantity obtained and as to the form in which it is produced and sold, whether as ammonia liquor, ammonium sulphate, or anhydrous ammonia

TABLE 39.—*Ammonium sulphate equivalent sold from coal-gas plants in 1917.*

State.	Number of plants reporting sales.	Quantity (pounds).	Value.	Average price per pound.
Alabama	3	1,019,392	$15,969	$0.016
Colorado and Utah	4	1,725,952	31,013	.018
Connecticut	5	2,338,848	80,064	.034
District of Columbia and New Jersey	3	934,056	19,499	.021
Florida, Georgia, Mississippi, and North Carolina	6	1,077,576	23,366	.022
Illinois	13	2,226,116	64,053	.029
Indiana	6	1,099,577	22,704	.021
Iowa and Missouri	3	12,350,895	277,184	.022
Maine, New Hampshire, and Rhode Island	5	2,838,104	49,320	.017
Massachusetts	16	6,709,343	135,674	.020
Michigan	17	9,663,473	209,745	.022
Minnesota and North Dakota	3	714,452	13,602	.019
New York	13	31,658,248	259,349	.008
Ohio and Pennsylvania	5	6,844,307	33,224	.005
Tennessee	3	790,168	10,010	.013
Virginia	6	771,044	12,322	.016
Washington	4	1,479,096	14,331	.010
Wisconsin	7	4,307,328	90,696	.021
	122	88,547,975	1,362,125	.015

TABLE 40.—*Ammonium sulphate equivalent produced and sold from coal-gas plants in 1918.*

State.	Number of plants reporting production.	Production (pounds).	Sales.		
			Quantity (pounds).	Value.	Average price per pound.
Alabama	3	462,776	410,384	$7,252	$0.018
Colorado and Utah	5	1,677,546	1,611,255	32,146	.020
Connecticut	5	1,810,368	1,484,376	64,842	.044
Florida, Georgia, and North Carolina	5	778,154	756,984	18,362	.024
Illinois	14	3,007,624	2,945,152	66,305	.023
Indiana	7	774,677	752,040	20,416	.027
Iowa	6	432,465	367,448	7,522	.020
Maine, New Hampshire, New Jersey, and Rhode Island	6	1,394,764	1,323,676	25,212	.019
Massachusetts	17	7,601,101	7,173,429	200,460	.028
Michigan	19	6,473,768	6,132,110	231,830	.038
Minnesota and North Dakota	3	1,027,800	1,034,136	23,432	.023
Mississippi and Tennessee	3	594,888	555,224	7,981	.014
Missouri and Texas	3	12,079,196	11,846,040	199,751	.017
New York	11	12,938,048	12,516,612	346,964	.028
Ohio	3	115,128	49,052	1,704	.035
Pennsylvania	4	2,120,363	2,206,680	76,755	.035
Virginia	6	613,808	472,024	6,563	.014
Washington	4	1,631,326	1,617,670	18,311	.011
Wisconsin	8	3,814,344	3,646,172	97,262	.027
	132	59,348,144	56,900,464	1,453,070	.026

In Table 41 is shown, according to the size of plant and reported efficiency, the yield of ammonium sulphate per ton of coal consumed. Very few small plants find it practicable to recover ammonia, and those which do recover it are by no means as efficiently operated as the larger plants. This table should be used with caution when considering the exact efficiency of plant operation, however, for, as pointed out above, there is considerable uncertainty in estimating the quantities of ammonia produced or sold by many individual plants.

TABLE 41.—*Yield of ammonium sulphate per ton of coal consumed in coal-gas plants in 1918, by size of plant and by efficiency groups.*

	A. 1-20,000 M.	B. 20,000-50,000 M.	C. 50,000-100,000 M.	D. 100,000-200,000 M.
Total sales of gas by coal-gas plants ... M..	1,501,169	4,057,995	4,664,570	4,182,702
Number of plants reporting production of ammonia [a]	1	22	36	28
Ammonium sulphate per ton of coal (pounds):				
Minimum		.3	.2	1.6
Maximum	22.4	14.8	20.2	30.4
Average		7.2	7.5	9.6
Number of plants recovering—				
Less than 2 pounds per ton		2	3	1
2-3.9 pounds		4	3	1
4-5.9 pounds		2	10	5
6-7.9 pounds		5	5	5
8-9.9 pounds		3	3	4
10-14.9 pounds		6	10	9
15-19.9 pounds			1	2
20-24.9 pounds	1		1	
25 pounds or more				1

	E. 200,000-500,000 M.	F. 500,000-1,000,000 M.	G. 1,000,000 M and over.	Total.
Total sales of gas by coal-gas plants ... M..	9,180,896	5,046,679	14,025,476	42,659,487
Number of plants reporting production of ammonia [a]	29	9	8	133
Ammonium sulphate per ton of coal (pounds):				
Minimum	3.7	5.6	2.3	.2
Maximum	28.0	20.0	22.0	30.4
Average	13.7	14.3	13.7	10.2
Number of plants recovering—				
Less than 2 pounds per ton				6
2-3.9 pounds	1		1	10
4-5.9 pounds	1	1	1	20
6-7.9 pounds	2	1		18
8-9.9 pounds	3		1	14
10-14.9 pounds	8	3	1	37
15-19.9 pounds	11	3	2	19
20-24.9 pounds	2	1	2	7
25 pounds or more	1			2

[a] Excludes a small number of plants for which reports were incomplete or otherwise defective.

TOLUOL.

During the World War the demand for toluol, benzol, and other light oils was so great that a considerable number of plants were installed to recover these products from coal gas, water gas, and oil gas. The vapors of toluol, benzol, and related hydrocarbons, which collectively are called light oils, are present in city gas supplies associated with other hydrocarbons. The problem of recovery was therefore simply that of separating these substances from the hydrocarbons of different characteristics. Processes commonly used for this purpose are described in a recent report [7] as follows:

To recover light oils from the gas the method now almost universally employed is to bring the gas into contact with a medium which has a solvent action upon the light oils. In any case to obtain complete absorption it is necessary that an adequate amount of the washing medium be brought into contact with the gas at a sufficiently low temperature. The temperature usually should not exceed 30° C. (86° F.). The temperatures obtainable in practice will, of course, depend upon the facilities available for cooling the gas and the washing oil. It is desirable to have the oil a little warmer than the gas to prevent condensation of water from the gas into the oil, which gives trouble in the further stages of recovery. The amount of washing medium circulated through the washers will depend upon the amount of light-oil vapors present in the gas, the temperature of the washing medium, the amount of gas to be washed, and the saturation of the washing medium which it is feasible to obtain. About 10 gallons of wash oil per 1,000 cubic feet of gas washed seems to be an average figure.

The washing medium now usually employed for this purpose in this country is a petroleum distillate called from its color "straw oil." Some plants use a creosote oil obtained from the distillation of coal tar. The choice seems to depend largely upon which is available in a given case. * * * Some operators claim to have successfully used ordinary gas oil, water-gas tar, or coal tar. Other operators, however, state that when gas oil is used the paraffin and olefine compounds in it are likely to contaminate the light oil and that, on account of emulsification, this oil soon becomes unfit for use. Water-gas tar used more than once may soon become too thick for use and also may lead to serious naphthalene deposits in the distribution system. * * *

To separate the light oils from the wash oil in which they are dissolved some form of still is employed. The difference in boiling points makes possible the separation. In small plants either continuous or intermittent stills may be used. The separation of light oils from the benzolized wash oil should be nearly complete. It is stated that good operating practice will leave only from 0.1 to 0.3 per cent of oils distilling below 200° C. in the debenzolized oil. In large plants there are used continuous stills in which steam comes in contact with the wash oil and boils off the light oils. The light-oil vapors, together with the uncondensed portion of the steam, ascend through a series of chambers, which will be described more in detail later. In their ascent they come in contact with descending wash oil carrying light oils, which they assist in freeing. The light-oil vapors, together with some steam, naphthalene, sulphur compounds, etc., pass away from the still and are condensed. Some operators advise the use of steam sufficiently superheated so that nearly all of it leaves the still uncondensed with the light-oil vapors. * * *

To obtain from the light oils those constituents which are in most demand, a further separation by distillation and chemical treatment is necessary. The light oil is distilled in some form of still, usually equipped with a rectifying column and dephlegmator, which will be described in more detail later. The latter apparatus acts as a partial condenser in which part of the vapor is condensed and, falling downward through the rectifying column, meets the ascending vapors and washes from them a portion of the high-boiling constituents. Only the light low-boiling constituents are able to pass the dephlegmator uncondensed. What vapors shall be allowed to pass on to the condensers depends upon the temperature maintained at the dephlegmator. This temperature is regulated according to the particular oil which it is desired to separate from the light-oil mixture at any particular stage of the distillation. By the use of the dephlegmator and rectifying column, it is possible to obtain much more definite separation of the benzol, toluol, and other aromatics than would otherwise be possible. In making the first distillation of the light oil, it is usual to collect the distillate in three successive portions or fractions, making the "cuts" at predetermined temperatures. The first fraction is collected in a containing vessel or receiver until the temperature at the top of the still is 100° C. This fraction is called crude benzol, since benzol is its chief constituent. The flow of distillate is then diverted into another receiver and collected until a temperature of 120° C. is reached. This fraction is termed crude toluol, from its chief component. The fraction collected above 120 C. is called crude solvent naphtha, from the use to which it is put as a solvent of various materials. The boiling points of pure benzol and pure toluol are about 80 and 110° C., respectively. It will be noted that one of the changes of fractions or cuts is made midway between these boiling points, while the boiling point of pure toluol is midway between the other cuts.

* * * * * * *

[7] McBride, R. S., and others, Toluol recovery: U. S. Bur. Standards Tech. Paper 117, 1918.

The above procedure is not universal. Some operators collect the crude benzol and toluol together and subsequently separate them. Some of the impurities present in the crude fractions have boiling points so close to those of benzol and toluol that they can not be separated from them by distillation. To remove a certain class of these compounds, called unsaturated hydrocarbons, the fractions are washed successively with strong sulphuric acid, caustic soda, and water. The unsaturated compounds form a thick tarry mass, which settles out by gravity upon standing and is drawn off. The fractions are then redistilled in stills with more efficient rectifying columns than those used for the crude distillation, and fractions are finally obtained which boil within a single degree of the temperatures which have been determined as the boiling points of pure benzol, toluol, etc.

Some operators prefer to distil the toluol fraction from water-gas light oils in a still without a rectifying column previous to final distillation in a column still. The vapors from the still in this case pass directly through a condenser coming out in liquid form. This liquid passes upward through a tank containing a solution of caustic soda. By this process any sulphonated olefines which remain in the toluol are removed. Otherwise they would be broken up in the column still and have a destructive action on the dephlegmator and condenser. The condenser coil and connections of this intermediate still should be made of lead.

The final distillates are considered as substantially pure materials if their specific gravities also agree with those which have been determined for the pure constituents. If, however, the specific gravity is lower than that of the pure benzol or toluol, it is indication of the presence of paraffins, and to a certain extent the lowering is a measure of the amount of paraffins present.

LIGHT OILS AND DRIP OR HOLDER OILS.

When the gas manufactured by any ordinary process is washed and purified, ready for distribution, it still contains certain oil vapors which tend to condense from the gas upon exposure to lower temperatures. The oil which thus condenses is known as "holder oil" or "drip oil," from the fact that it collects in the gas holder or in the drips which are placed at the lowest points in the main system under the city streets. This oil contains many of the same constituents as the crude light oil, and it derives its value from this fact.

In 1918 the recovery of drip or holder oils was reported by 76 water-gas companies in 19 States. All but four of these companies reported sales during the same year The quantity of these and related miscellaneous oils recovered was 3,484,165 gallons, and the sales were 3,430,232 gallons, valued at $455,949 at the works, or an average of 13.3 cents per gallon. The quality and consequently the price per gallon varied greatly, some works realizing only a few cents per gallon from the sale of these oils. In general, the oil does not command a higher price than crude light oil, and hence the maximum price realized is usually only one-half to two-thirds that of gasoline.

The coal-gas companies reporting the recovery of holder oils or drip oils during 1918 were few in number. Fourteen establishments in ten States recovered 179,614 gallons and sold 176,289 gallons, valued at $42,949. The average price of coal-gas drip and holder oils sold was therefore 24.4 cents, or much more than that of the product recovered from water gas. The reason for this considerable difference is not evident. It was probably due to the circumstances that happened to attend the recovery and sale in the few localities where coal-gas drip oils were marketed.

In Table 42 are summarized the data as to drip and holder oils recovered in both coal-gas and water-gas plants.

TABLE 42.—*Drip and holder oils produced and sold from gas plants in the United States in 1918.*

State.	Production (gallons).	Sales.	
		Quantity (gallons).	Value.
Connecticut	53,433	53,433	$12,139
Illinois	450,164	409,206	44,729
Indiana	16,503	16,503	3,524
Iowa	46,723	45,873	4,919
Massachusetts	427,812	409,908	77,426
Michigan	1,373	1,373	155
Minnesota	235,875	235,875	37,425
Missouri	19,276	19,047	904
New Hampshire	14,048	14,048	2,647
New Jersey	345,238	350,868	77,420
New York	1,609,746	1,610,407	182,805
Pennsylvania	33,523	33,723	4,367
South Dakota	6,207	4,207	409
Washington	22,234	19,674	2,914
Delaware, Maryland, and Rhode Island	240,347	240,347	23,754
Ohio, South Carolina, and Virginia	27,804	27,804	3,576
Montana, Nebraska, and Wisconsin	113,473	114,225	19,785
	3,663,779	3,606,521	498,898

Light oil was produced by scrubbing oil gas at four localities in California in 1918. The production of crude light oil in these four plants amounted to 21,494 gallons, including slightly less than 1,000 gallons of the product called by the maker "residue." The sales in 1918 amounted to 20,376 gallons, including the residue mentioned, having a total value at the plants of $4,274, or an average of 21 cents a gallon. The average price per gallon ranged from 16 cents for the residue above mentioned to 22.7 cents at one of the plants. No refined products were reported as manufactured at gas works making oil gas. Presumably, therefore, all the crude light oil produced at these works was refined or used elsewhere.

Table 43 gives a summary for the entire country of the production and sales of crude light oil and of the products made from it for each kind of gas. In Table 44 are given further details regarding the quantity of benzol, toluol, solvent naphtha or xylol, and other derived products produced at gas works by the refining of crude light oil. These data do not represent by any means complete figures for the output of products from the light oil recovered at gas works, as considerable quantities recovered at gas works were refined elsewhere and therefore not reported to the Geological Survey in response to its inquiries regarding gas-plant operations.

TABLE 43.—*Benzol products produced and sold from gas plants in the United States in 1918.*

Kind of gas.	Production of crude (gallons).	Sales of crude and all products.		
		Quantity (gallons).	Value.	Average price per gallon.
Coal gas	5,729,629	2,032,883	$1,457,972	$0.717
Water gas	11,909,702	4,613,751	3,830,392	.830
Coal gas and water gas mixed	4,230,908	2,229,535	1,220,138	.547
Oil gas	21,494	20,376	4,274	.210
	21,891,733	8,896,545	6,512,776	.732

TABLE 44.—*Derived products of light oil produced and sold at gas plants in the United States in 1918.*

Product.	Production (gallons).	Sales.		
		Quantity (gallons).	Value.	Average price per gallon.
Benzol	5,632,594	2,177,168	$572,950	$0.263
Toluol	4,527,345	3,965,518	5,597,353	1.411
Solvents and xylol	2,028,450	1,442,267	191,475	.133
Other derived products	1,100,690	722,632	71,529	.098
	13,289,079	8,307,585	6,433,307	.774

If the light oil produced but not represented by sales of crude light oil or of its derived products could have been sold at 13.8 cents a gallon—the average price obtained for the crude sold as such—the gas companies would have realized about $1,500,000 more than they did.

NAPHTHALENE AND MISCELLANEOUS PRODUCTS.

Table 45 gives data on naphthalene produced and sold in 1915, 1917, and 1918. There has been a large increase in the number of plants manufacturing naphthalene during recent years. Forty-two plants reported production of either crude or refined naphthalene in 1918, whereas only 10 reported sales in 1915 and 32 in 1917. The production and sales increased correspondingly. This product—one of the so-called coal-tar intermediates—finds extensive application in the chemical industries as well as in the familiar moth balls. Its value in the aggregate as a by-product of gas manufacture will therefore doubtless increase during the coming decade, though the average price may decline materially as greater supplies become available.

TABLE 45.—*Naphthalene produced and sold from gas plants and coke-oven plants in the United States in 1915, 1917, and 1918.*

	1915 [a]	1917	1918
Number of plants reporting:			
Coal gas—			
Crude	4	6	6
Refined			1
Water gas—			
Crude	....	1	2
Refined			....
Coke-oven gas—			
Crude	6	25	24
Refined			9
	10	32	42
Production [b] (pounds):			
Coal gas—			
Crude	....	....	424,679
Refined	....	....	5,119
Water gas—			
Crude	....	....	539,884
Refined	....	....	....
Coke-oven gas—			
Crude	....	....	10,614,799
Refined	....	....	5,472,699
	....	....	17,057,180

[a] Data on naphthalene were not asked for specifically in 1915, hence the figures shown may not cover the entire output of the country.
[b] Figures of production were not asked for until 1918.

TABLE 45.—*Naphthalene produced and sold from gas plants and coke-oven plants in the United States in 1915, 1917, and 1918*—Continued.

	1915	1917	1918
Sales (pounds):			
Coal gas—			
Crude	222,925	383,349	387,878
Refined			5,119
Water gas—			
Crude	....	16,548	503,083
Refined			....
Coke-oven gas—			
Crude	465,865	17,276,044	10,403,758
Refined			5,486,689
	688,790	17,675,941	16,786,527
Value of sales:			
Coal gas—			
Crude	$3,565	$9,584	$10,200
Refined			475
Water gas—			
Crude	....	103	3,607
Refined			....
Coke-oven gas—			
Crude	46,959	569,449	287,581
Refined			362,648
	50,524	579,136	664,511
Average price per pound (cents):			
Coal gas—			
Crude	1.6	2.5	2.6
Refined			9.3
Water gas—			
Crude	....	0.6	0.7
Refined			....
Coke-oven gas—			
Crude	10.0	3.3	2.8
Refined			6.6
	7.3	3.3	4.0

In a considerable number of gas works miscellaneous products are occasionally available and sold, but only a few such miscellaneous sources of income have been reported to the Geological Survey. In 1918 three such reports were received; one company reported the production and sale of yellow prussiate of soda; one the sale of spent oxide; and one the sale of other residuals not named. The value of these three products as reported was $25,826.

METHODS OF GAS MANUFACTURE.

For the convenience of readers some of the methods of manufacturing gas commonly employed in the United States are described briefly in the following quotation taken from a report prepared for the Bureau of Standards under the direction of the writer.[8]

Coal gas.—Coal gas is produced by the destructive distillation of bituminous coal in externally fired retorts of refractory material. As distributed for use it is a colorless gas with a pungent odor caused by the hydrocarbon vapors which it contains. It is of low specific gravity, being usually between 0.45 to 0.50 as heavy as air.

Only such coals as contain a high percentage of volatile matter, are reasonably free from sulphur, and will form coke, are considered suitable for the production of coal gas, while a low ash content is very desirable, as the coke recovered has a correspondingly higher value. A typical high-grade gas coal might have an analysis similar to the following, though considerable variation from this may be expected. It should further be noted that the gas-making quality of the coal is very largely dependent upon the quantity of volatile combustible present.

[8] McBride, R. S., Standards of gas service: U. S. Bur. Standards Circ. 32, 4th ed., 1920.

	Per cent.
Moisture	3
Volatile matter	35
Fixed carbon	57
Ash	5
	100

Contained in the above analysis is the sulphur, which should not be over 1¼ per cent.

The type of gas-making apparatus used varies from the simple, horizontal, direct-fired bench containing from three to six or sometimes nine D-shaped fire-clay retorts, the coal being charged with shovels and the coke drawn with hand rakes, to the elaborate installations of inclined slot ovens and vertical retorts made of the finest grade silica brick and equipped with labor-saving devices, with gas producers for heating the ovens or retorts, and with various means for utilizing heat that would be wasted under the old systems. However, the fundamental principle in all is the same. A quantity of gas coal, varying in weight from 300 to 400 pounds in the case of horizontal stop-end retorts to several tons in other types of installations, is heated in the retorts or ovens for a period of from 4 to 24 hours, depending on the type of installation, the weight of coal used, the temperature of the retorts, and numerous other factors. The volatile matter and moisture in the coal are driven off in the form of gas, leaving the fixed carbon and ash in the form of coke.

The gas when first produced contains large quantities of tar and ammonia in the form of vapor, while part of the sulphur in the coal passes off with the gas either in the form of hydrogen sulphide or of organic sulphur compounds. Tar and ammonia are first removed in the condensers and scrubbers where the gas is cooled and finally washed with water. The tar and ammonia pass to appropriate settling tanks, where they separate because of their difference in specific gravities. They are then drawn off, the tar stored for sale in a suitable tank, while, except in the smaller plants, the ammonia is concentrated and sold. Tar and ammonia are two valuable by-products of coal-gas manufacture.

The hydrogen sulphide is removed generally by passing the gas through a bed of iron oxide and shavings. The iron oxide removes the hydrogen sulphide, the shavings serving merely to keep the mass open and permit the free passage of gas through it. The organic sulphur compounds are usually not removed. No easy and economical method for doing so has been discovered; and if coals reasonably low in sulphur content are used, the quantity of sulphur compounds left in the gas after the complete removal of the hydrogen sulphide is not sufficient to be objectionable. The use of coals with high sulphur content is thus undesirable, for combined with the very much increased cost of purification because of the larger quantity of hydrogen sulphide in the gas, there is also an increase in the organic sulphur compounds to such a point that they become objectionable.

In this connection it should be mentioned that the introduction of not over 2 per cent of air into the crude gas will greatly increase the efficiency of purification. The oxygen of this air is absorbed in the purifiers and tends to keep the iron oxide in condition to absorb hydrogen sulphide. The nitrogen remaining, though a diluent, is so small in quantity that it is not objectionable. The use of small quantities of air to assist in purification is considered good practice and should be encouraged.

After purification the gas is metered and stored in the holders.

In practice, each pound of coal carbonized may be expected to produce from 4.5 to 5.5 cubic feet of gas; but this varies with the quality of the coal, the temperature and period of carbonization, the type and condition of the equipment, the heating value of the gas produced, and numerous other factors. In general, however, with a given coal, the greater the yield of gas per pound, the lower will be the heating value of the gas produced. Vertical retorts and coke ovens usually give greater yields of gas per pound of coal than do horizontal retorts. Pennsylvania, West Virginia, and eastern Kentucky coals generally give larger yields of higher heating value gas than do coals of the type found in Indiana and Illinois. A great number of factors might thus be discussed.

In general, the factors which influence the yield also affect the heating value of the gas, though certain additional points enter. For example, long exposure to the hot surface of the retort or oven after the gas is once formed tends to break down the illuminants, which, as before stated, have high heating value. Again, the proper cooling and scrubbing of the gas is of importance, for unless suitable apparatus is used and care is exercised, a part of these illuminants will be removed with the tar, and the heating value thus reduced. However, with processes generally in use, and with the higher grade materials available, coal gas may be expected to have a heating value of from about 550 to slightly over 600 B. t. u. per cubic foot.

In this connection it should be noted that the gas produced during the early part of the carbonizing period—that is, the gas first driven off from the coal—contains high percentages of illuminants and methane, and is thus of high heating value. As carbonization progresses the illuminants almost entirely disappear, the percentage of methane greatly decreases, while hydrogen becomes the principal constituent of the gas. The heating value is thus much decreased. Failure to drive off all the gas from the coal will therefore result in an increase in the heating value of the gas per cubic foot, though, of course, because of the fact that the gas which could still be extracted from the coal contains some heat, the total British thermal unit yield per pound of coal must decrease. The practice of drawing the coke before practically all the gas is driven off is uneconomical and should be discouraged.

The yield of by-products obtained varies greatly. Usually each net ton of coal will yield from 1,250 to 1,400 pounds of coke, though usually from 300 to 500 pounds of this will be required to heat the retorts. In some places it is found more economical to buy bituminous coal for this latter purpose and sell the total output of coke.

From each net ton of coal carbonized there should also be obtained from 9 to 15 gallons of tar and from 4 to 7 pounds of ammonia, though the losses in the recovery and concentration of this latter may materially reduce the amount available for sale.

Before leaving the subject of coal gas a word should be said about naphthalene. This troublesome substance, when present in the gas in considerable quantities, crystallizes on the inside of the works and distribution gas mains, causing stoppage. Its elimination from a distribution system can only be accomplished at great trouble and expense, while the dissatisfaction caused by the poor service resulting is in itself a serious matter. Excessive quantities of naphthalene are usually caused by high retort or oven temperatures, though the character of the coal used is often partially responsible for its presence. Where changes in operating practice are impracticable or fail to remove the cause of the trouble, the installation of a scrubber suitable for removing naphthalene from the gas is usual.

By-product coke-oven gas is a coal gas made in ovens designed primarily for the production of a high-grade coke that is suitable for use in blast furnaces or for other metallurgical purposes. The coke is usually considered the primary product and the gas merely one of the by-products.

The distinction between the by-product coke oven and the old-fashioned beehive coke oven should be clearly kept in mind. A by-product coke-oven plant is an elaborate installation, equipped with all possible labor-saving devices and methods of effecting economies in heat utilization, and capable of recovering and handling the various by-products, which in fact provide one of the sources of revenue. A beehive coke oven, on the other hand, is built for the production of coke alone. It is of comparatively crude construction; gas is usually wasted and other by-products are not recovered.

While most by-product oven plants are operated by manufacturing companies, and are in no sense of the word public utilities, they have more and more come to sell the surplus gas which they produce to public-utility companies for distribution by them. Thus an entirely satisfactory commercial gas is obtained at usually a slightly lower cost, while from the standpoint of conservation, if for no other reason, this practice should be encouraged.

A by-product coke oven is merely a special type of coal-gas retort, the principle of its operation being identical with that of a coal-gas installation. The ovens themselves where the coal is heated are rectangular in cross section, usually from 13 to 20 inches wide, 8 to 10 feet high, and 35 to 40 feet long. Each oven will thus hold from 10 to 15 tons of coal. The ovens are placed side by side with only the necessary refractory construction between them, any number up to about 60 usually forming a unit or "battery." The coal capacity of the oven being large, the carbonizing time is naturally long; that is to say from 16 to 24 hours. The same considerations enter as to the selection of coal as in coal-gas manufacture, though on account of the nature of the business the coking quality of the coal rather than ability to produce high yields of gas is most desired. As a matter of fact, however, the yield of gas per pound of coal is usually higher in a coke oven than in a coal-gas retort, though the heating value is correspondingly lower.

Since coke is the primary product all that is made is usually sold, part of the gas being burned under the ovens to maintain them at the proper temperature. In modern efficiently operated plants approximately one-half of the gas produced is thus used.

As stated above under the subject of coal gas, the gas produced during early stages of carbonization is of higher heating value than that coming off later. In certain cases advantage has been taken of this fact, and the gas produced during the first part of the carbonizing period is separated from that produced during the latter part, the former, having high heating value, being supplied to the city, the latter, of low heating value, being used to heat the ovens.

The by-products recovered are the same as in coal gas, and the method of recovery is quite similar. Frequently, however, the ammonia is recovered by washing the gas with sulphuric acid instead of water, the ammonia being separated as solid ammonium sulphate, which is then dried, bagged, and sold.

In coke-oven plants it is also usual to extract the illuminants from the gas by washing it with so-called "straw oil." The illuminants are dissolved in this oil and are later distilled off, forming "light oil." The light oil is then separated by fractional distillation into crude benzol, crude toluol, and crude solvent naphtha; these are washed with sulphuric acid, caustic soda, and water, the washed benzol and toluol being then distilled to pure benzol and toluol suitable for use in the manufacture of chemicals or explosives, while by proper distillation the washed solvent naphtha may be separated into the xylols and other products.

The effect of the recovery of light oil is to decrease the heating value of the gas, usually by about 5 per cent, while the open-flame candlepower is reduced to almost nothing. However, if so desired, a part of the illuminants may be left in the gas by the proper manipulation of the apparatus, or, if actually removed, some of the crude products, in the past usually benzol, may be returned to bring up the candlepower or heating value to the desired standard; however, the economy or desirability of reenrichment is usually questionable.

When operated for the production of gas as the primary product, the ovens are sometimes heated by producer gas generated in independent producers; thus all the gas obtained from the carbonization of the coal is made available for distribution. Under such circumstances the ovens are usually called gas ovens. Occasionally regular coke ovens operated for the production of gas rather than of coke are spoken of as gas ovens. In such case there is no difference in the method of construction, and the operation is changed only in so far as it may appear economically advantageous under the circumstances. Slot ovens and chamber ovens are merely modifications of the coke oven, the principles of construction and the general character of the gas obtained being the same.

Carbureted water gas is formed by the action of steam on highly heated coke or anthracite coal with enrichment by the addition of a high heating value oil gas simultaneously generated. It contains the same constituents as coal gas, but in quite different proportions. Like coal gas, it is colorless and has a pungent odor, but it is considerably heavier, being usually from 0.60 to 0.65 as heavy as air.

The more modern types of water-gas making apparatus generally consist of three cylindrical steel chambers, lined with fire brick, and provided with appropriate gas, steam, oil, and air-blast connections. The first of these chambers, the generator, contains a coke or anthracite coal fire, usually from 4 to 9 feet deep, laid on a grate. A door at the top of the generator provides for replenishing the fire, while doors near the bottom allow the removal of clinker and ash. The second chamber, the carbureter, is provided with an oil spray at the top, and is filled with a checkerwork of fire brick. The superheater, which is the third chamber, is filled with fire-brick checkerwork in a similar manner to the carburetor.

The size of a water-gas set is determined by the diameter of the steel chambers, not by the internal diameter of the fire-brick lining. In practice, sizes run from about 3 feet 6 inches to 12 feet, the larger sets, of course, giving higher capacities and usually slightly better efficiencies.

Actual manufacture of gas is intermittent, and is divided into the "blow," during which period the set is brought up to proper gas-making temperatures, and the "run," the period when gas is actually made. During the blow, air is forced through the generator fire, burning some of the coke or coal and thus raising the temperature of that which remains. The products of combustion, themselves at high temperature, pass to the carbureter and superheater, where they give up part of their heat to the checker brick there, and finally pass out the stack at the top of the superheater into the air. Some carbon monoxide is formed in the generator during the blow and is burned in the carbureter by an air blast. This secondary combustion affords an important additional source of heat for raising the temperature of the checker brick. The adjustment of conditions so that all parts of the set will come to the proper temperatures at the same time is one of the factors requiring skill in operation. This condition being attained, the air is shut off, steam and oil turned on, and the stack at the top of the superheater closed. The steam, acting on the highly heated coke or coal and partially combining with it chemically, produces "blue water gas." At the same time, the gas oil, a petroleum distillate, admitted at the top of the carbureter through the spray provided for that purpose, is vaporized by coming in contact with the hot checker brick in the carbureter and superheater. The oil gas as formed mixes with the blue water gas, the mixture forming the crude carbureted water gas. The formation of blue water gas and the gassification of oil both absorb heat, so that the run can only continue for a certain length of time before the temperatures become too low for efficient gas generation. The oil is therefore turned off after the desired quantity has been admitted, while the admission of steam usually is continued for a certain definite total length of time. It is then shut off, the stack opened, and another blow is made.

As in the case of coal gas, the crude water gas contains tar, hydrogen sulphide, and organic sulphur compounds, but there is no ammonia. The tar, which is produced in gassifying the oil, is quite different in composition from coal tar and of much less value. However, it is removed from the gas in the same general manner as coal tar. The sulphur comes from both the generator fuel and the oil, but the quantities of both hydrogen sulphide and organic sulphur are usually considerably less than in coal gas. Hydrogen sulphide is removed by iron oxide, as in the case of coal gas. Since water-gas tar may be extracted from the gas at higher temperatures than coal tar, since there is no ammonia to recover, and since the quantity of hydrogen sulphide is less, it is evident that the removal of impurities from water gas is much less difficult than from coal gas.

In view of the fact that the process is intermittent, and it is desirable to maintain a continuous flow of gas through the tar-extracting and purifying apparatus, as well as to decrease the operating pressures in the gas-generating apparatus, it is customary to provide a so-called relief holder, which is merely a small gas holder, into which the crude gas is conducted after passing through a water seal and sometimes a scrubber or condenser. From the relief holder it is pumped through the remaining apparatus to the storage holder, and from there distributed.

Theoretically the blue water gas should consist of equal volumes of hydrogen and carbon monoxide; in practice, however, the percentage of carbon monoxide is usually somewhat lower, and a small amount of carbon dioxide is present. Blue water gas is thus of relatively low heating value, averaging about 300 B. t. u. per cubic foot. When burned its flame is nonluminous, while the gas itself has no odor.

The oil gas, on the other hand, containing a very high percentage of illuminants, is of high heating value and high open flame candlepower, and also imparts to the gas its characteristic odor.

Generally speaking, the heating value of carbureted water gas is dependent upon the proportion of blue gas and oil gas which it contains. In other words, the greater the quantity of oil used per 1,000 cubic feet of gas made, the higher should be the heating value. In practice from 3 to 4½ gallons are usually used per 1,000 cubic feet of gas, and with such quantities of oil, the heating value should be between 525 and 650 B. t. u. per cubic foot. It should be noted that within reasonable limits, the lower the quantity of oil used per 1,000 cubic feet of gas the higher will be the efficiency of its utilization; that is to say, the greater will be the number of heat units each gallon of oil will contribute to the gas. The whole question of oil efficiency, however, is extremely complicated, and in addition to the proper gassifying temperatures, so many other factors enter that no further discussion of the subject is here attempted.

Proper regulation of generator fire conditions so as to obtain maximum fuel efficiency likewise requires considerable technical skill. In actual practice, about 30 to 45 pounds of coke or anthracite coal are required per 1,000 cubic feet of gas made.

Tar, which is usually the only important by-product of water-gas manufacture, is recovered in amounts equal to about 15 per cent of the oil used.

Mixed gas.—In general, the term "mixed gas" is understood to mean a mixture of carbureted water gas and coal or coke-oven gas. Due to its economic advantages, it is supplied in many of the larger cities in the United States.

The manufacturing installation for mixed gas consists, in fact, of two complete installations, one for coal or coke oven gas and the other for carbureted water gas. Each is equipped with auxiliary scrubbing, condensing, purifying, and metering apparatus entirely independent and separate. The two gases are usually mixed at the inlet of the storage holders, and are, of course, delivered through a single distribution system.

Advantages of coal and water gas.—The advantages of coal, water, and mixed gas must be considered primarily from the economic or manufacturing standpoint, since the advantages of each to the user are in most cases only the indirect result of the economy of manufacture.

The actual cost of manufacturing coal gas is high, and were it not for the valuable by-products obtained—that is to say, coke, tar, ammonia, and occasionally light oil and cyanide—it could not usually compete with water gas. Unless the coal-gas by-products are intelligently and economically handled, and unless a favorable market for them is available, the net cost of coal gas will generally be relatively high. The greatest difficulty in extension of large coal-gas works is the lack of suitable outlet for the coke, as the coke produced is ordinarily not suitable for foundry or metallurgical purposes. It is, however, suitable for domestic consumption, and since in such cases it usually replaces anthracite coal, its use should be encouraged from a conservation standpoint, if for no other reason.

In the beginning of the industry coal gas was the only kind produced, but the rapidity with which water gas was introduced after the invention of the Lowe process was remarkable. At the time of its introduction by far the major part of all gas used was burned in open flame, and both municipal requirements and popular demand called for high candlepower. Under the commercial conditions then existing, especially the cheap supply of naphtha, for which there was practically no other use, manufacturers were able to meet this demand very economically. Some of the other factors which may be mentioned as contributing to the rapid growth of the water-gas industry are: The abundant production of anthracite coal at reasonable price (in certain parts of the country); the lower investment required for manufacturing plant (approximately only half that for coal gas); greater flexibility of operation from hour to hour or day to day (allowing rapid change in rate of manufacture to meet the changes in demand); the smaller number of men necessary to operate a water-gas plant; and the very important fact that no difficulty is met in the disposal of the very small amounts of by-products formed.

The advantages of mixed gas were also very influential in increasing the amount of water gas made. In a mixed-gas plant the coke made in the coal-gas works can be used to make water gas, the heating value of the mixture can be readily and quickly raised by the use of high heating value water gas; the coal gas is usually somewhat cheaper when a uniform rate of make and a good coke outlet are assured, the water-gas part taking care of the variations in demand and utilizing surplus coke. The relative amounts of coal and water gas in a mixture are determined by a number of factors. Mixed gas of varying proportions is distributed to a greater or less extent in most of the large cities of this country.

The conditions which caused the water-gas industry to grow rapidly to such large proportions have been gradually changing. The open-flame light has largely disappeared, and candlepower requirements have been replaced by heating-value standards. The candlepower of water gas of a given heating value is considerably higher than the candlepower of coal gas having the same heating value, so that the general change in requirements has been favorable to coal gas. Furthermore, the increasing price of gas oil and the discovery of other important uses for this oil, which was formerly regarded as nearly worthless, except for gas enrichment, together with the constantly increasing demand for the by-products of coal-gas manufacture, are factors which are causing the cost of water gas to increase relative to that of coal gas. At the same time coke ovens and new and improved types of coal-gas equipment are being developed and installed. The result is that a new impetus has been given to the manufacture of coal gas, although the quantity of water gas made has not yet greatly decreased.

Natural gas is one of the natural resources of the country. It is found in many different localities, Pennsylvania, West Virginia, Oklahoma, and California having some of the more extensive fields.

Natural gas is obtained from wells similar to oil wells and is frequently piped for long distances. As found it is ready for use without purification, it being merely necessary to deliver it to the customer at proper pressure. It is a colorless gas, composed principally of methane with small quantities of other hydrocarbon vapors. It therefore has a very high heating value, the heating value of pure methane being about 1,000 B. t. u. per cubic foot.

Oil gas.—An important process of gas manufacture, confined principally to the Southwestern and Pacific Coast States, is the manufacture of gas from crude oil. The magnitude of the industry may be judged from the fact that in 1911, 20 per cent more oil gas than unmixed coal gas was distributed in the United States.

Oil gas is essentially the product of destructive distillation of petroleum. This accounts for the great similarity in composition of oil gas and coal gas, the former being produced from oil, the latter from bituminous coal, under such conditions that somewhat similar reactions occur. The generating machinery used for production of oil gas resembles markedly the water-gas machinery. Oil is gassified in cylindrical steel shells lined with fire brick and filled with a checkerwork of fire brick. The process bears a further resemblance to water gas in that it is carried out in alternate heating and gas-making periods. However, the chemical processes involved and the effect of various factors are so different from those found in the case of water gas that it is undesirable to make comparison with the latter when considering oil gas. Comparison may be made with the carbureting process used in water-gas manufacture, but even this has led to some misunderstandings.

There are three distinct processes in use for the manufacture of oil gas: First, the "straight-shot process," in which a single-shell machine is utilized; second, the two-shell process, in which the second shell is used only to conserve heat, no gas being made in it; third, the two-shell machine, in which gas is made in both shells.

There are many variations in each of these processes; for example, the heating oil may be introduced at the top or at the bottom; the making oil may be introduced at the same point as the heating oil or at the opposite end of the machine; gas may be taken off at one end of one shell or at the side of the larger of the two; a secondary blast may be used or not.

The process of making oil gas takes place in alternate periods of heating the generator and of gas making; the heating period is made up of the interval during which the blast (without oil) is introduced to burn out the carbon collected in the machine, and the interval during which oil for heating the machine is introduced. The true making period is followed by a period of purging, during which steam is introduced to eliminate the gas remaining in the machine. The total as well as the relative time of these several periods varies greatly in different plants. In addition to this regular cycle it is occasionally necessary to have a long period of blasting in order to more thoroughly burn out the carbon collected in the generator. At intervals of 5 to 10 days it is, in some plants, necessary to entirely shut down manufacture and burn out this carbon under natural drafts.

The temperature maintained in the generator varies with the character of oil employed and with the quality of gas which is to be made. In general, a higher temperature produces a larger quantity of poorer gas; and, within limits, the converse is true that the lower the temperature at which the generator can be operated the higher will be the quality of the gas. This condition results from the fact that the decomposition of the oil into gas is a progressive process.

The heating oil is introduced into the generator with steam or under high pressure without steam; and, if properly injected, it enters practically atomized. This fine oil spray is quickly vaporized by the hot checker brick and the decomposition of the vapor begins at once. The higher the temperature to which the oil vapor is subjected and the longer the time at the high temperature the more complete will be the decomposition. Practically speaking, if this decomposition went to completion the oil would be converted into hydrogen and lampblack. As a matter of fact a small portion of the oil is always decomposed in this manner, but of course a much larger part is decomposed only into those hydrocarbon gases which make up the methane, ethylene, and benzene series. In addition there are also formed complex hydrocarbons, such as naphthalene.

The significance of this successive decomposition is apparent if we consider that a specification of a certain heating value for the gas will necessitate that the generator be operated at such temperature as to produce gas at least of the richness specified. The standard fixed is therefore a determining factor in controlling the works operation. Moreover, if the quality be fixed too high, it will be found that certain difficulties of operation are introduced because of the low temperature which must be maintained in the generator. For example, when operating at lower temperature a smaller amount of lampblack may be made; but this as produced is mixed with the tar, and the resulting tar and lampblack mixture is difficult to handle.

The numerous variations in detail make it impossible to give any generalizations as to the present operating practice in many particulars. However, two particular points on which striking differences in operating practice have been noted, should be considered in connection with standards for oil-gas service. The first of these points has to do with the method of introducing the oil into the generator, the second with the manner of handling the gas in wash boxes and condensers.

With care it is possible to introduce the oil in a very fine spray, which permits almost immediate vaporization in the generator; practically none of the spray drops in liquid form into the checker brick, and thus the "stewing" of the oil is eliminated. It is essential, as is recognized by all water-gas makers in connection with the carbureting process, that the oil be immediately vaporized when it enters the hot checker brick or the liquid will be greatly superheated in some parts and very incompletely heated in others before it can be converted into gas. The result of this so-called stewing is the production of a tar very difficult to handle, the carbonization of the checkerwork with resulting lowering of generator efficiency, and a general operating difficulty due to irregularity of temperatures throughout the generators, a condition which is most detrimental to good operation.

When the gas leaves the generator it carries suspended in it a considerable amount of lampblack, varying in quantity from 5 to 50 pounds of carbon per 1,000 cubic feet of the gas. It also carries a considerable amount of tar and naphthalene, which also must be eliminated before the gas can be purified and placed in the holder. The gas leaving the generator bubbles through water in the wash box, and most of the lampblack is separated from the gas by this process. Proper operation at this point will eliminate subsequent difficulty in condensing; if the gas is not properly freed from lampblack in the wash box, the mixture obtained in condensing is made up of tar, water, and lampblack in proportions that are very difficult to separate and handle. Notable progress has been made in the operation of the wash box in some of the California plants, where the gas is passed for the distance of 5 to 15 feet under water in order that practically all of the lampblack may be removed before the gas enters the scrubber. This elimination of lampblack greatly facilitates condensing and results in the production of a tar which can be easily handled.

Considerable attention has been given to the two points above, since one of the most important points to be considered in the adoption of a heating-value standard for oil gas has been whether or not a company could operate without serious works difficulty when making a gas of moderately high heating value.

NATURAL-GAS GASOLINE.[1]

By E. G. Sievers.

The term "natural-gas gasoline," as used by the United States Geological Survey, includes the gasoline recovered by all methods from both "wet" and "dry" natural gas and is synonymous with the term "casing-head gasoline," which is largely used in the industry.

The hearty cooperation of the producers, which has made the completion of this report possible, is gratefully acknowledged.

PRODUCTION.

The natural-gas gasoline industry continued its rapid expansion in 1919, the output during the year increasing 24 per cent over that in 1918. The output of the compression plants, which have been the largest producers since the beginning of the industry, increased 19 per cent, and the output by the absorption process increased 44 per cent. The average daily production in 1919 was 963,110 gallons, as compared with 774,070 gallons in 1918.

The total output of gasoline in the United States in 1919 was 4,185,207,321 gallons. Of this quantity 3,833,672,295 gallons,[2] or 92 per cent, was straight-run gasoline, distilled from crude petroleum, and the remainder was produced from natural gas.

The market value of the natural-gas gasoline produced in 1919 was $13,833,228 greater than in 1918, and the value of compression gasoline and absorption gasoline increased 21 and 47 per cent, respectively. The average yield of gasoline per 1,000 cubic feet of gas was 0.10 gallon greater in 1919 than in 1918. The yield from dry gas is less than that from wet gas, a fact that accounts for the smaller production of the absorption plants from a larger volume of gas treated.

In 1919 every producing State increased its output except Colorado, which ceased producing entirely. The producing States, with their percentages of increase over 1918, are Wyoming, 253; New York, 110; Kentucky, 54; Louisiana, 43; West Virginia, 39; Kansas, 37; Illinois, 32; Ohio, 30; Pennsylvania, 29; Texas, 27; California, 25; Oklahoma, 16.

[1] The statistical tables in this report were compiled by Miss H. Backus and Miss M. E. Cox, of the United States Geological Survey.
[2] From statistics compiled by the Bureau of Mines.

Natural-gas gasoline produced in the United States, 1911–1919.

Year.	Number of operators.	Number of plants.	Gasoline produced.			Gas used.		
			Quantity (gallons).	Value.	Average price per gallon (cents).	Estimated volume (M cubic feet).	Value.[a]	Average yield of gasoline per M cubic feet (gallons).
1911	132	176	7,425,839	$531,704	7.16	2,475,697	$176,961	3.00
1912	186	250	12,081,179	1,157,476	9.60	4,687,796	331,985	2.60
1913	232	341	24,060,817	2,458,443	10.22	9,889,442	566,224	2.43
1914	254	386	42,652,632	3,105,909	7.28	16,894,557	889,906	2.52
1915	287	414	65,364,665	5,110,823	7.88	24,064,391	1,202,555	2.72
1916	460	596	103,492,689	14,331,148	13.85	208,705,023	[b] 14,609,300	.496
1917	750	886	217,884,104	40,188,956	18.45	429,287,797	[b] 34,343,000	.508
1918	[c]503	1,004	282,535,550	50,363,535	17.83	449,108,661	[b] 40,419,700	.63
1919	[c]611	1,191	351,535,026	64,196,763	18.26	480,403,963	[b] 41,314,700	.73

[a] The value of the gas is based on sales to gasoline producers, not on sales for domestic or industrial purposes.
[b] Estimated.
[c] The number of operators in 1918 and 1919 is not comparable with that for earlier years, as the method of listing has been changed.

Unblended natural-gas gasoline produced in the United States in 1919.

State.	Number of operators.[a]	Number of plants.	Gasoline produced.		
			Quantity (gallons).	Value.	Average price per gallon (cents).
Oklahoma	161	329	189,995,038	$32,564,532	17.1
West Virginia	89	227	52,150,045	12,179,638	23.4
California	30	60	40,385,796	5,744,867	14.2
Pennsylvania	241	343	20,283,336	4,407,318	21.7
Louisiana	12	23	10,063,025	1,667,275	16.6
Texas	15	24	9,336,437	1,772,503	19.0
Ohio	35	59	8,800,961	1,963,763	22.3
Illinois	42	93	6,059,828	1,115,083	18.4
Wyoming	3	5	5,580,599	931,722	16.7
Kentucky	7	9	5,136,326	1,144,746	22.3
Kansas	10	13	3,283,850	620,876	18.9
New York	6	6	457,985	84,083	18.4
	[a] 611	1,191	[b] 351,535,026	[b] 64,196,763	18.3
Total, 1918	[a] 503	1,004	282,535,550	50,363,535	17.8

State.	Gas used.		Percentage of total production.				
			State.		United States.		
	Estimated volume (M cubic feet).	Average yield per M cubic feet (gallons).	Compression.	Absorption.	Compression.	Absorption.	Total.
Oklahoma	100,776,135	1.89	92.5	7.5	67.31	15.7	54.0
West Virginia	167,239,089	.31	30.3	69.7	6.05	40.2	14.8
California	39,647,251	1.02	73.0	27.0	11.29	12.1	11.5
Pennsylvania	56,280,578	.36	57.6	42.4	4.47	9.5	5.8
Louisiana	26,383,936	.38	63.6	36.4	2.45	4.1	2.9
Texas	8,732,133	1.07	70.8	29.2	2.53	3.0	2.7
Ohio	43,609,762	.20	26.9	73.1	.91	7.1	2.5
Illinois	3,160,907	1.92	100.0	....	2.32	....	1.7
Wyoming	3,687,907	1.51	89.2	10.8	1.91	.7	1.6
Kentucky	20,216,945	.25	2.9	97.1	.06	5.5	1.5
Kansas	10,432,079	.31	42.1	57.9	.53	2.1	.9
New York	237,241	1.93	100.0	....	.17	....	.1
	480,403,963	.73	74.3	25.7	100.00	100.00	100.00
Total, 1918	449,108,661	.63	77.8	22.2	100.00	100.00	100.00

[a] The number of operators in 1918 and 1919 is not comparable with that for earlier years, as the method of listing has been changed.
[b] Includes 1,800 gallons of drip gasoline, valued at $357, produced in Indiana.

Natural-gas gasoline produced in 1919 by principal methods of manufacture.

Produced by compression and by vacuum pumps.

State.	Number of plants.	Gasoline produced.			Gas used.	
		Quantity (gallons).	Value.	Average price per gallon (cents).	Estimated volume (M cubic feet).	Average yield per M cubic feet (gallons).
Oklahoma	280	175,796,157	$30,097,432	17.1	55,966,497	3.14
California [a]	46	29,483,543	4,738,824	16.1	35,639,250	.83
West Virginia [b]	185	15,795,423	3,401,165	21.5	8,354,071	1.89
Pennsylvania	314	11,683,744	2,375,141	20.3	4,931,001	2.37
Texas	19	6,609,048	1,101,551	16.7	3,921,509	1.69
Louisiana [c]	17	6,397,018	1,007,645	15.8	2,093,825	3.06
Illinois	93	6,057,268	1,114,685	18.4	3,160,907	1.92
Wyoming	3	4,978,443	823,410	16.5	1,341,699	3.71
Ohio	46	2,366,407	504,674	21.3	846,860	2.79
Kansas	10	1,382,367	284,251	20.6	1,119,629	1.23
New York	6	457,985	84,083	18.4	237,241	1.93
Kentucky	6	150,184	30,597	20.4	56,843	2.64
	1,025	261,157,587	45,563,458	17.4	117,669,332	2.22
Total, 1918	865	219,767,207	37,644,649	17.1	99,897,528	2.20

a Includes 6 combination compression and absorption plants.
b Includes 2 combination compression and absorption plants.
c Includes 3 combination compression and absorption plants.

Produced by absorption.[a]

West Virginia	42	36,354,622	$8,778,473	24.1	158,885,018	0.23
Oklahoma	49	14,198,881	2,467,100	17.4	45,084,959	.31
California	14	10,902,253	1,006,043	9.2	15,358,225	.71
Pennsylvania	29	8,599,592	2,032,177	23.6	51,349,577	.17
Ohio	13	6,434,554	1,459,089	22.7	42,762,902	.15
Kentucky	3	4,986,142	1,114,149	22.3	20,160,102	.25
Louisiana	6	3,666,007	659,630	18.0	24,858,901	.15
Texas	5	2,727,389	670,952	24.6	4,810,624	.57
Kansas	3	1,901,483	336,625	17.7	9,312,450	.20
Wyoming	2	602,156	108,312	18.0	2,346,208	.26
	166	[b] 90,377,439	[b] 18,633,305	20.6	[c] 374,928,966	.24
Total, 1918	139	62,768,343	12,718,886	20.3	349,211,133	.18

a Includes drip gasoline.
b Includes 4,360 gallons of drip gasoline, valued at $755, produced in Illinois and Indiana.
c Includes 12,194,335 M cubic feet of gas that was first treated at compression plants and that is included in the total volume of gas treated at the compression plants but not duplicated in the total for the United States.

ECONOMIC ASPECTS.

The year 1919 showed a marked increase in the growth of the natural-gas gasoline industry, but its greatest expansion was reached in 1917, when the production was 110 per cent more than that of 1916. At first gasoline was extracted only by the compression process from "wet" natural gas, or that occurring with oil; afterwards it was removed also from "dry" gas by the absorption process. "Dry" gas can not be treated by compression, but it contains sufficient gasoline vapors to warrant their extraction by the absorption method.

The extraction of gasoline from natural gas was long believed by gas consumers to reduce the heating value of the gas. Experiments, however, have demonstrated that this belief is unfounded and that the loss is negligible. The advantages in removing the gasoline before utilizing the gas are apparent. Removal of the gasoline means less pipe-line troubles, decreased losses of gas, increased safety of operations, and a greater uniformity in distribution of gas, especially in cold weather. Furthermore, the intrinsic value of the vapor is higher if converted to liquid than if sold as natural gas.

The fact that the extraction of gasoline from natural gas is 100 per cent conservation and that it contributes an important quantity to the supply of motor fuel makes it a process of economic consequence. It is of especial importance in new oil fields. An enormous quantity of gas occurring in the new oil fields of Wyoming, Arkansas, and parts of Texas is wasted because there is no market for it. Most of this gas contains gasoline vapors which would warrant extraction. In some States the gas has been shut in, but this is found impracticable in new oil fields because of the necessity of developing the oil resources. Certain States prohibit the burning of the gas, as in the manufacture of carbon black, even after the gasoline has been extracted.

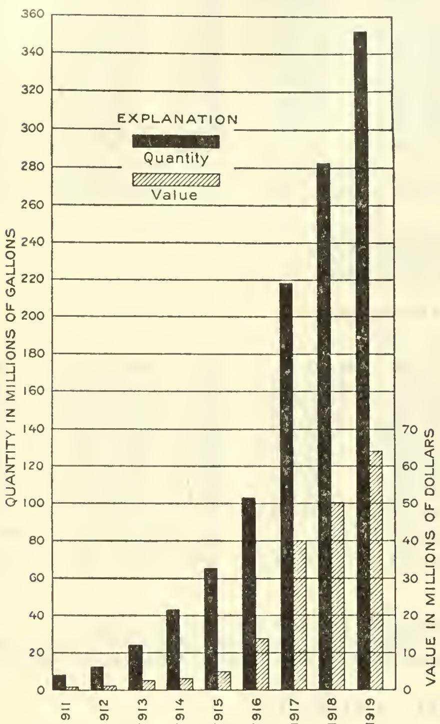

FIGURE 22.—Quantity and value of natural-gas gasoline produced in the United States, 1911–1919.

Manufacturers of carbon black have learned that removing the gasoline before burning the gas does not reduce the production of carbon black or injure its quality, and they have established many gasoline plants in connection with the carbon-black plants.

A study of the accompanying diagrams showing the progress of the natural-gas gasoline industry from 1911 to 1919 will disclose the rapid expansion during the period from 1915 to 1917. This expansion was due to the development of the absorption process, which made it possible to extract gasoline from "dry" gas and also to treat a larger quantity of gas. The increased demand for gasoline during the war and the continued demand since has stimulated the progress of the industry, increased plant construction, and developed the capacities of the plants. The building of plants must necessarily depend upon numerous factors, especially upon the quantity and quality of gas available and the probable duration of the supply. The present tendency to construct plants only after careful investigation of conditions has resulted in more efficient operation and more intelligent investments.

That the industry is growing in importance is shown in the recent organizing of the Natural Gasoline Manufacturers' Association, of which W. H. Welch, of the Tidal Gasoline Co., has been chosen president. The purpose of the organization is to promote the development of the industry and bring about a better classification of natural-gas gasoline in order that it may be put to the best use. The association has formulated specifications which should result in placing on the market a uniform product divided into several different grades and designated by letters and figures, enabling the jobber to order by specifications and to obtain a product which will meet his requirements in every way.

The outstanding economic features in the natural-gas gasoline industry may be summarized as follows:

1. The industry is constantly expanding.

2. The expansion is due to a greater demand for gasoline and to an increase in the conservation of the total product of most gas fields. The present tendency is to remove the gasoline from gas that is to be used for domestic and industrial purposes, including the manufacture of carbon black.

3. The recovery of gasoline from natural gas does not destroy the gas from which it is taken nor impair its value, but on the contrary benefits it for domestic and industrial use by removing the water, and also the gasoline, which causes leakage in the conveying pipes by disintegrating the rubber gaskets.

4. Natural-gas gasoline is highly volatile and must therefore be blended with naphthas, so that the industry has provided a larger market for the blending materials and has brought the oil and gas

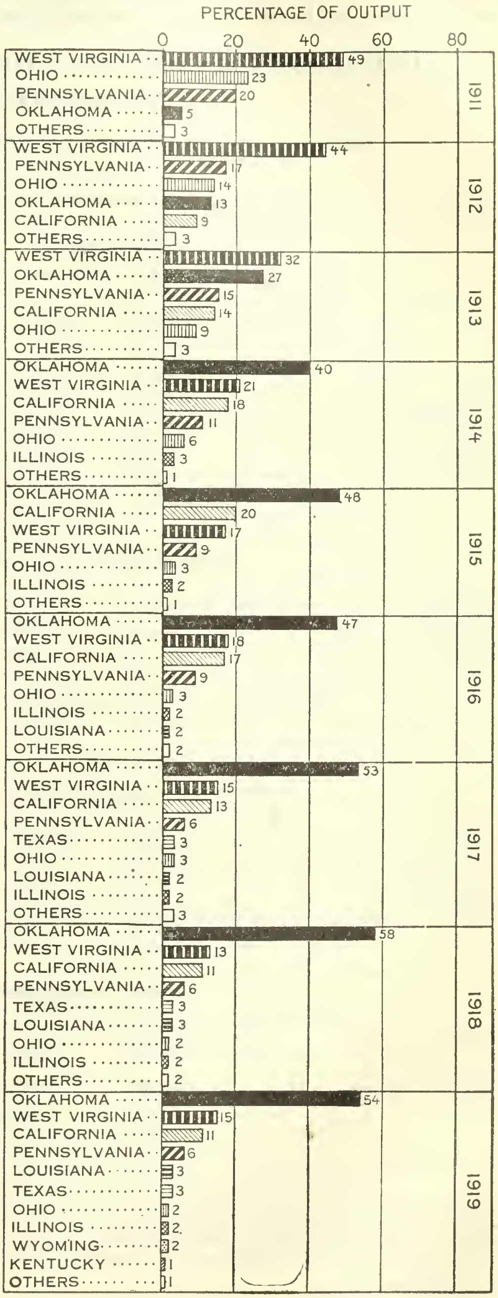

FIGURE 23.—Natural-gas gasoline produced in the United States, by States, 1911–1919.

producer and the refiner into closer relations. By using the lighter gasoline made from natural gas in connection with the distillates from oil, it is possible to make more gasoline from the oil than could be obtained without using the natural-gas gasoline in blending.

NATURAL-GAS GASOLINE INDUSTRY, BY STATES.

CALIFORNIA.

Natural-gas gasoline produced in California in 1918 and 1919.

1918.

Gasoline produced by compression and by vacuum pumps.

County.	Number of operators.[a]	Number of plants.	Gasoline produced. Quantity (gallons).	Gasoline produced. Value.	Estimated volume of gas treated (M cubic feet).	Range in yield of gasoline per thousand cubic feet of gas (gallons).	Range in gravity of gasoline as produced and before blending (°Baumé).
Kern	9	13	11,517,906	$1,738,066	14,891,343	0.5 -1.25	66-77.5
Santa Barbara	5	8	7,354,082	1,073,664	4,428,075	1.5 -2.41	72-77
Orange	6	6	3,998,931	625,881	10,952,745	.11-3.0	64-79
Los Angeles	6	8	1,565,213	258,131	1,813,436	.5 -2.0	62-80
Ventura	2	2	899,208	150,599	587,008	1.12-1.62	78-82
Fresno	2	2	432,006	60,014	490,125	.72-1.5	67-71
	[a] 25	39	25,767,346	3,906,355	33,162,732	[b] .78	62-82
Gasoline produced by absorption.[c]							
Kern	7	11	3,511,369	$537,199	8,661,653	0.1-1.0	47-69
Los Angeles }	1	1	2,321,091	461,367	7,565,271	.29	40-60
Fresno }	1	1				.64	69
Orange	3	4	669,127	104,231	1,100,363	.5-2.26	68-81
	[a] 10	17	6,501,587	1,102,797	17,327,287	[b] .38	40-81
Grand total	[a] 29	56	32,268,933	5,009,152	50,490,019	[b] .64	40-82

1919.

Produced by compression and by vacuum pumps.

County.	Number of operators.[a]	Number of plants.	Quantity (gallons).	Value.	Estimated volume of gas treated (M cubic feet).	Range in yield (gallons).	Range in gravity (°Baumé).
Kern [d]	7	19	13,457,113	$2,155,037	14,393,911	0.71-1.7	70-78
Santa Barbara	6	9	8,215,561	1,253,231	4,860,576	.47-2.6	50-77
Orange [d]	6	7	5,024,460	816,548	12,031,829	.25-2.5	69-75
Los Angeles	6	7	1,514,338	280,964	3,613,855	.02-1.12	62-80
Ventura }	3	3	1,272,071	233,044	739,079	.8 -2.0	65-78
Fresno }	1	1				.58	70
	[a] 25	46	29,483,543	4,738,824	35,639,250	.02-2.6	50-80
Produced by absorption.[c]							
Orange [d]	4	6	6,168,063	$552,607	8,823,893	0.58-2.8	65-81
Kern [e]	5	5	4,415,968	397,433	6,139,986	.6 -2.0	47-70
Los Angeles }	1	1				.75	60
Fresno }	1	1	318,222	56,003	394,346	.76	70
Ventura }	1	1				1.0	70
	[a] 10	14	10,902,253	1,006,043	[f] 15,358,225	.58-2.8	47-81
Grand total	[a] 30	60	40,385,796	5,744,867	39,647,251	.02-2.8	47-81

[a] This number is irrespective of the kind, number, and location of the plants operated. The sum of the number of operators listed for each method employed and for each county will therefore not give the correct number of operators in the State. A comparison with the number of operators for prior years can not be made because the method of listing has been changed.
[b] Average.
[c] Includes drip gasoline.
[d] Includes 2 combination compression and absorption plants.
[e] Includes 4 combination compression and absorption plants.
[f] Includes 11,350,224 M cubic feet of gas that was first treated at compression plants and that is included in the total volume of gas treated at the compression plants but not duplicated in the total for the State.

ILLINOIS.

Natural-gas gasoline produced in Illinois in 1918 and 1919.

1918.

Produced by compression and by vacuum pumps.

County.	Number of operators.[a]	Number of plants.	Gasoline produced.		Estimated volume of gas treated (M cubic feet).	Range in yield of gasoline per thousand cubic feet of gas (gallons).	Range in gravity of gasoline as produced and before blending (°Baumé).
			Quantity (gallons).	Value.			
Lawrence	11	25	2,505,893	$492,960	1,144,945	1.0–3.5	72–86
Crawford	25	44	2,045,200	392,808	1,159,908	1.0–4.0	68–95
Clark	3	3	23,472	4,668	11,793	1.5–2.0	65–84
	[a]34	72	4,574,565	890,436	2,316,646	1.0–4.0	65–95

1919.

Produced by compression and by vacuum pumps.

County.	Number of operators.[a]	Number of plants.	Quantity (gallons).	Value.	Estimated volume of gas treated (M cubic feet).	Range in yield (gallons).	Range in gravity (°Baumé).
Lawrence	14	31	3,044,802	$565,031	1,537,642	0.5 –4.2	76–90
Crawford[b]	28	55	2,954,174	539,187	1,571,233	1.0 –6.0	70–98
Clark	4	6	60,852	10,865	52,032	.67–1.5	78–86
Cumberland	1	1				1.0	85
	[a]42	93	[b]6,059,828	1,115,083	3,160,907	.5 –6.0	70–98

[a] See California table, footnote [a].
[b] Includes 2,560 gallons of drip gasoline.

KANSAS.

Natural-gas gasoline produced in Kansas in 1918 and 1919.

1918.

Produced by compression and by vacuum pumps.

County.	Number of operators.[a]	Number of plants.	Gasoline produced.		Estimated volume of gas treated (M cubic feet).	Range in yield of gasoline per thousand cubic feet of gas (gallons).	Range in gravity of gasoline as produced and before blending (°Baumé).
			Quantity (gallons).	Value.			
Cowley	1	2	504,523	$126,131	3,500,997	0.13–0.165	86–90
Montgomery	1	1				.10	86–90
Chautauqua	2	3	298,250	74,562	125,792	2.25–3.0	78–85
	4	6	802,773	200,693	3,626,789	.10–3.0	78–90
Produced by absorption.							
Cowley	1	2	1,587,083	$393,037	12,396,278	0.13–0.16	64–76
Montgomery	2	1				.15	72
Wilson	1	1				.75	....
Butler	1	1				.31	76
	[a]3	5	1,587,083	393,037	12,396,278	.13–.75	64–76
Grand total	[a]5	11	2,389,856	593,730	16,023,067	.10–3.0	64–90

1919.

Produced by compression and by vacuum pumps.

County.	Number of operators.[a]	Number of plants.	Quantity (gallons).	Value.	Estimated volume of gas treated (M cubic feet).	Range in yield (gallons).	Range in gravity (°Baumé).
Chautauqua	6	7	1,173,977	$239,825	990,125	0.20–2.13	71–85
Butler	1	1	208,390	44,426	129,504	2.0	81
Wilson	1	1				1.0	80
Allen	1	1				2.0	....
	[a]8	10	1,382,367	284,251	1,119,629	.20–2.13	71–85
Produced by absorption.							
Montgomery	2	2	1,901,483	$336,625	9,312,450	0.1–0.14	64–74
Cowley	1	1				.32	
	[a]2	3	[b]1,901,483	336,625	9,312,450	.1– .32	64–74
Grand total	[a]10	13	3,283,850	620,876	10,432,079	.1–2.13	64–85

[a] See California table, footnote [a].
[b] Includes 1,500 gallons drip gasoline recovered in Chautauqua County.

KENTUCKY.

Natural-gas gasoline produced in Kentucky in 1918 and 1919.

1918.

Produced by compression and by vacuum pumps.

County.	Number of operators.[a]	Number of plants.	Gasoline produced. Quantity (gallons).	Gasoline produced. Value.	Estimated volume of gas treated (M cubic feet).	Range in yield of gasoline per thousand cubic feet of gas (gallons).	Range in gravity of gasoline as produced and before blending (°Baumé).
Wayne	3	3	96,313	$13,135	47,807	[b] 2.0	[b] 80
Morgan	1	1				1.7-3.5	78
	4	4	96,313	13,135	47,807	1.7-3.5	78-80

Produced by absorption.[c]

County.	Number of operators.[a]	Number of plants.	Quantity (gallons).	Value.	Estimated volume of gas treated (M cubic feet).	Range in yield (gallons).	Range in gravity (°Baumé).
Boyd	1	1	3,234,673	$646,973	19,768,711	0.15	86
Martin	1	1				.22	88
	[a] 1	2	3,234,673	646,973	19,768,711	.15-.22	86-88
Grand total	[a] 5	6	3,330,986	660,108	19,816,518	[b] .16	78-88

1919.

Produced by compression and by vacuum pumps.

County.	Number of operators.[a]	Number of plants.	Quantity (gallons).	Value.	Estimated volume of gas treated (M cubic feet).	Range in yield (gallons).	Range in gravity (°Baumé).
Wayne	4	5	150,184	$30,597	56,843	2.0-4.0	80-90
Morgan	1	1				4.0	86
	5	6	150,184	30,597	56,843	2.0-4.0	80-90

Produced by absorption.

County.	Number of operators.[a]	Number of plants.	Quantity (gallons).	Value.	Estimated volume of gas treated (M cubic feet).	Range in yield (gallons).	Range in gravity (°Baumé).
Boyd	2	2	4,986,142	$1,114,149	20,160,102	0.19-0.52	83-86
Martin	1	1				.27	88
	[a] 2	3	4,986,142	1,114,149	20,160,102	.19-.52	83-88
Grand total	[a] 7	9	5,136,326	1,144,746	20,216,945	.19-4.0	80-90

[a] See California table, footnote [a].
[b] Average.
[c] Includes drip gasoline recovered in Menifee County.

LOUISIANA.

Natural-gas gasoline produced in Louisiana in 1918 and 1919.

1918.

Produced by compression and by vacuum pumps.

Parish.	Number of operators.[a]	Number of plants.	Gasoline produced. Quantity (gallons).	Gasoline produced. Value.	Estimated volume of gas treated (M cubic feet).	Range in yield of gasoline per thousand cubic feet of gas (gallons).	Range in gravity of gasoline as produced and before blending (°Baumé).
Caddo	6	9	4,726,132	$673,630	1,518,402	1.51-4.0	60-80.4
De Soto	4	6	1,177,591	173,879	388,435	2.15-6.0	72-80.0
	[a] 7	15	5,903,723	847,509	1,906,837	[b] 3.10	60-80.4

Produced by absorption.[c]

Parish.	Number of operators.[a]	Number of plants.	Quantity (gallons).	Value.	Estimated volume of gas treated (M cubic feet).	Range in yield (gallons).	Range in gravity (°Baumé).
Caddo	3	3	1,116,815	$331,142	11,555,480	[b] 0.10	69-82
Grand total	[a] 9	18	7,020,538	1,178,651	13,462,317	[b] .52	60-82

[a] See California table, footnote [a].
[b] Average.
[c] Includes drip gasoline.

Natural-gas gasoline produced in Louisiana in 1918 and 1919—Continued.

1919.

Produced by compression and by vacuum pumps.

Parish.	Number of operators.[a]	Number of plants.	Gasoline produced. Quantity (gallons).	Gasoline produced. Value.	Estimated volume of gas treated (M cubic feet).	Range in yield of gasoline per thousand cubic feet of gas (gallons).	Range in gravity of gasoline as produced and before blending (°Baumé).
Caddo [b]	7	11	5,209,605	$822,818	1,731,243	1.6–7.2	58–80
De Soto	4	6	1,187,413	184,827	362,582	2.4–9.7	71–78
	[a] 8	17	6,397,018	1,007,645	2,093,825	1.6–9.7	58–80

Produced by absorption.

Parish.	Number of operators.[a]	Number of plants.	Quantity (gallons).	Value.	Estimated volume of gas treated (M cubic feet).	Range in yield (gallons).	Range in gravity (°Baumé).
Caddo [b]	3	2	2,714,590	$507,816	18,273,564	0.03–1.3	64.3–88
Bossier, De Soto [c], Morehouse	2	2	491,130	79,171	3,542,467	.10–.15	73–81
Ouachita	2	2	460,287	72,643	3,042,870	.10–.75	81
	[a] 5	6	3,666,007	659,630	[d] 24,858,901	.03–1.3	64.3–88
Grand total	[a] 12	23	10,063,025	1,667,275	26,283,936	.03–9.7	58–88

[a] See California table, footnote [a].
[b] Includes 3 combination compression and absorption plants.
[c] Drip gasoline.
[d] Includes 568,790,000 cubic feet of gas that was first treated at compression plants and that is included in the total volume of gas treated at the compression plants but not duplicated in the total for the State.

NEW YORK.

Natural-gas gasoline produced in New York in 1919.

Produced by compression and by vacuum pumps.

County.	Number of operators.[a]	Number of plants.	Gasoline produced. Quantity (gallons).	Gasoline produced. Value.	Estimated volume of gas treated (M cubic feet).	Range in yield of gasoline per thousand cubic feet of gas (gallons).	Range in gravity of gasoline as produced and before blending (°Baumé).
Allegany, Cattaraugus	5 / 1	5 / 1	457,985	$84,083	237,241	0.65–5.5 / .2	80–92 / 100
	[a] 6	6	457,985	84,083	237,241	.2–5.5	80–100
1918	[a] 5	3	218,131	55,405	99,487	1.5–2.4	88–90

[a] See California table, footnote [a].

OHIO.

Natural-gas gasoline produced in Ohio in 1918 and 1919.

1918.

Produced by compression and by vacuum pumps.

County.	Number of operators.[a]	Number of plants.	Gasoline produced. Quantity (gallons).	Gasoline produced. Value.	Estimated volume of gas treated (M cubic feet).	Range in yield of gasoline per thousand cubic feet of gas (gallons).	Range in gravity of gasoline as produced and before blending (°Baumé).
Monroe	14	28	1,481,112	$282,633	470,007	1.0 – 8.0	74–92
Jefferson	9	9	325,112	68,006	149,789	1.50–11.3	85–94
Washington	10	6	224,454	44,025	89,110	2.0 – 3.50	78–88
Columbiana, Fairfield	1 / 1	1 / 1	4,728	962	1,450	3.5	....
	[a] 28	45	2,035,406	395,626	710,356	[b] 2.87	74–94

[a] See California table, footnote [a].
[b] Average.

Natural-gas gasoline produced in Ohio in 1918 and 1919—Continued.

1918—Continued.

Produced by absorption. [a]

County.	Number of operators.[b]	Number of plants.	Gasoline produced: Quantity (gallons).	Gasoline produced: Value.	Estimated volume of gas treated (M cubic feet).	Range in yield of gasoline per thousand cubic feet of gas (gallons).	Range in gravity of gasoline as produced and before blending (°Baumé).
Licking	2	2	2,574,737	$490,689	13,524,638	[c] 0.18	83–85
Richland	2	2	1,238,220	281,851	10,762,622	[c] 1.7	81–83
Fairfield	1	1	}	}	}	.4	68–80
Lorain	1	1	}	}	}	....	....
Washington	1	1	574,410	115,685	10,854,406	1.1	70–76
Noble	1	1	}	}	}	.33	82
Monroe	......	......	}	}	}	....	....
Knox	2	2	322,134	71,596	1,887,300	[c] .15	74–81
	[b] 8	10	4,709,501	959,821	37,028,966	[c] .13	68–85
Grand total	[b] 36	55	6,744,907	1,355,447	37,739,322	[c] .18	68–94

1919.

Produced by compression and by vacuum pumps.

County.	Number of operators.	Number of plants.	Quantity (gallons).	Value.	Estimated volume of gas treated (M cubic feet).	Range in yield (gallons).	Range in gravity (°Baumé).
Monroe	14	24	1,594,888	$344,538	501,315	1.0 -8.0	76–88
Jefferson	8	9	355,838	72,495	126,205	2.0 -5.0	86–98
Washington	9	11	319,780	67,172	172,557	.65–4.0	76–89
Carroll	2	2	95,901	20,469	46,783	1.5 -3.0	85–96
	[b] 27	46	2,366,407	504,674	846,860	.65–8.0	76–98

Produced by absorption. [a]

County.	Number of operators.	Number of plants.	Quantity (gallons).	Value.	Estimated volume of gas treated (M cubic feet).	Range in yield (gallons).	Range in gravity (°Baumé).
Licking	2	2	3,061,869	$668,353	12,618,221	0.25	78–82
Fairfield	1	1	}	}	}	.07	80
Hocking	1	1	}	}	}	.23	83
Lorain	1	1	}	}	}	.10	82
Noble	1	1	1,477,361	326,829	17,837,219	.25	82
Washington	1	1	}	}	}	2.5	80
Wayne	1	1	}	}	}	.2	78
Monroe [d]	......	......	}	}	}	....	....
Harrison [d]	......	......	}	}	}	....	....
Richland	2	2	1,449,044	351,694	10,892,498	.11– .22	82
Knox	3	3	446,280	112,213	1,414,964	.2 -2.0	72–80
	[b] 8	13	6,434,554	1,459,089	42,762,902	.07–2.5	72–83
Grand total	[b] 35	59	8,800,961	1,963,763	43,609,762	.07–8.0	72–98

[a] Includes drip gasoline.
[b] See Califonia table, footnote [a].
[c] Average.
[d] Drip gasoline only.

OKLAHOMA.

Natural-gas gasoline produced in Oklahoma in 1918 and 1919.

1918.

Produced by compression and by vacuum pumps.

County.	Number of operators.[a]	Number of plants.	Gasoline produced. Quantity (gallons).	Gasoline produced. Value.	Estimated volume of gas treated (M cubic feet).	Range in yield of gasoline per thousand cubic feet of gas (gallons).	Range in gravity of gasoline as produced and before blending (°Baumé).
Creek	42	78	83,853,919	$14,254,783	23,787,025	1.0 -7.59	70-90
Nowata	17	23	16,337,260	2,105,928	4,209,713	1.25-9.5	70-90
Tulsa	26	36	16,027,265	3,121,213	4,735,041	1.6 -4.2	69-86
Okmulgee	17	26	9,322,162	1,646,597	2,744,299	.80-6.2	70-90
Washington	12	19	6,453,647	1,307,701	2,407,287	1.0 -4.0	69-88
Rogers	6	9	5,289,743	889,049	1,118,587	2.5 -6.0	79-87
Osage	5	6	5,143,912	973,662	3,364,696	1.0 -2.74	72-88
Wagoner	4	5	3,109,666	698,856	776,844	2.7 -5.7	73-90
Pawnee	6	6	2,904,671	441,332	1,055,127	1.2 -5.18	72-85
Muskogee	14	17	2,901,520	580,170	1,071,540	.85-4.1	72-86
Carter	4	7	1,001,715	122,537	762,962	1.0 -5.0	80-89
Garfield	2	2	613,465	163,366	234,418	2.25-3.5	76-96
Kay	1	2	} 1,312,660	216,204	417,444	{ [b]5.0	[b]85
Payne	2	2				.8 -1.04	74-80
	[a] 116	238	154,271,605	26,521,398	46,684,983	[b]3.30	69-96

Produced by absorption.[c]

County.	Number of operators.[a]	Number of plants.	Quantity (gallons).	Value.	Estimated volume of gas treated (M cubic feet).	Range in yield (gallons).	Range in gravity (°Baumé).
Creek	7	11	2,906,992	$489,436	3,893,202	1.0 -2.50	60-84
Kay	2	4	1,725,703	386,379	6,306,836	.125-1.20	75
Osage	6	8	1,605,882	346,262	15,578,123	.10 -2.40	52-79
Pawnee	3	4	1,237,479	256,597	830,352	.125-1.00	74-80
Payne	1	2	}			{ [b].15	[b] 74
Lincoln	1	1				.125	74-76
Oklahoma	1	1				.25	....
Wagoner	1	1	955,888	199,916	4,840,123	2.00	78
Rogers [d]	......	......				....	....
Nowata [d]	......	......				....	60-90
Washington [d]	......	......				....	....
Okmulgee	2	2	521,240	125,786	2,000	.2 -1.0	64-72
Carter	2	2	388,045	43,859	119,780	2.3 -3.5	80
Tulsa	2	2	87,716	19,412	66,908	[b].125	74-76
	[a] 20	38	9,428,945	1,867,647	31,637,324	[b].30	52-90
Grand total	[a] 133	276	163,700,550	28,389,045	78,322,307	[b]2.09	52-96

1919.

Produced by compression and by vacuum pumps.

County.	Number of operators.[a]	Number of plants.	Quantity (gallons).	Value.	Estimated volume of gas treated (M cubic feet).	Range in yield (gallons).	Range in gravity (°Baumé).
Creek	43	88	97,279,412	$15,525,730	28,344,499	0.77-7.1	60-95
Nowata	15	24	16,525,861	3,009,467	4,875,614	1.99-9.22	70-95
Tulsa	32	41	14,490,550	2,804,623	3,932,479	.85-6.53	28-95
Okmulgee	21	25	8,295,777	1,522,094	2,767,217	.87-6.84	70-86
Washington	15	22	7,558,778	1,502,092	2,762,586	.88-6.37	72-88
Osage	7	8	6,242,996	1,124,609	2,750,974	1.0 -2.86	60-79
Rogers	6	9	5,918,998	1,092,655	1,118,375	2.75-6.44	85-88
Wagoner	7	11	4,651,495	983,679	1,020,600	2.75-8.11	76-89
Muskogee	20	23	3,622,263	573,240	1,539,934	1.0 -5.0	70-96
Payne	3	3	} 2,949,763	528,831	1,651,016	{ .77- .93	75-90
Noble	1	1				4.5	89
Pawnee	7	7	2,367,985	376,287	1,079,903	1.62-5.0	77-80
Carter	7	10	2,304,221	424,743	2,891,064	.44-1.7	79-90
Garfield	4	4	2,251,271	410,365	878,745	2.4 -2.7	86-89
Kay	3	4	1,336,787	219,017	353,491	1.82-4.4	80-86
	[a] 140	280	175,796,157	30,097,432	55,966,497	.44-9.22	28-96

[a] See California table, footnote [a].
[b] Average.
[c] Includes drip gasoline.
[d] Drip gasoline only.

Natural-gas gasoline produced in Oklahoma in 1918 and 1919—Continued.

1919—Continued.

Produced by absorption.[a]

County.	Number of operators.[b]	Number of plants.	Gasoline produced. Quantity (gallons).	Gasoline produced. Value.	Estimated volume of gas treated (M cubic feet).	Range in yield of gasoline per thousand cubic feet of gas (gallons).	Range in gravity of gasoline as produced and before blending (°Baumé).
Creek	10	15	5,721,828	$834,431	11,560,534	0.05–3.83	36–82
Osage	7	9	2,536,063	496,582	7,964,029	.12–1.6	31–85
Pawnee	4	5	1,726,501	328,571	1,521,767	.12–2.0	42–75
Kay	2	5	1,519,281	273,382	7,433,937	.09–.2	36–76
Payne	2	3	851,123	153,807	5,624,320	.15–.7	74–84
Lincoln	1	1				.058	36–38
Oklahoma	1	1				.06	46–48
Muskogee[c]	......	......				....	60–64
Wagoner	1	2				2.8–3.0	74
Rogers[c]	......	......	849,163	171,897	6,217,838	....	54
Nowata[c]	......	......				....	....
Washington[c]	......	......				....	58
Carter	1	1				.27	80
Tulsa	1	1				.09	36–74
Noble	2	2	537,912	116,113	1,001,263	1.79–2.78	36–38
Okmulgee	3	4	457,010	92,317	3,761,271	.06–.12	46–74
	[b] 26	49	14,198,881	2,467,100	[d] 45,084,959	.05–3.83	31–85
Grand total	[b] 161	329	189,995,038	32,564,532	100,776,135	.05–9.22	28–96

[a] Includes drip gasoline.
[b] See California table, footnote [a].
[c] Drip gasoline only.
[d] Includes 275,321,000 cubic feet of gas that was first treated at compression plants and that is included in the total volume of gas treated at the compression plants but not duplicated in the total for the State.

PENNSYLVANIA.

Natural-gas gasoline produced in Pennsylvania in 1918 and 1919.

1918.

Produced by compression and by vacuum pumps.

County.	Number of operators.[a]	Number of plants.	Gasoline produced. Quantity (gallons).	Gasoline produced. Value.	Estimated volume of gas treated (M cubic feet).	Range in yield of gasoline per thousand cubic feet of gas (gallons).	Range in gravity of gasoline as produced and before blending (°Baumé).
Warren	35	55	2,267,814	$484,993	843,796	1.50–3.5	71–92
McKean	13	15	2,107,222	471,707	1,039,754	.5–3.5	80–92
Forest	17	21	1,480,527	228,485	522,202	2.0–5.0	75–90
Butler	91	110	1,449,876	261,237	632,656	1.0–7.0	68–90
Allegheny	10	19	726,117	135,950	189,706	.25–5.0	72–90
Crawford	4	4	257,701	43,087	89,425	2.0–5.0	85–91
Venango	7	7	238,164	44,729	283,039	.45–3.0	80–90
Beaver	8	9	213,020	44,992	81,037	2.25–5.0	78–90
Armstrong	3	4	161,519	32,304	64,154	1.0–5.0	72–84
Clarion	9	9	126,195	23,420	126,954	1.0–3.0	75–88
Washington	3	5	130,640	22,430	64,400	1.00–5.0	76–84
Potter	1	1				1.0	95
	[a] 192	259	9,158,795	1,793,334	3,937,123	[b] 2.33	68–95

[a] See California table, footnote [a].
[b] Average.

Natural-gas gasoline produced in Pennsylvania in 1918 and 1919—Continued.

1918—Continued.

Produced by absorption.[a]

County.	Number of operations.[b]	Number of plants.	Gasoline produced. Quantity (gallons).	Gasoline produced. Value.	Estimated volume of gas treated (M cubic feet).	Range in yield of gasoline per thousand cubic feet of gas (gallons).	Range in gravity of gasoline as produced and before blending (°Baume).
Greene	3	5	3,221,861	$733,310	25,416,561	0.10–1.0	70–80
Venango	1	2				[c].174	74–87
McKean	1	1				.086	87
Warren	1	1				.118	84
Washington	1	1	2,023,624	421,877	17,452,899	.172	55–78
Armstrong	1	2				[c].086	[b]78
Allegheny	1	1				.03	62–80
Beaver	1	1				.10	....
Butler[d]	......	......				....	60–87
Elk	2	2	605,538	134,939	5,377,612	.10 – .11	80–84
Forest	2	2	264,073	56,765	292,970	[c].19	[b]80
Clarion	2	2	255,275	55,542	3,869,522	.056– .098	72–86
Potter	3	3	245,892	53,466	635,376	.257–1.0	80–82
	[b] 12	23	6,616,263	1,455,899	53,044,940	[c].12	55–87
Grand total	[b] 200	282	15,775,058	3,249,233	56,982,063	[c].28	55–95

1919.

Produced by compression and by vacuum pumps.

County.	Number of operations.[b]	Number of plants.	Quantity (gallons).	Value.	Estimated volume of gas treated (M cubic feet).	Range in yield (gallons).	Range in gravity (°Baume).
Warren	43	63	3,469,450	$715,670	1,172,488	0.4 –8.0	71 –96
McKean	10	14	2,247,933	449,207	1,054,179	.55–5.7	72 –95
Forest	19	23	1,711,970	346,124	584,609	.33–9.0	74 –95
Butler	105	132	1,634,060	328,370	598,661	.33–9.2	70 –95
Allegheny	8	17	958,461	213,624	248,225	2.0 –5.0	78 –92
Venango	12	13	477,247	88,150	410,739	.5 –7.0	70 –95
Clarion	14	17	399,356	78,252	545,767	.12–9.4	69.5–96
Crawford	12	12	367,746	66,923	136,375	2.0 –4.0	74 –96
Beaver	12	13	280,525	61,829	111,203	1.25–5.0	74 –98
Washington	4	6	107,941	20,748	47,815	1.0 –5.0	78 –88
Armstrong	4	4	29,055	6,244	20,940	.5 –2.5	72 –84
	[b] 227	314	11,683,744	2,375,141	4,931,001	.12–9.4	69.5–98

Produced by absorption. [a]

County.	Number of operations.[b]	Number of plants.	Quantity (gallons).	Value.	Estimated volume of gas treated (M cubic feet).	Range in yield (gallons).	Range in gravity (°Baume).
Greene	3	5	3,398,766	$813,734	16,615,988	0.20–1.0	78
Washington	3	3	1,453,635	320,447	8,855,809	.12–.17	76.1–80
Venango[d]						.23	80 –91
Armstrong						.10	78
Beaver	5	7	1,022,778	246,529	4,582,229	.74	....
Butler[d]						1.31	60 –75
Forest[d]						1.08	72
Warren	2	2	932,414	224,936	6,088,676	.15–2.0	85
McKean[a]	2	2	787,000	187,127	8,403,950	.08– .72	82 –92
Elk	2	2	355,773	87,508	2,771,553	.11– .37	79 –84
Potter	3	3	337,079	75,656	786,710	.26– .72	82 –85
Clarion	2	2	255,923	63,907	2,943,912	.08– .12	78 –90
Allegheny[a]	2	3	56,224	12,333	300,750	.16–3.0	78
	[b] 15	29	8,599,592	2,032,177	51,349,577	.08–3.0	60 –92
Grand total	[b] 241	343	20,283,336	4,407,318	56,280,578	.08–9.4	60 –98

[a] Includes drip gasoline.
[b] See California table, footnote [a].
[c] Average.
[d] Drip gasoline only.

TEXAS.

Natural-gas gasoline produced in Texas in 1918 and 1919.

1918.

Produced by compression and by vacuum pumps.

County.	Number of operators.[a]	Number of plants.	Gasoline produced. Quantity (gallons).	Gasoline produced. Value.	Estimated volume of gas treated (M cubic feet).	Range in yield of gasoline per thousand cubic feet of gas (gallons).	Range in gravity of gasoline as produced and before blending (°Baumé).
Wichita	6	7	3,797,215	$574,622	1,486,680	2.05-6.1	70-80
Palo Pinto	1	1	227,683	44,319	88,330	3.5	70
Williamson	1	1				2.0	75
	[a] 6	9	4,024,898	618,941	1,575,010	[b] 2.56	70-80

Produced by absorption.[c]

County.	Number of operators.	Number of plants.	Quantity (gallons).	Value.	Estimated volume of gas treated (M cubic feet).	Range in yield (gallons).	Range in gravity (°Baumé).
Clay	1	1	3,301,224	$595,624	6,918,172	0.48	84
Wichita	1	1				.32	81
Shackelford	1	1				.16	76
Eastland	1	1				.25	80
	4	4	3,301,224	595,624	6,918,172	[b] .48	76-84
Grand total	[a] 8	13	7,326,122	1,214,565	8,493,182	[b] .86	70-84

1919.

Produced by compression and by vacuum pumps.

County.	Number of operators.	Number of plants.	Quantity (gallons).	Value.	Estimated volume of gas treated (M cubic feet).	Range in yield (gallons).	Range in gravity (°Baumé).
Wichita	11	13	5,950,223	$971,652	3,019,029	1.3-7.4	54-90
Eastland	2	4	375,636	75,055	707,327	.5-1.3	79-90
Palo Pinto	1	1	283,189	54,844	195,153	1.0	82
Williamson	1	1				4.8	79-90
	[a] 13	19	6,609,048	1,101,551	3,921,509	.5-7.4	54-90

Produced by absorption.[c]

County.	Number of operators.	Number of plants.	Quantity (gallons).	Value.	Estimated volume of gas treated (M cubic feet).	Range in yield (gallons).	Range in gravity (°Baumé).
Clay	1	1	2,552,924	$637,672	4,112,764	0.14-0.82	72-82
Shackelford	1	1					
Wichita[d]	......	......					
Eastland	2	3	174,465	33,280	697,860	.25	78
	4	5	2,727,389	670,952	4,810,624	.14- .82	72-82
Grand total	[a] 15	24	9,336,437	1,772,503	8,732,133	.14- 7.4	54-90

[a] See California table, footnote [a].
[b] Average.
[c] Includes drip gasoline.
[d] Drip gasoline only.

WEST VIRGINIA.

Natural-gas gasoline produced in West Virginia in 1918 and 1919.

1918.

Produced by compression and by vacuum pumps.

County.	Number of operators.[a]	Number of plants.	Gasoline produced. Quantity (gallons).	Gasoline produced. Value.	Estimated volume of gas treated (M cubic feet).	Range in yield of gasoline per thousand cubic feet of gas (gallons).	Range in gravity of gasoline as produced and before blending (°Baumé).
Tyler	23	62	4,255,558	$829,446	1,452,694	2.0 -4.0	75-87
Kanawha	6	12	2,503,369	467,493	1,321,502	.99-4.0	80-94
Roane	6	8	1,298,262	220,730	515,611	1.4 -4.0	72-90
Ritchie	14	18	700,739	135,583	499,379	.50-3.0	74-90
Hancock	6	11	581,132	105,999	154,684	1.5 -6.0	88-91
Wetzel	7	10	566,871	115,999	359,773	.33-3.0	75-86
Brooke	10	14	511,007	97,621	214,001	1.5 -3.5	74-94
Pleasants	9	18	379,381	65,012	201,456	1.5 -4.0	75-88
Clay	2	2	278,236	55,647	243,500	.96-1.25	80-82
Doddridge	2	3	235,906	42,304	114,646	2.00-2.5	83-88
Harrison	1	1				3.00	83
Marion	1	1				2.00	80
Lewis	1	1	232,129	42,808	101,050	.18	83
Calhoun	1	2				[b] 1.0	80-90
Marshall	1	2				[b] 2.50	[b] 80
Wood	5	5	67,229	11,807	40,099	.50-2.50	80-86
Wirt	2	2	2,295	918	345	[b].66	[b] 82
	[a] 71	172	11,612,114	2,191,367	5,218,740	[b] 2.23	72-94

Produced by absorption.[c]

County.	Number of operators.[a]	Number of plants.	Gasoline produced. Quantity (gallons).	Gasoline produced. Value.	Estimated volume of gas treated (M cubic feet).	Range in yield of gasoline per thousand cubic feet of gas (gallons).	Range in gravity of gasoline as produced and before blending (°Baumé).
Lewis	3	5	5,545,531	$1,069,607	31,909,291	0.16-0.17	73-85
Wetzel	1	3				.11-2.00	68-80
Cabell	1	1				.20	88
Jackson	1	1				.18	88
Lincoln	1	1				.14	88
Wood	1	1	10,935,875	2,337,195	81,186,817	.07	73-83
Doddridge	1	1				.20	82
Putnam	1	1				.125	84-92
Pleasants	......	......				.15	80-87
Hancock	1	1				.10	80
Braxton	1	1				.25	79
Kanawha	4	6	4,205,567	837,917	22,994,462	.10- .33	80-82
Marion	3	4	2,346,881	437,398	12,494,089	.11- .18	73-81
Harrison	2	3	1,729,589	370,124	2,221,402	.16- .20	80-86
Tyler	2	3	989,084	204,970	6,572,728	.18- .50	[b] 86
Ritchie	2	2	136,250	28,923	546,305	.13- .75	79-90
Clay	2	2	103,012	21,303	785,716	.10- .25	[b] 80
	[a] 12	36	25,991,789	5,307,437	158,710,810	[b].16	68-92
Grand total	[a] 79	208	37,603,903	7,498,804	163,929,550	[b].23	68-94

1919.

Produced by compression and by vacuum pumps.

County.	Number of operators.[a]	Number of plants.	Gasoline produced. Quantity (gallons).	Gasoline produced. Value.	Estimated volume of gas treated (M cubic feet).	Range in yield of gasoline per thousand cubic feet of gas (gallons).	Range in gravity of gasoline as produced and before blending (°Baumé).
Tyler	22	60	5,079,972	$1,188,814	1,707,953	1.0 -9.0	64-96
Kanawha[d]	7	14	4,481,033	910,154	3,006,491	1.25-3.0	84-95
Roane	7	11	1,688,230	366,664	855,386	1.14-3.0	75-90
Ritchie	14	25	1,381,078	281,345	913,652	.5 -3.0	75-88
Brooke	12	15	696,264	125,327	247,243	.66-4.5	82-92
Wetzel	8	11	656,823	151,360	430,617	.33-3.0	75-82
Lincoln	1	1				1.0	80
Marion	1	1				2.0	80
Wirt[d]	1	1				1.8 -2.2	80-90
Lewis	1	1	632,875	140,731	559,553	.5	....
Monongalia	1	1				3.0	80
Calhoun	1	1				.5	90
Marshall	1	2				2.0	80
Pleasants	12	23	423,747	77,926	226,582	1.5 -3.0	72-88
Doddridge	3	4	286,917	60,153	141,533	2.0 -2.5	83-88
Clay	2	2	172,455	36,102	149,924	1.0 -1.2	83-84
Hancock	5	5	126,380	24,733	50,410	6.8 -3.0	74-98
Harrison	3	3	124,697	29,723	42,250	1.5 -3.0	76-83
Wood	4	4	44,952	8,133	22,477	.5 -3.0	80-86
	[a] 79	185	15,795,423	3,401,165	8,354,071	.33-9.0	64-98

[a] See California table, footnote [a].
[b] Average.
[c] Includes drip gasoline.
[d] Includes one combination compression and absorption plant.

Natural-gas gasoline produced in West Virginia in 1918 and 1919—Continued.

1919—Continued.

Produced by absorption.[a]

County.	Number of operators.[b]	Number of plants.	Gasoline produced. Quantity (gallons).	Gasoline produced. Value.	Estimated volume of gas treated (M cubic feet).	Range in yield of gasoline per thousand cubic feet of gas (gallons).	Range in gravity of gasoline as produced and before blending (°Baumé).
Cabell	1	1	8,638,219	$2,010,046	29,599,618	0.3	85
Jackson	1	1				.25	84
Tyler	1	2				.24	70–75
Lincoln	1	1				1.52	86
Wood	1	1				.1	83.4
Roane	1	1				.5	80.4
Braxton	1	1				.16	81
Wetzel	3	5	7,220,674	1,795,368	44,844,900	.11– .31	78.8–88.5
Lewis	2	5	6,423,404	1,652,759	25,823,100	.20– .41	81.3–88.4
Kanawha	6	7	5,814,998	1,303,527	22,706,156	.07– .62	62–80
Marion	3	4	3,307,356	804,813	11,760,276	.13– .38	77.7–86.5
Harrison	2	4	3,050,694	780,917	15,463,440	.18– .23	84.9–87.5
Doddridge	2	3	1,172,590	267,345	5,249,980	.20– .24	82–88.1
Marshall	2	2	477,535	102,293	1,972,754	.11– .25	77–80
Clay	2	2	180,847	44,098	1,089,000	.10– .27	82
Pleasants	2	2	68,305	17,307	375,794	.17–2.0	80–80.1
	[b] 13	42	36,354,622	8,778,473	158,885,018	.07–2.0	.62–88.5
Grand total	[b] 89	227	52,150,045	12,179,638	167,239,089	.07–9.0	62–98

[a] Includes drip gasoline.
[b] See California table, footnote [a].

WYOMING.

Natural-gas gasoline produced in Wyoming in 1919.

Produced by compression and by vacuum pumps.

County.	Number of operators.[a]	Number of plants.	Gasoline produced. Quantity (gallons).	Gasoline produced. Value.	Estimated volume of gas treated (M cubic feet).	Range in yield of gasoline per thousand cubic feet of gas (gallons).	Range in gravity of gasoline as produced and before blending (°Baumé).
Natrona, Park	[a] 2	3	4,978,443	$823,410	1,341,699	2 –3.95	78–80
Produced by absorption.[b]							
Big Horn, Natrona	[a] 2	2	602,156	$108,312	2,346,208	.24– .29	71–76
Grand total	[a] 3	5	5,580,599	931,722	3,687,907	.24–3.95	71–80
1918	[a] 2	2	1,579,526	268,339	1,433,564	.33–2.13	76–90

[a] See California table, footnote [a].
[b] Includes drip gasoline.

SULPHUR AND PYRITES.[1]

By Philip S. Smith.

GENERAL SITUATION.

The outstanding feature of the sulphur and pyrites industries in 1919 was their effort to accommodate themselves to the changed conditions brought about by the signing of the armistice. For more than a year and a half prior to November, 1918, every effort had been made by the Government to assure an adequate supply of these raw materials necessary for the production of the war matériel. With the signing of the armistice and the undertaking of negotiations which obviously would terminate in peace, the need for these supplies ended, and the problem became one of the disposal of surplus stocks and the curtailment of production. Early in February, 1919, the producers, unable to find markets for their commodities that had been produced to meet a national need, naturally turned to the Government for relief. Numerous plans were adopted to absorb some of the surplus, but these measures were not adequate, and early in March Congress passed an act establishing the War Minerals Relief Commission, with funds to pay for losses incurred by producers of pyrites and certain other specified minerals in response to direct Government appeal. Strict legal interpretation of many of the rather indefinite terms of this act has resulted in affording less actual relief than was expected by many of the producers.

The situation was further complicated by the fact that during 1919 another great sulphur plant, that of the Texas Gulf Sulphur Co., in the eastern part of Texas near Matagorda, began producing, thus making three main sulphur producers. This additional production and the general business stagnation throughout the country resulted in a lessened market for domestic sulphur, and large stocks of it accumulated. Under these conditions every effort was made to find new uses for sulphur or to extend old uses. Some relief was afforded by the lesson learned during the war period that sulphur could be substituted in many of the industries for pyrites, but this substitution, though largely advantageous to the producers of sulphur, led to a marked cessation in mining and importation of pyrites. Among the most promising fields for the increased use of sulphur is its application as a direct fertilizer. Tests conducted by agricultural experiment stations and independent observers point unequivocally to the conclusion that the use of sulphur on many soils is decidedly advantageous and that, in fact, it is now even questioned whether certain fertilizer substances are not really effective mainly because of the sulphur they contain.

[1] The statistics of production in this report were compiled by Miss Jane Hanna, and the tables of imports and exports by J. A. Dorsey, both of the United States Geological Survey.

In March, 1919, the litigation that had been in progress for several years, regarding the method of mining underground deposits of sulphur by the introduction of superheated water, was settled by the decision of the court that the methods used were to all intents and purposes the same as those covered by the original Frasch patents, which had expired, or were matters of such general knowledge that they were not susceptible of patent and were therefore open to the use of all. This decision makes available to all the remarkable process perfected by Doctor Frasch, the only process by which the sulphur domes of the Gulf coast could be economically developed. The application of this process, however, requires expensive plants, elaborate machinery, highly trained technical assistance, large expenditure of money, and practically continuous operation of the plant.

During 1919 considerable interest was displayed in the exploitation of sulphur deposits in Culberson County in western Texas. However, it seems doubtful whether the deposits of sulphur in this region can be profitably developed in competition with the large going concerns near the Gulf seaboard, owing to their long distance from markets, the absence of suitable supplies of water and fuel, and the high cost of recovering the sulphur. Attempts made to separate the sulphur in these ores by subjecting them to heat in retorts have so far been unsuccessful, but experiments in concentrating them by flotation have yielded promising results. The general conclusions expressed by J. M. Hyde,[2] of the Bureau of Mines, who has investigated this problem, are that

> The ores from several districts can certainly be treated successfully by flotation if suitable water is obtainable. Under favorable conditions better than 80 per cent of the sulphur should be recoverable as concentrate, containing more than 80 per cent of sulphur. Much better results may be obtained.

SULPHUR.

DOMESTIC PRODUCTION.

Sulphur was reported to have been produced in 1919 by seven mines, one each in Louisiana, Nevada, and Utah and two each in California and Texas. Practically all the sulphur was produced by the three mines in Louisiana and Texas. These are the mines of the Union Sulphur Co. at Sulphur, Calcasieu Parish, La.; the Texas Gulf Sulphur Co., at Big Hill, Matagorda County, Tex.; and the Freeport Sulphur Co., near Freeport, Brazoria County, Tex. These three mines produced more than 99.5 per cent of the total domestic sulphur in 1919, which amounted to 1,190,575 tons, about 160,000 tons less than the output in 1918, but otherwise the largest production yet recorded and considerably more than had been produced in any other year. Markets for much of this sulphur were not found, and only 678,257 tons is reported to have been shipped, so that more than 500,000 tons was added to the stocks held at the mines. The total value of the sulphur shipped was $10,252,000, which would indicate an average price per ton of $15.12. At this average price per ton the total value of the sulphur produced in 1919 would have been $18,000,000.

[2] Hyde, J. M., Concentration of native sulphur ores by flotation: Bur. Mines, Mineral Inv. Ser. 15, p. 18, April, 1919.

Sulphur produced and shipped in the United States, 1915–1919.

Year.	Mined (long tons).	Shipped.	
		Quantity (long tons).	Value.
1915	520,582	293,803	$4,959,000
1916	649,683	766,835	12,246,000
1917	1,134,412	1,120,378	23,987,000
1918	1,353,525	1,266,709	27,868,000
1919	1,190,575	678,257	10,252,000

The successful bringing into production of a new field is of such importance that a brief description of the new mine of the Texas Gulf Sulphur Co., near Matagorda, Tex., may be of interest. Exploration and testing work at this mine begun in 1917 showed that the sulphur-bearing beds were sufficiently extensive to justify the large expenditures required for the erection of a plant. In 1918 the J. G. White Engineering Construction Corporation began to build a plant, which was completed in March, 1919. The plant is thoroughly modern in all its equipment and was planned to produce at least 1,000 tons of sulphur a day, requiring the installation of boilers with oil-fired furnaces capable of furnishing 10,000 horsepower, two steam turbogenerators with a rated capacity of 500 kilowatts each, and four steam-driven air compressers for an air pressure of 700 pounds, together with the usual station auxiliaries.[3] As this mine was developed in a practically unsettled part of Texas it was necessary not only to install the mining equipment but also to build a town and the essential adjuncts for the workers. This has given rise to an industrial settlement planned and executed in accordance with the best modern practice. The deposit at this place is essentially similar in its geologic aspects to the sulphur deposits at Freeport, Tex., and Sulphur, La. The dome, formerly known as Big Hill, has a diameter of about three-quarters of a mile, and before mining began the highest point rose to an elevation of about 40 feet above the surrounding country. The removal of the sulphur has allowed settling underground, so that the height has been materially reduced. The sulphur deposits are some 700 to 1,000 feet below the surface and are covered by sands, muds, and other unconsolidated deposits. The process used for the extraction of the sulphur is in general the well-known Frasch process, by which cased holes are drilled to the deposit and superheated water forced through them. The heat melts the sulphur, which accumulates at the bottom of the wells and is forced to the surface by the use of compressed air.

IMPORTS.

The quantity of foreign crude sulphur imported into the United States in 1919 was insignificant, amounting to only 77 tons, although this was some 22 tons more than was imported in 1918. The quantity of domestic sulphur available in stocks at the mines was so great as to discourage the importation of sulphur from foreign deposits.

[3] Wells, E. R., and Shoudy, W. A., The Texas Gulf Sulphur Co.'s immense new plant in operation: Manufacturers' Record, May 1, 1919, pp. 141-143, 4 illustrations.

The data in the following table were complied from the records of the Bureau of Foreign and Domestic Commerce:

Crude sulphur imported into the United States in 1919.

Country.	Port of entry.	Quantity (long tons).	Value.
Canada	Maine and New Hampshire	67	$1,673
England	New York and Pittsburgh	6	99
Japan	New York		8
	Southern California	3	174
	Hawaii	1	43
		77	1,997

In the foregoing table the imports credited to Canada and England were doubtless reshipments of crude sulphur produced in some other foreign countries, inasmuch as neither Canada nor England produces any crude sulphur. The total value of the imported crude sulphur was $1,997, which is equivalent to about $26 a ton. In addition to the crude sulphur, 24 tons of lac or precipitated sulphur, valued at $6,621, was imported into the United States in 1919. No refined sulphur or flowers of sulphur are recorded as having been imported.

EXPORTS.

The sulphur exported in 1919 amounted to 224,712 long tons, valued at $6,325,552. This quantity was about 70,000 tons more than was exported in 1917 and about 90,000 tons more than was exported in any other year.

Sulphur exported from the United States, 1915–1919.

Year.	Quantity (long tons).	Value.
1915	37,312	$724,679
1916	128,755	2,505,857
1917	152,736	3,500,819
1918	131,092	3,626,638
1919	224,712	6,325,552

The following table shows the crude sulphur exported from the United States in 1919 and the customs districts from which it was cleared. Although the customs districts are distributed around the entire border of the country, practically all the sulphur exported was produced by the large mines in Texas and Louisiana already noted.

Sulphur exported from the United States in 1919, in long tons.

Destination.	Ports of clearance.							
	New York City.	Maine, New Hampshire, Massachusetts, Vermont.	St. Lawrence, Buffalo, Michigan, St. Louis.	Dakota, Minnesota, Washington.	California and Arizona.	Texas and Louisiana.	Florida, Mobile, Virginia, Porto Rico.	Total.
North America	403	13,159	20,090	7,868	287	7,879	57	49,743
South America	4,360				198	4,718	371	9,647
Europe	15,395	134				126,743	3,033	145,305
Asia and Oceanica	626			63	9,354			10,043
Africa	606					9,368		9,974
	21,390	13,293	20,090	7,931	9,839	148,708	3,461	224,712

Of the 49,743 tons exported to North American countries, 41,136 tons was shipped to Canada, 4,970 tons to Mexico, 2,801 tons to Newfoundland, and smaller quantities to Central America, Cuba, British and French West Indies, and the Dominican Republic. Of the 145,305 tons sent to European countries, 77;206 tons went to France, 28,902 tons to Sweden, 12,424 tons to Finland, and smaller quantities to Greece, Portugal, Belgium, England, Spain, Norway, Denmark, and the Netherlands. Of the 9,647 tons sent to South American countries, 6,072 tons went to Argentina, 2,351 tons to Brazil, and smaller quantities to Uruguay, Peru, Chile, Ecuador, Venezuela, Colombia, and Paraguay. Of the 9,974 tons sent to Africa, 3,824 tons went to British Africa, 3,200 tons to French Africa, and 2,950 tons to Portuguese Africa. Of the 10,043 tons sent to Asia and Oceanica, 9,010 tons was shipped to Australia and New Zealand, 596 tons to British possessions in India and the Straits Settlements, and smaller quantities to the Dutch East Indies, China, Japan, the Philippine Islands, and Hongkong.

THE WORLD'S SULPHUR INDUSTRY.

The three countries producing the largest quantities of sulphur in 1919 were the United States, Italy, and Japan. As has been shown, the United States produced 1,190,575 long tons. So far as records are available it appears that Sicily, which is the main producer of the Italian sulphur, produced 181,374 metric tons of sulphur in 1919, and that Japan produced 50,631 metric tons. Probably all the other countries of the world did not produce as much as 5 per cent of the output of these three countries. From these figures it is evident that the United States produced nearly four-fifths of the entire sulphur of the world in 1919. It is doubtful whether so high a percentage of the world's production can be maintained by the United States, but it seems certain that this country can meet its own needs in sulphur and have large stores available for export for many years to come.

While the sulphur industry of the United States was increasing within the last five years, the Sicilian sulphur industry was decreasing, as is shown by the following record:[4]

Statistics of sulphur industry in Sicily, 1915–1919, in metric tons.

Year.	Production.	Stocks on hand.	Exports.
1915	319,230	323,860	359,806
1916	233,835	155,372	396,035
1917	177,453	156,800	162,971
1918	194,585	112,050	230,769
1919	181,374	136,859	149,755

Very little of the Sicilian sulphur is consumed locally, most of it being exported, as is shown in the table. Large stocks, nearly equal to a year's production, have also been accumulated. Furthermore, the sulphur industry in the United States is not likely to be seriously affected by competition with Sicilian product, because the cost of mining sulphur in the Gulf region is very low, whereas the cost of mining it in Sicily is high. According to official records,[5] "the cost of the Freeport Co. in 1917 was $6.15 per ton. In 1918 it is estimated that increase will bring the cost up to not over $9.50 per ton. In the first half of 1917 the Union Co.'s costs were $5.73 per ton." On the other hand, the cost of producing Sicilian sulphur as reported by the official organization of Sicilian sulphur producers was as follows:[6]

Cost per ton of producing sulphur in Sicily.

Labor	$14.00	
Materials	4.00	
General expenses	1.25	
Depreciation and interest	1.50	
		$20.75
25 per cent royalty		5.19
		25.94
Transportation to station	1.50	
Railway and insurance	1.80	
Taxes and expenses	4.20	
		7.50
		33.44

NOTE.—These charges were reported in lire and converted into dollars on the basis of 1 lira=5 cents.

These two sets of figures are not strictly comparable, because they do not both include the same charges, but they indicate that there is a clear difference in favor of the United States.

The Japanese sulphur industry, although showing a marked increase during the early years of the World War, has declined since 1917, as is shown by the folllowing table:

Sulphur produced in Japan, 1915–1919, in metric tons.

1915	72,206	1918	64,711
1916	106,520	1919	50,631
1917	118,086		

[4] Dreyfus, L. G., jr. (consul, Palermo), Decline of the Sicilian sulphur industry: Commerce Repts., Aug. 19, 1921, p. 874.
[5] U. S. Official Bull. 348, vol. 2, p. 13, Jan. 29, 1918.
[6] Dreyfus, L. G. jr., (consul, Palermo), Sulphur crisis in Sicily, U. S. consular report, Sept. 20, 1921.

PYRITES.

DOMESTIC PRODUCTION.

The domestic production of pyrites in 1919 decreased about 44,000 long tons in quantity and $100,000 in value, as compared with the production in 1918. The consumption of pyritic ores—that is, the domestic production plus imports—amounted to less than 810,000 tons, or 150,000 tons less than was consumed in 1918, and was less than the quantity consumed in any other year since 1905, and indicates very clearly the depression suffered by the pyrites industry. The decrease is largely attributable to the increased use of sulphur by the producers of sulphuric acid, who have found that sulphur not only costs less originally, but is less expensive through all the processes of manufacture.

The production in 1919 was reported by 47 mines in 12 States, as against 64 mines in 15 States in 1918.

Pyrites produced in the United States in 1919, by States.

State.	Lump.		Fines.		Total.	
	Quantity (long tons).	Value.	Quantity (long tons).	Value.	Quantity (long tons).	Value.
California	(a)	(a)	(a)	(a)	128,803	$530,678
Colorado	17,474	$85,261			17,474	85,261
Georgia	(a)	(a)	(a)	(a)	34,412	349,779
Illinois	(a)	(a)	(a)	(a)	13,353	46,634
New York	(a)	(a)	(a)	(a)	60,544	468,257
Ohio	4,609	16,886			4,609	16,886
Virginia	57,805	341,725	61,359	$549,583	119,164	891,308
Wisconsin			26,053	19,287	26,053	19,287
Other States [b]	10,037	92,944	6,198	57,138	16,235	150,082
	[c] 136,779	[c] 812,637	[c] 283,868	[c] 1,745,535	420,647	2,558,172

[a] Output of lump and fines not shown separately, as there were less than 3 producers of one or the other.
[b] Includes Alabama, Missouri, Pennsylvania, and Tennessee.
[c] Includes quantity produced in States whose individual output is not shown separately.

California was the leading State, producing about 17,000 tons of pyrites more in 1919 than in 1918; Virginia was second but produced nearly 25,000 tons less than in 1918; the two States together furnished nearly 60 per cent of the total.

Of the total quantity, 136,779 tons was reported to be lump and 283,868 tons was fines or concentrates. The total sulphur content of the lump ore was equivalent to 51,077 tons, or about 37 per cent, and that of the fines or concentrates was 119,155 tons, or about 42 per cent. The lump ore was valued at $812,637, and the fines or concentrates at $1,745,535. The average price of the lump ore was therefore $5.94 a ton, and that of the fines $6.15 a ton. According to these figures the average price per unit of sulphur in the lump ore was 16 cents and in the fines or concentrates 14⅔ cents.

Pyrites produced in the United States, 1915–1919.

Year.	Quantity (long tons).	Value.
1915	394,124	$1,674,933
1916	439,132	2,038,002
1917	482,662	2,593,035
1918	464,494	2,644,515
1919	420,647	2,558,172

IMPORTS AND EXPORTS.

The imports of pyrites decreased nearly 110,000 tons in 1919 as compared with 1918, and were smaller than in any other year since 1900 and less than 40 per cent as much as the average in 1911 to 1917. This decrease was due in part to difficulties of transportation, but was very largely caused by the substitution of domestic native sulphur for pyrites in the sulphuric acid industry.

The following table was compiled from the records of the Bureau of Foreign and Domestic Commerce:

Sulphur ore imported in 1919 as pyrites, containing more than 25 per cent of sulphur' by countries and districts of entry.

Country exporting.	Quantity (long tons).	Value.	Districts of entry.	Quantity (long tons).	Value.
Canada	84,761	$387,490	Buffalo	25,677	$118,782
			Chicago	21,717	100,761
			Michigan	555	3,120
			New York	350	14,000
			Ohio	27,385	128,784
			Vermont	9,077	22,043
Cuba	23,237	211,839	Florida	350	3,556
			Maryland	22,887	208,283
France	250	3,000	Philadelphia	250	3,000
Spain	280,725	1,574,236	Florida	11,779	47,192
			Georgia	15,287	106,788
			Maryland	56,724	357,923
			Massachusetts	9,735	38,664
			New York	70,845	317,712
			North Carolina	5,998	20,658
			Philadelphia	81,052	535,333
			South Carolina	25,287	121,840
			Virginia	4,018	28,126
	388,973	2,176,565		388,973	2,176,565

A comparison of this table with the record for 1918 shows that imports from Canada decreased about 140,000 tons and that the imports from Spain increased about 10,000 tons. Cuba for the first time became an exporter to the United States and supplied about 23,000 tons. The ore imported from France was probably produced in some other country and reshipped to the United States.

The value of the imported pyritic ore, according to the Bureau of Foreign and Domestic Commerce, was $2,176,565, an average of $5.60 a ton. This value was nearly $600,000 less than for 1918, though the average price was about 5 cents a ton higher. The average price of the Canadian ore was $4.57 a ton, against $4.25 in 1918; the average price of the Spanish ore was $5.61 a ton, a marked decrease from the price of $6.50 a ton in 1918. The average sulphur content of the

Spanish pyritic ore was 48 per cent, which would make the average unit price of the sulphur it contains somewhat less than 12 cents. The Canadian ore generally averages not more than 42 per cent of sulphur. It is significant to note that the average price per unit of sulphur received from the domestic ores was 14⅗ to 16 cents, as against 12 cents or less for the imported ores.

The United States does not export any pyrites.

THE WORLD'S PYRITES INDUSTRY.

The United States contributes only about 6 per cent of the world's production of pyrite. This small contribution, however, does not indicate that the country is poorly supplied with this material, for there are in fact thousands of mines in the United States that could furnish pyrites if the cost of mining and transportation did not control production. For many years the pyrites industry in the United States has faced the fact that owing to low wages, economical methods of mining, and cheap freight, pyrites from the great Spanish deposits can be mined, transported, and laid down duty free at our larger domestic ports, which are near the centers of consumption of pyrites, more cheaply than pyrites from our domestic deposits can be brought to the same market. Furthermore, so long as the production of native sulphur in the United States is so greatly in excess of the domestic consumption no great expansion of the domestic pyrites industry is commercially practicable.

In order to stimulate the domestic pyrites industry many proposals have been made to place a traiff on the importation of pyrites, but the Tariff Commission, in a pamphlet [7] prepared for the use of the Committee on Ways and Means of the House of Representatives, says: "For like reasons American pyrites producers can expect little, if any, benefit either from a duty on sulphur or one on pyrites. The serious competition which domestic pyrites producers face comes from American sulphur, not from imported pyrites."

SULPHURIC ACID INDUSTRY.

The use of pyrites and sulphur is so closely related to the production of sulphuric acid and that acid enters so largely into all industries that for a number of years the Geological Survey has collected statistics on the production of sulphuric acid. In 1919, however, owing to the thorough canvass conducted by the Bureau of the Census, no independent statistical inquiries were made by the Survey, and the records compiled by the Census Bureau have been utilized in preparing the following statement.

The total reported production of sulphuric acid, computed as acid of 50° B. strength, was 5,534,353 short tons. Of this quantity 3,331,362 short tons was sold at $35,932,605, and the rest was consumed by the companies producing it. The average price per ton of the acid sold was $10.79. If all the acid produced had been sold at this average price the total value in 1919 would have been $60,000,000. These figures do not represent the exact quantity of acid manufactured during the year, because the inquiry was made regarding only

[7] U. S. Tariff Commission, Information concerning pyrites and sulphur industry, p. 9, Washington, 1919.

the acid sold or consumed by the producer and did not cover acid made and held in storage. Under normal conditions the quantity of acid manufactured and held in storage is about equivalent to the quantity taken from storage and consumed; but under the abnormal business conditions that followed the World War doubtless the quantity of acid made and placed in storage was greater than usual.

The plants reported as engaged in the manufacture of sulphuric acid numbered 216. Of the total output 2,731,884 short tons was produced as acid of 50° B. strength, 1,020,052 short tons as acid of 60° B., 834,195 short tons as acid of 66° B., 76,678 short tons as oleum, and 75,126 short tons as trioxide.

The following table indicates the principal industries producing sulphuric acid for sale or for their own use:

Sulphuric acid produced by industries in 1919, computed as acid of 50° B. strength.

Industry.	Quantity (short tons).	Value of acid sold.
Sulphuric, nitric, and mixed acids	2,684,047	$24,729,294
Chemicals in general	869,544	7,027,224
Fertilizers	1,877,394	3,639,010
Explosives	85,228	537,077
Others (including petroleum refining)	18,140	0
	5,534,353	35,932,605

The following table shows that 811,509 short tons of acid of 60° B. strength, included in the preceding table mostly under the head of "sulphuric, nitric, and mixed acids" (1,012,796 short tons computed as acid of 50° B. strength), was produced from the gases given off by the smelting of copper and zinc ores at smelters.

Sulphuric acid produced in 1919 from fumes and gases of copper and zinc smelters, in terms of 60° B.

	Number of establishments.	Made and consumed (short tons).	Produced for sale.		Total production (short tons).
			Quantity (short tons).	Value.	
Copper smelters	6	410	[a] 364,581	[a] $2,084,087	364,991
Zinc smelters	11	7,385	439,133	5,340,277	446,518
	17	7,795	803,714	7,424,364	811,509

[a] Some production under a pre-war long-term contract.

Data are not available as to the quantity of copper and zinc ores from which the acid was produced, but a conservative estimate would be that each ton of acid required the equivalent of a ton of ore for its production.

The records show that 460,899 long tons of sulphur and 1,017,882 long tons of pyrites were used in the manufacture of sulphuric acid. This material was distributed by industries as follows:

Sulphur and pyrites used in 1919 in the manufacture of sulphuric acid.

Industry.	Sulphur used (long tons).	Pyrites used (long tons).
Sulphuric, nitric, and mixed acids	98,746	460,257
Chemicals	136,623	172,189
Fertilizers	197,817	355,894
Explosives	23,033	6,082
Others (including petroleum refining)	4,680	23,460
	460,899	1,017,882

The great increase in the use of sulphur in the manufacture of sulphuric acid may be realized by comparing the foregoing figures with those for even so recent a year as 1915, when only 52,481 long tons was used, and the contrast is even more striking if they are compared with those for 1913, when only 16,318 long tons of sulphur was used.

The report that 1,017,882 long tons of pyrites was used in the manufacture of sulphuric acid is unexpected when it is remembered that only about 810,000 long tons of pyritic ores, including both domestic ores mined and foreign ores imported, were received during the year. Doubtless most of the excess pyrites was drawn from stocks that had been accumulated at the plants during 1918 in anticipation of a possible shortage. So far as can be learned stocks of pyrites held at the sulphuric acid plants in 1919 were small.

IMPORTS.

Very little sulphuric acid is at any time imported into the United States. The imports in 1919 amounted to 7,373 short tons and came largely from Canada. The statistics have been compiled from records of the Bureau of Foreign and Domestic Commerce.

Sulphuric acid imported for consumption in the United States, 1915–1919.

Year.	Quantity (short tons).	Value.
1915	4,693	$69,920
1916	706	21,672
1917	10,071	228,982
1918	5,687	176,223
1919	7,373	116,725

The average price of the imported acid was $15.83 a ton. This indicates that most of the acid was of low strength.

EXPORTS.

The exports of sulphuric acid in 1919 amounted to 10,648 short tons, valued at $489,966. The average price of the acid was therefore approximately $46 a ton, and indicates that only acids of the highest strengths were exported. The following table was compiled from records of the Bureau of Foreign and Domestic Commerce:

Sulphuric acid exported, 1915–1919.

Year.	Quantity (short tons).	Value.
1915	38,920	$998,249
1916	33,232	1,847,995
1917	31,761	1,006,125
1918	40,147	1,278,027
1919	10,648	489,966

Of the acid exported, 6,808 short tons was shipped to either North American countries or the islands adjacent to them. Mexico received nearly 4,000 tons, and Canada and Cuba about 1,200 tons each. South American countries received 3,745 short tons, of which Argentina received more than 2,000 tons and Brazil 600 tons. Only 69 tons was shipped to Asia and Oceanica, 17 tons to Europe, and 9 tons to Africa.

INDEX.

A. Page.

Abrasive materials, by L. M. Beach and A. T. Coons..... 381, 386
  artificial..... 381, 386
  consumption..... 381
  imports..... 381
  introduction..... 381
  list of States producing..... 382
  natural abrasives..... 382
  value, total..... 381
    by kinds..... 382
Africa, asbestos, imports from..... 305
  asphalt, exports to..... 286
  cement, exports to..... 402
  diamond..... 171–176
  graphite..... 182, 316
  lime, exports to..... 416
  mica..... 273–274
  monazite sand..... 10
  phosphate rock..... 220–223
  potash, imports from..... 86
  salt, exports to..... 247
    imports from..... 245
  slate, exports to..... 373, 374
  sodium compounds, exports to..... 51
  stone, exports to..... 424
  sulphur, exports to..... 539
Aggregate for concrete..... 333
Agricultural gypsum and its uses, by William Crocker..... 109–111
  (*See also* Gypsum.)
Alabama, ammonia..... 505
  artificial gas..... 466, 471, 473, 475, 484, 487, 493, 498, 501, 505
  barytes..... 335, 338
  cement, Portland..... 390, 395, 397
    puzzolan..... 401
  crushed stone..... 442, 451
  fuller's earth..... 258
  furnace flux..... 444
  graphite..... 310–311
  lime..... 406, 410, 413, 415
  limestone..... 435, 444
  marble..... 434
  mica..... 269–270, 274
  millstones..... 382
  mineral waters..... 116, 119, 123
  pyrites..... 541
  sand and gravel..... 157–158
  sandstone..... 446, 450
  silica..... 380
  stone..... 423
Alaska, barytes..... 338
  cement..... 395, 397
  graphite..... 310
  gypsum..... 101, 104, 105
  lime..... 415
  marble..... 434
  stone..... 423
Alcohol, peat as source of..... 44–45
Algeria, phosphate rock..... 218, 220–221
Allanite..... 28
Alsace, potash..... 77, 87
Alunite, potash from..... 79–80
Ammonia, sulphate..... 504–506
Analyses, asbestos..... 302
  baddeleyite..... 19
  graphite..... 202, 207–208
  lithium minerals..... 39
  peat..... 44
  talc..... 267
  thorium minerals..... 12–13, 14–15
  zirkite..... 18
Angaur Island, phosphate rock..... 218

Page.

Architectural stone..... 328, 330
Argentina, asphalt, exports to..... 285
  cement, exports to..... 402
  diamonds, imports from..... 169
  graphite, exports to..... 315
  gypsum, exports to..... 107–108
  mica..... 272, 274
  potash..... 86
  salt, exports to..... 247
  sand and gravel, exports to..... 160
  sodium compounds, exports to..... 50
  stone, exports to..... 424
  sulphur, exports to..... 546
Arizona, artificial gas..... 466, 474, 490
  asbestos..... 299, 300–304
    chemical composition..... 302–304
      analyses..... 302
    geology and structure of Globe field..... 300–301
    mining operations..... 301–302
    occurrence..... 301
      section from Cerro del Temporal to summit of Coon Creek Butte..... 301
  cement, Portland..... 395, 397
  concrete blocks..... 328
  crushed stone..... 430, 442, 451, 454
  fluorspar..... 352, 353
    stocks..... 355
  furnace flux..... 444
  gadolinite..... 31
  granite..... 426, 429
  gypsum..... 101, 102, 104, 105
  lime..... 406, 410, 413, 415
  limestone..... 435, 442
  precious stones..... 168
  quartz..... 380
  sand and gravel..... 157–158
  sandstone..... 446, 450
  silo blocks and staves..... 328–329
  stone..... 423
  strontium..... 95, 98
  turquoise..... 168
Arkansas, artificial gas..... 466, 471, 473, 484, 487, 493, 498
  basalt..... 431
  calcareous marl..... 417
  cement..... 395, 397
  concrete blocks..... 328
    brick..... 329
  crushed stone..... 430, 442, 451, 454
  diamond..... 165, 170
  fuller's earth..... 258
  glass sand..... 162
  granite..... 426, 429
  lime..... 406, 410, 415
  limestone..... 435, 442
  marble..... 434
  mineral waters..... 116, 119, 123
  oilstones (novaculite)..... 382
  precious stones..... 165, 168
  sand and gravel..... 157–158
  sandstone..... 446, 450
  stone..... 423
Artificial abrasives..... 381, 386
Artificial gas and by-products, 1917–18, by R. S. McBride..... 457–518
  acknowledgments..... 458
  by-products of gas manufacture..... 491–511
    ammonia..... 504–506
    coke..... 492–496
    light oils and drip or holder oils..... 508–510
    naphthalene and miscellaneous products..... 510–511
    retort carbon and lamp black..... 503–504
    tar..... 496–503
    toluol..... 506–508

Page.

Artificial gas and by-products, capacity of gas plants 475–477
curve showing artificial gas sold per plant in the United States, 1898–1918 476
gas unaccounted for 477–479
kinds of gas produced and sold 466–477
artificial-gas plants by kinds of gas and by States 468
coal gas 470–471
coke-oven gas 474–475
oil gas 474
water gas 472–473
number of companies distributing artificial gas by States 469
magnitude and development of the gas industry 462–466
curve showing artificial gas sold in the United States, 1898–1918 462
gas sold by kinds 463–464
by States 465–466
materials used in making gas 483–491
fuels used in manufacture of coal gas, by States 484–485
number of plants reporting production of coal gas 485
fuels used in manufacture of water gas 487–489
solid fuel for carbureted water gas 488
oil for carbureted water gas 489
oil used in manufacture of oil gas 490–491
methods of gas manufacture 511–518
municipal gas supply, an engineering and chemical resource problem 457
price of gas 481–483
curve showing average price of artificial gas in United States, 1898–1918 482
coal, water, and oil gas plants reporting average price in 1918 482–483
scope of report 457–458
summary of data 459–461
units of measurement 459
utilization of gas 479–481
artificial gas sold, 1898–1918, by uses 479
curve showing gas sold per capita in United States, 1898–1918 480
consumption per capita and average price of gas, 1898–1918 481
Aruba, phosphate rock 218
Asbestos, by J. S. Diller 299–307
domestic output 299
by States 299
exports 306
imports 305–306
industry, by States 300–304
journal 307
prices 299, 304–305
principal foreign sources 306
producers 300
Asphalt and related bitumens, by K. W. Cottrell 279–297
association 288–296
pavement of different types in American cities 290–296
diagram showing percentages of pavements by types 296
consumption 286
exports 284–286
ichthyol, imports 283–284
imports 282–284
introduction 279
ozokerite, imports 283
prices 279, 281–282
producers 296–297
production 279–282, 288
manufactured or oil 287
from Mexiean petroleum 281–282
natural 280–281
by varieties and by States 281
in principal countries 286–288
street and alley paving by types 290–295
Australia, asphalt 286
cement, exports to 402
fluorspar 360, 366
gadolinite 10
graphite 182, 205, 315, 316
gypsum, exports to 107–108
mica 273
Australia, monazite sand 10, 13
opal 178
salt, exports to 247
imports from 245
slate, exports to 373
sodium compounds, exports to 51, 59
stone, exports to 424
sulphur, exports to 539
thorium minerals 16
Austria-Hungary, asphalt 287
cement, imports from 403
graphite 182, 186–189, 314, 316
ichthyol 283
magnesite 228–229
mineral waters, imports 122
sodium compounds, exports to 49

B.

Barbados, asphalt 282, 285
cement, exports to 402
lime, exports to 416
phosphate rock 217
stone, exports to 424
Barytes and barium products, by G. W. Stose 335–347
barium products 341–347
imports 346–347
manufacture, barium chemicals 337, 341, 344
ground barytes 337, 341, 342–343, 346
lithopone 337–341, 343–344, 346
production 345
prices 341, 343, 344, 345, 346, 347
consumption 337–338
imports 336
industry, by States 338–341
markets 337
prices 335, 337
production, by States 335
stocks 336
Basalt and related rocks (*see also* Stone) 419, 431–433
crushed stone 431, 433, 455
paving blocks 431
value, by States 431
uses 433
Bascom, F., paper on graphite mining in Pennsylvania 318–322
Beach, L. M., paper on graphite 309–324
abrasive materials 381–386
feldspar 377–378
silica 379–380
Bedford oolitic limestone 420
Belgian Kongo, cement, exports to 402
salt, exports to 247
Belgium, asphalt 285
cement, exports to 402
diamonds, imports from 169
flint pebbles, imports 386
gypsum, exports to 107
phosphate rock 216–217, 218, 219
potash, imports from 86
sodium compounds, exports to 49
stone, imports from 425
exports to 424
Bermuda, cement, exports to 402
lime, exports to 416
phosphate rock, exports to 217
salt, exports to 246
slate, exports to 373
Bituminous rock. (*See* Asphalt and bituminous rock.)
Blast-furnace dust, potash from 79–80
Bluestone, production, by States (*see also* Stone) 452
by uses 452
Bohemia, graphite 316
Bolivia, asphalt 285
cement, exports to 402
diamonds, imports from 109
lime, exports to 416
sodium compounds, exports to 50
Borax. (*See* Sodium salts.)
Brazil, asphalt 285
cement, exports 402
diamonds 169, 176
imports from 169
graphite 182, 186, 314, 315, 316
gypsum 107
lime, exports to 416
mica 272, 273, 274

Page.
Brazil, monazite sand.................... 6–8, 12, 14
  sand and gravel, exports to.............. 160
  sodium compounds, exports to........... 50, 59
  stone, exports to........................ 424
  sulphur, exports to...................... 539
  zirconium minerals................... 19, 23, 27
    analysis............................... 26
British Africa, asphalt, exports to........... 286
  asbestos................................. 305
  cement, exports to....................... 402
  diamonds, imports from................... 169
  graphite............................ 203, 315
  lime, exports to......................... 416
  mica..................................... 274
  natural soda............................. 621
  potash................................... 86
  salt, exports to......................... 247
  slate, exports to................... 373, 374
  sodium compounds, exports to............. 51
  stone, exports to........................ 424
  sulphur, exports to...................... 539
British Australasia, asphalt, exports to...... 286
British East Africa Protectorate, mica........ 274
British East Indies, asbestos, imports from.. 305
  asphalt.................................. 286
  cement, exports to....................... 402
  graphite....................... 182, 315, 316
  gypsum................................... 107
  pebbles.................................. 386
  salt, exports to......................... 247
  sodium compounds, exports to............. 50
British Guiana, cement, exports to........... 402
  diamonds, imports from................... 169
British Honduras, cement, exports to......... 402
  lime, exports to......................... 416
  salt, exports to......................... 246
British India, asbestos....................... 305
  asphalt.................................. 286
  cement................................... 402
  flint pebbles, imports................... 386
  graphite............................ 315, 316
  gypsum, exports to....................... 107
  potash................................... 86
  salt, exports to......................... 247
  stone, exports to........................ 424
British Isles. (*See* Great Britain.)
British Oceania, asphalt, exports to......... 286
  cement, exports to....................... 402
  lime, exports to......................... 416
  phosphate rock, exports to............... 217
  salt, exports to......................... 247
British West Indies, asphalt............. 282, 285
  cement, exports to....................... 402
  lime, exports to......................... 416
  salt, exports to......................... 246
    imports from........................... 245
  slate, exports to........................ 373
  stone, exports to........................ 424
  sulphur, exports to...................... 539
Bromine, by Herbert Insley (*see also* Salt, bromine, and calcium chloride). 249–255
  development of industry.............. 253–255
  methods of manufacture................... 250
  nature and occurrence.................... 250
  prices................................... 250
  production........................... 249–250
    diagram showing quantity, value, average price, 1890–1919........ 252, 253
  uses..................................... 253
Burma, monazite sand......................... 10
Burrstones and millstones, imports........... 383

C.

Calcareous marl.............................. 417
Calcium chloride (*see also* Salt, bromine, and calcium chloride).............. 255–256
  production............................... 255
  uses..................................... 256
California, architectural stone.............. 328
  artificial gas........... 466, 471, 474, 484, 487, 493
  asbestos............................ 299, 304
  asphalt.................................. 281
  barytes............................. 335, 338
  basalt.............................. 431, 433
  borax................................ 74–75
  calcareous marl.......................... 417
  calcium chloride......................... 255
Page.
California, cement, Portland.......... 390, 395, 397
    potash from............................ 401
  concrete blocks.......................... 328
  crushed stone.............. 430, 433, 442, 451, 454
  diatomaceous earth.................. 382, 385
  feldspar................................. 377
  fuel briquetting...................... 34, 36
  fuller's earth........................... 258
  furnace flux............................. 444
  glass sand............................... 162
  granite......................... 426, 429–430
  graphite............................. 310–311
  gypsum..................... 101, 102, 104, 105
  kelp..................................... 79
  lime....................... 406, 410, 413, 416
  limestone........................... 435, 442
  lithium minerals...................... 37, 39
  magnesite................. 227, 230–233, 235
  marble................................... 434
  mineral waters................. 116, 119, 124
  natural-gas gasoline....... 520, 521, 523, 524
  natural soda............................. 62
  natural sodium sulphate.................. 73
  peat plants........................... 45, 46
  pebbles for grinding..................... 382
  potash................................ 78–81
  precious stones.......................... 168
  pumice................................... 382
  pyrites.................................. 541
  quartz.............................. 178, 380
  salt..................................... 241
  sand and gravel...................... 157–158
  sand-lime brick.......................... 238
  sandstone........................... 446, 450
  slate............................... 370, 371
  stone................ 423, 426, 434, 435, 446
  strontium............................. 95, 98
  sulphur.................................. 536
  talc..................................... 265
Canada, asbestos............................ 305, 306
  asphalt.................................. 282
    exports to............................. 285
  cement............................... 403–404
    exports to............................. 402
    imports from........................... 403
  corundum................................. 383
  diamonds, imports from................... 169
  feldspar................................. 378
  fluorspar...................... 357, 362, 366
  graphite................. 182, 185, 314, 315, 316
  grindstones.............................. 383
  gypsum............................... 108–109
    exports to......................... 107–108
  lime, exports to......................... 416
  magnesite............................ 228–229
  mica................................ 272, 274
    exports to............................. 273
  mineral waters, imports.................. 122
  natural sodium sulphate.................. 72
  pebbles for grinding..................... 386
  phosphate rock, exports to......... 216–217, 218
  potash, imports from..................... 86
  pyrites.................................. 542
  salt, imports from....................... 245
    exports to............................. 246
  sand and gravel, exports to.............. 160
  scythestones............................. 383
  slate, exports to................... 373, 374
  sodium compounds, exports to.......... 49, 59
  stone, exports to........................ 424
    imports from........................... 425
  strontium salts, use of.................. 98
  sulphur, exports to...................... 539
  talc, imports from....................... 268
Canary Isles, cement, exports to............. 402
Cape Colony, asbestos........................ 306
Cement dust, potash from............... 78–80, 401
Cement industry, by Ernest F. Burchard.. 387–404
  exports..................... 394, 397, 402–403
  foreign trade........................ 402–404
  imports............................. 394, 403
  introduction............................. 387
  natural............................. 388, 401
    production by States................... 401
  Portland............................ 388, 397
    Canada......................... 402, 403–404
    consumed per capita................ 394–396
    consumption, domestic........ 393–394, 397
    increase, percentage of................ 390

Page.

Cement industry, Portland, local supplies. 396–397
manufacturing conditions. 399, 401
capacity. 400
kilns. 399
kiln fuels. 399
plants. 399
recovery of potash. 401
potash from. 78–80, 401
prices, at factory. 390, 398
at market. 398
by States. 390
production and shipments. 388–393, 397
by districts. 391–393
Lehigh district. 392–393
by States. 390
shipments, by States. 390
stocks, at mills. 393
by districts. 391
by States. 390
value. 390
production. 387–388
puzzolan. 388–401
production by States. 401
total marketed production. 388
1818–1919. 388
value. 388
Central America, lime, exports to. 416
stone, exports to. 424
Cerium. 28–32
Ceylon, graphite. 182, 196, 312, 314, 316
mica. 274
monazite sand. 10, 13, 14
thorianite. 15–16
thorite. 14–15
zirconium minerals. 18–19, 25
Chile, asphalt. 285
cement, exports to. 402
graphite. 186, 315
gypsum, exports to. 107
potash, imports from. 86
salt, exports to. 247
slate, exports to. 373
sodium compounds, exports. 50
sodium nitrate. 67
stone, exports to. 424
sulphur, exports to. 539
China, asbestos. 306
asphalt. 286
cement, exports to. 402
graphite. 315
gypsum, exports to. 107
mica. 273, 274
potash. 86
salt, imports from. 245
sand and gravel, exports to. 160
sodium compounds, exports to. 50
stone, exports to. 424
sulphur, exports to. 539
imports from. 425
Christmas Island, phosphate rock. 218
Chosen (Korea), graphite. 182, 197, 314, 316
sodium compounds, exports to. 50
Clay. See note, p. iv.
Coal. See note, p. iv.
Coke (*see* Gas coke, also note, p. iv). 492–496
Colombia, asbestos. 305
asphalt. 282, 285
cement, exports to. 402
emerald. 176–177
graphite. 315
lime, exports to. 416
potash. 86
salt, exports to. 247
slate, exports to. 373
sodium compounds, exports to. 50
stone, exports to. 424
sulphur, exports to. 539
Colorado, architectural stone. 328
artificial gas. 466, 471, 473, 475, 484, 487, 493, 498, 501, 505
basalt. 431
cement, Portland. 390, 395, 397
concrete blocks. 328
crushed stone. 430, 433, 442, 451, 454
fluorspar. 352, 353
stocks. 355
furnace flux. 444
granite. 426, 429
graphite. 310, 312

Colorado, gypsum. 101, 102, 105
lime. 406, 410, 415
limestone. 435, 442
marble. 434
mica. 269, 274
mineral waters. 116, 119, 125
potash. 81
precious stones. 168
pyrites. 541
quartz. 380
sand and gravel. 157–158
sandstone. 446, 450
stone. 423
Concrete. 430, 433, 442, 451, 454, 455
Concrete blocks. 328, 331
Concrete brick. 329, 331
Concrete stone and blocks, by G. F. Loughlin and M. E. McCaslin. 325–333
aggregate, by districts. 333
condition of industry. 326
definition of terms. 325
introduction. 325
production. 326–332, 429, 451, 454, 455
architectural stone. 328, 330–331
concrete blocks. 328, 331
concrete brick. 329, 331
miscellaneous concrete products. 329, 332
silo blocks and staves. 329, 332
value. 327, 329
average. 328–329
Connecticut, architectural stone. 328
artificial gas. 466, 471, 473, 484, 487, 493, 498, 501, 505
basalt. 431, 433
cement. 395, 397
concrete blocks. 328
crushed stone. 430, 433, 442, 451
diatomaceous earth. 382, 385
feldspar. 377
furnace flux. 444
granite. 426, 429
lime. 406, 410, 413, 415
limestone. 435, 442
mineral waters. 116, 119, 125
quartz. 380
sand and gravel. 157–158
sandstone. 446, 450
stone. 423
Coons, A. T., paper on abrasive materials. 381–386
lime. 405–417
slate. 369, 375
stone. 419–455
Corundum and emery. 381–384
Canada. 384
imports. 381, 384
production. 384
Costa Rica, cement, exports to. 402
phosphate rock, exports to. 217
salt, exports to. 246
sodium compounds, exports to. 49
Cottrell, K. W., paper on asphalt. 279–297
on peat. 41–46
Crocker, William, paper on agricultural gypsum and its uses. 109–111
Crushed stone. 420, 426, 430, 431, 433, 436, 442, 446, 451, 452, 453, 454, 455
prices. 455
production, by kinds. 455
Cryolite. 366–367
imports and prices (*see also* Fluorspar and cryolite). 367
Cuba, asbestos. 305
asphalt. 282, 287
exports to. 285
cement, exports to. 402
diamonds, imports from. 169
graphite. 375
gypsum, exports to. 107–108
lime, exports to. 416
mineral waters, imports from. 122
phosphate rock, exports to. 216–217
potash. 86
pyrites, imports from. 542
salt, exports to. 246
imports from. 245
sand and gravel, exports to. 160
slate, exports to. 373
sodium compounds, exports to. 50

	Page.
Cuba, stone, exports to	424
imports from	425
sulphur, exports to	539
Curaçao, phosphate rock	218
Czecho-Slovakia, graphite	189–191
Curbstone	420–450

D.

Davis, Hubert W., paper on fluorspar and cryolite	349–368
Delaware, artificial gas	466, 471, 473, 484, 487, 493, 501
cement	395, 397
crushed stone	430
granite	426–430
lime, consumption	415
lithopone	343
mineral waters	118
sand and gravel	157–158
stone	423, 426–430
Denmark, asphalt	285
diamonds, imports from	169
flint pebbles, imports	386
gypsum, exports to	107
peat	44–45
phosphate rock	216–217
sodium compounds, exports to	49
stone, exports to	424
sulphur, exports to	539
Diamond	165, 169, 170–176
(*See also* Gems and precious stones.)	
Arkansas	170–171
Brazil	169, 176
condition of industry	171
diamond cutting in the United States	171
England	169, 176
Gold Coast Colony	175–176
imports	169
prices	171, 172, 176
Scotland	176
South Africa	169, 171–175
control of South African diamonds	174–175
De Beers mines, production	172
Natal	171
new diamond district north of Kimberley	173
notes on diamond mining	175
operations on Vaal River	173–174
Premier mine, production	173
prices	172
sales in 1918–1919	171–172
Diatomaceous earth (*see also* Abrasives *and* Silica)	379
imports	381
production	379, 382, 384, 385
Diller, J. S., paper on asbestos	299–307
talc and soapstone	265–268
District of Columbia, artificial gas	466, 471, 473, 484, 487, 501
cement	395, 397
crushed stone	430
granite	426, 429
lime, consumption	415
mineral waters	116, 119, 126
sand-lime brick	238
stone	423
Dominican Republic, cement, exports to	402
asphalt	285
lime, exports to	416
salt, exports to	246
imports from	245
slate, exports to	373
sodium compounds, exports to	50
stone, exports to	424
sulphur, exports to	539
Dutch East Indies, asphalt	286
cement, exports	402
graphite	315
gypsum, exports to	107
lime, exports to	416
potash	86
salt, exports to	247
sodium compounds, exports to	51
stone, exports to	424
sulphur, exports to	539
Dutch Guiana, cement, exports to	402
Dutch West Indies, asphalt	282
cement, exports to	402
phosphate rock	218
Dutch West Indies, salt, imports from	245
exports to	247
stone, exports to	424

E.

Ecuador, asphalt, exports to	285
cement, exports to	402
sodium compounds, exports to	50
stone, exports to	424
sulphur, exports to	539
Egypt, phosphate rock	218
sodium compounds, exports to	51
Ellis, A. J., paper on mineral waters	115–149
Emerald, Colombia	176–177
Emery (*see also* Corundum and emery)	382, 384
imports	382
production	384
Engine sand, production	151, 157–158
England, asbestos	305
asphalt	282, 285
cement, exports to	402
diamond, exports from	169, 176
fuller's earth	260–262
graphite	315
gypsum, exports to	107–108
lime, exports to	416
magnesite	228
mica	272, 273
pebbles for grinding	386
phosphate rock, exports to	216–217, 219
potash	86
salt, imports from	245
sand and gravel, exports to	160
slate, exports to	373
stone, exports to	424
imports from	425
strontium	96
sulphur, exports to	539
imports from	538
Esthonia, peat	42
Exports, asbestos	306
asphalt	284–285
by countries	285
cement	394, 397, 402–403
graphite	314–315
gypsum	106–108
lime	416
by countries	416
marble	423–424
mica	273
mineral waters	122
phosphate rock	215–217
potash	81
salt	246–248
sand and gravel	160
slate	373–374
sodium compounds	49–52, 59, 65, 76
stone	423–424
sulphur	538–539
sulphuric acid	545–546

F.

Feldspar, by L. M. Beach	377–378
prices	377
prodution, by States	377
in Canada	378
Fertilizers of all kinds, imported	84, 86
peat	41
Filter sand	151, 157–158
Finland, sulphur exports to	539
Fire sand, production	151, 157–158
Flagstone	420–450
Flint pebbles, imports (*see also* Silica)	379, 386
Florida, architectural stone	328
artificial gas	466, 471, 473, 484, 487, 493, 498, 501, 505
cement	395, 397
concrete blocks	328
concrete brick	329
crushed stone	442, 454
fuller's earth	258
lime	406, 410, 413, 415
limestone	435, 442
mineral waters	116, 119, 126
monazite sand	6
peat plants	45, 46
phosphate rock	212–213
exports	215–217
sand and gravel	157–158

Page.

Florida, sand-lime brick 238
stone 423
zircon 19–20
Fluorspar and cryolite, by Hubert W. Davis 349–368
bibliography 367
consumption 357–359
curve of production of fluorspar, 1883–1919, and of imports, 1910–1919 354
curve showing average prices of fluorspar at mines, 1883–1919 355
imports 355–357
in foreign countries, Argentina 360
Australia 360–362, 366
New South Wales 360, 366
Queensland 362, 366
Canada 357, 362–363, 366
France 366
Germany 363
Great Britain 357, 364–365
Italy 366
Mexico 365
Norway 366
Spain 366
Introduction 349
mined and shipped 349–354
by States 351–353
optical fluorite 366
prices 349, 352, 355, 357, 360
shipped by uses 360
open-hearth steel 359
stocks 355
Foreign graphite, by Arthur H. Redfield 181–210
analyses 202, 207, 208
bibliography 209–210
Africa 203–205
British East Africa (Kenia Colony) 203
Madagascar 203–205
Union of South Africa 205
Asia 196–202
Ceylon 196–197
Chosen (Korea) 197–199
Map showing location of graphite deposits in Chosen 198
French Indo-China 199–201
map showing location of graphite deposits in French Indo-China 200
Japan 201–202
Australasia 205–208
Australia 205–206
New Zealand 206–208
map showing location of graphite deposits in New Zealand 207
Europe 186–196
Austria 186–189
map showing location of graphite deposits in Austria and Czecho-slovakia 187
Czecho-Slovakia 189–191
France 192
Germany 193–194
Italy 194–195
Norway 195–196
Spain 196
Sweden 196
introduction 181
North America 185–186
Canada 185
Mexico 185–186
South America 186
Brazil 186
Chile 186
Uruguay 186
World's production 181–184
by countries, 1913–1919 182
graph sowing production of graphite in principal countries, 1910–1919 183
value of world's production of natural graphite, 1913–1919 184
average exchange values of foreign coins cited, 1913–1919 184
France, asbestos 305
asphalt 285, 287
cement, exports to 402
diamonds, imports from 169
flint pebbles 386
fluorspar 366
graphite 182, 192, 315, 316

Page.

France, mica, exports to 273
mineral waters, imports 122
pebbles for grinding 386
phosphate rock, exports to 217, 218, 219
potash 86
pyrites, imports from 542
salt, imports from 245
sodium compounds exports to 49
stone exports to 424
imports from 425
sulphur, exports to 539
talc, imports from 268
French Africa, asphalt 285
cement 402
natural soda 62
potash 86
salt, exports to 247
sulphur, exports to 539
French East Indies, asphalt 286
salt 247
French Guiana, cement 402
lime, exports to 416
phosphate rock 218
French Indo-China, graphite 182, 199, 316
French Oceania, cement 402
lime, exports to 416
sodium compounds, exports to 51
French West Indies, cement, exports to 402
salt, exports to 246
imports from 245
sodium compounds, exports to 50
stone, exports to 424
sulphur, exports to 539
Fuel briquetting, by F. G. Tryon 33–36
curve showing production, 1907–1919 33
number of plants 34
production of fuel briquets 34
plants by States 34, 36
raw materials and binders 35–36
value 35
Fuller's earth, by Jefferson Middleton 257–264
bibliography 262–264
general conditions 257
imports 259–260
in Great Britain 260–262
occurrence 257
prices 258–259, 260
production 258–259
diagram showing production, total value, and average selling price, 1895–1919 259
uses 258
Furnace flux, by States 444
Furnace sand, production 151, 157–158

G.

Gaddolinite 30–31
Ganister 420, 446, 450
Garnet (abrasive), production 384
Gas, artificial (*see* Artificial gas).
Gas coke 492–496
Gas, natural. See note, p. IV.
Gasoline from natural gas (*see* Natural-gas gasoline).
Gems and precious stones, by B. H. Stoddard 165–180
bibliography 179
corundum 170
diamond 169, 170–176
emerald 176–177
imports 168–170
jet 177
opal 177–178
producers 166–167
production, by varieties 165
quartz 178
rank of States 168
topaz 179
tourmaline 179
value 165–166
Georgia, artificial gas 466, 471, 473, 484, 487, 493, 498, 501, 505
asbestos 299, 304
barytes 335–336, 338
cement, Portland 390, 395, 397
concrete blocks 328
crushed stone 430, 442, 454
fuller's earth 258

Page.
Georgia, furnace flux........ 444
glass sand........ 162
granite........ 426, 429
lime........ 415
limestone........ 435, 442
marble........ 434
mica........ 269–270, 274
mineral waters........ 116, 119, 127
potash........ 79, 81
pyrites........ 541
sand and gravel........ 157–158
sand-lime brick........ 238
stone........ 423
talc........ 265
German Africa (former), cement, exports to. 402
German Oceania (former), salt, exports to.. 247
Germany, asbestos........ 305
asphalt........ 285, 287
fluorspar........ 363
graphite........ 182, 193, 314, 316
magnesite........ 228
mineral waters, imports........ 122
peat........ 42
phosphate rock, exports to........ 216
potash salts, deposits........ 77, 87
imports from........ 86
prices........ 77
salt, imports from........ 245
sodium compounds, exports to........ 49
stone, imports from........ 425
Glass sand (*see also* Sand and gravel)........ 151, 157–158, 160–162
localities........ 162
price........ 160–162
production........ 151, 157–158
by States........ 161
Glauconite, potash from........ 79
Gold Coast Colony, diamond........ 175–176
Granite (*see also* Stone industry).. 419, 425, 426–430
crushed stone........ 426, 430, 455
imports........ 425
sold, by States, and uses........ 426, 429–430
value, by States........ 426
by uses........ 426
Graphite, by L. M. Beach........ 309–324
diagram showing production of crystalline graphite in United States........ 311
diagram showing production of manufactured graphite in United States 313
diagram showing production of graphite in principal countries........ 317
exports........ 314–315
imports........ 313–314
introduction........ 309
literature........ 322–324
prices........ 315–316
production........ 309–313
amorphous........ 309, 312
crystalline........ 309, 310–312
manufactured........ 313
in principal countries........ 316, 317
world's production........ 316
(*see also* Foreign graphite.)
Graphite mining in Pennsylvania, by F. Bascom........ 318–322
map showing location of graphite mines and mills in Chester County, Pa.. 318
Gravel (*see also* Sand and gravel).
Great Britain, asbestos........ 305
asphalt, exports to........ 285
cement, exports to........ 402
diamond........ 169, 176
flint pebbles........ 386
fluorspar........ 357, 364–365, 366
fuller's earth........ 260–262
graphite, exports to........ 315
gypsum, exports to........ 107–108
lime, exports to........ 416
magnesite........ 228
mica, exports to........ 273
phosphate rock, exports to........ 216–217, 219
potash........ 86
salt, imports from........ 245
sand and gravel, exports to........ 160
stone, exports to........ 424
imports from........ 425
sulphur, exports to........ 539
imports from........ 538
talc........ 268
Great Salt Lake, potash........ 79
Greece, cement, exports to........ 402
gypsum, exports to........ 107
potash........ 86
slate, exports to........ 373
sodium compounds, exports to........ 49
stone, imports from........ 425
sulphur, exports to........ 539
Greenland, cryolite........ 366–367
Greensand........ 79
Grinding and polishing sand........ 151, 157–158
Grindstones........ 382–383
imports........ 383
production........ 383
by States........ 383
Canadian........ 383
Guatemala, cement, exports to........ 402
gypsum, exports to........ 107
lime, exports to........ 416
mica........ 273, 274
salt, exports to........ 246
sodium compounds, exports to........ 49
Gypsum, by R. W. Stone........ 99–113
agricultural........ 101, 102, 103, 109–112
business notes........ 104
disposition as to uses........ 102
exports........ 106–108
Gypsum Industries Association........ 104–105
imports........ 105–106
increase or decrease, in per cent........ 100
Keenes cement........ 102, 103
manufacturers of gypsum........ 112
mine and mill data........ 105
prices........ 102, 103
production........ 99–104
by States........ 101
by uses........ 102–104
in Canada........ 108–109
uses........ 102–104
blocks and tile........ 102
calcined........ 102
by States........ 101, 102, 105
dental plaster........ 102, 103
glass factories........ 102, 103
miscellaneous........ 102
plaster board........ 102, 103–104
exports of........ 107–108
Portland cement........ 101, 102, 103
wall plaster........ 102, 103
uncalcined........ 101, 102
value........ 99

H.

Haiti, asphalt........ 285
cement, export to........ 402
salt, exports to........ 247
Hawaiian Islands, basalt........ 431, 433
cement........ 395, 397
crushed stone........ 433
lime........ 406, 410, 413, 415
limestone........ 435
salt........ 241
sand and gravel........ 157–158
stone........ 423
Hicks, W. B., and Nourse, M. R., paper on potash........ 77–94
Holland (*see* Netherlands).
salt........ 248
Honduras, cement, exports to........ 402
gypsum, exports to........ 107
lime, exports to........ 416
salt, exports to........ 246
slate, exports to........ 373
sodium compounds, export to........ 49
Hones........ 384
Hongkong, asbestos........ 305
asphalt........ 286
cement, exports to........ 402
gypsum, exports to........ 107
potash........ 86
salt, exports to........ 247
imports from........ 245
slate, exports to........ 373
sodium compounds, exports to........ 51
sulphur, exports to........ 539
Hydrated lime........ 413
production........ 413
sales, by States........ 413
by uses........ 413

I.

	Page.
Iceland, asbestos	305
asphalt	285
cement, exports to	240
salt, exports to	246
stone, exports to	424
Ichthyol	283–284
Idaho, artificial gas	466, 471, 484, 487, 493, 498
basalt	431, 433
cement	395, 397
crushed stone	433, 442, 451, 454
diatomaceous earth	382, 385
furnace flux	444
granite	426
lime	406, 410, 413, 415
limestone	435, 442
mica	274
monazite sand	614
phosphate rock	212, 215
salt	241
sand and gravel	157–158
sand-lime brick	238
sandstone	446, 450
stone	423
topaz	179
Illinois, architectural stone	328
artificial gas	466, 471, 473, 475, 484, 487, 493, 498, 501, 505
asphalt	281
barium chemicals	344–345
barytes	335, 339
building sand	163
cement, Portland	390, 395, 397
natural	401
concrete blocks	328
concrete brick	329
crushed stone	442, 451
fluorspar	352, 353
stocks	355
furnace flux	444
glass sand	157, 161–162
lime	406, 410, 413, 415
limestone	435, 442
lithopone	343
mineral waters	116, 119, 127
molding sand	163
natural-gas gasoline	520, 521, 523, 525
plat plants	45, 46
pyrites	541
sand and gravel	152, 157–159
sandstone	446, 450
silo blocks and stones	329
stone	423
tripoli	382, 385
Imports, abrasives	381
asbestos	305–306
asphalt	282–284
barium products	346–347
barytes	336
burrstones and millstones	381, 383
cement	394, 403
corundum	381, 384
cryolite	367
diamond	169
diamond dust and bort	169, 381
diatomaceous (infusorial) earth	379, 381, 385
emery	381, 384
flint pebbles	379, 386
fluorspar	357
fuller's earth	259–260
gems and precious stones	169
granite	425
graphite	313–314
grindstones	381, 383
gypsum	105–106
hones	381, 384
ichthyol	284
kainit	84
lime	416
lithohone	346
magnesite	228–229
manure salts	86
marble	425
mica	272–273
millstones	381, 383
mineral waters	122
monazite sand	4
mosaic cubes	425
oilstones and scythestones	381, 384
onyx	425
Imports, ozokerite	283
pearls	169, 170
peat	45
pebbles for grinding	379, 386
potash	81–86
pulpstones	381, 383
pumice	381
pyrites	542
rottenstone	381, 385
salt	244–246
sand and gravel	160
silica	379, 386
slate	375
sodium nitrate	48
sodium salts	48, 59, 65, 76
stone	425
strontium	96
sulphur	537–538
sulphuric acid	545
talc	267–268
thorium nitrate	4
thorium oxide	5
tripoli	379, 381, 384
whetstones and oilstones	381, 384
zirconium ore	28
India, graphite	316
mica	272, 274
monazite sand	6, 8–9, 13, 14
potash, imports from	86
Indiana, architectural stone	328
artificial gas	466, 471, 473, 475, 484, 487, 493, 498, 501, 505
building sand	163
cement, natural	401
Portland	390, 395, 397
potash from	401
concrete blocks	328
concrete brick	328
crushed stone	442, 451
furnace flux	444
glass sand	162
lime	406, 410, 413, 415
limestone	435, 442
mineral waters	116, 119, 128
molding sand	163
oilstones	382
potash	81
sand and gravel	157–159
sand-lime brick	238
sandstone	446, 450
silo blocks and staves	329
stone	423
Infusorial (diatomaceous) earth. (*See also* Abrasives *and* Silica.)	
Insley, Herbert, paper on lithium minerals	37–40
on salt, bromine, and calcium chloride	239–256
on mica	269–277
Iowa, architectural stone	328
artificial gas	466, 471, 473, 474, 484, 487, 493, 498, 501, 505
cement, Portland	390, 395, 397
concrete blocks	328
concrete brick	329
crushed stone	442
furnace flux	444
gypsum	101, 103, 104, 105
lime	406, 410, 415
limestone	435, 442
mica	274
mineral waters	116, 119, 128
potash	81
sand and gravel	157–159
sandstone	446
silo blocks and staves	329
stone	423
Ireland, phosphate rock, exports to	217
Italian Africa, potash	86
Italy, abestos	305
asphalt	285, 287
cement, exports to	402
fluorspar	366
graphite	182, 194, 314, 315, 316
magnesite	228
mineral waters, imports	122
pebbles	386
phosphate rock, exports to	217
potash	86
sodium compounds, exports to	49
stone, exports to	424

Page.

Italy, stone, imports from 425
  sulphur 539, 540
    imports from 540
  talc, imports from 268

J.

Jamaica, cement exports to 402
  salt, exports to 246
  sodium compounds, exports to 49
  stone, exports to 424
Japan, asbestos 305
  asphalt 286, 287
  cement, exports to 402
    imports from 403
  graphite 182, 201, 315, 316
  gypsum, exports to 107–108
  mineral waters, imports 122
  pebbles 386
  phosphate rock 218
  potash 86
  salt, exports to 247
    imports from 245
  sand and gravel, exports to 160
  sodium compounds, exports to 51
  stone, exports to 424
    imports from 425
  sulphur, imports from 538
    exports to 539
    production 539–540
Jet, Utah 177

K.

Kainit, imports 84
Kansas, architectural stone 329
  artificial gas ... 466, 471, 473, 484, 487, 493, 498, 501
  cement, natural 401
    Portland 390, 395, 397
      potash from 78, 401
  crushed stone 442
  gypsum 101, 105
  lime 406, 415
  limestone 435, 442
  mineral waters 116, 119, 129
  natural-gas, gasoline 520, 521, 525
  pumice 382
  salt 241
  sand and gravel 157–159
  sandstone 446
  silo blocks and staves 329
  stone 423
Keene's cement 102, 103
Kelp, potash from 79, 80, 102, 103
Kentucky, architectural stone 328
  artificial gas 466,
    471, 473, 475, 484, 487, 493, 498, 501
  asphalt 281
  barytes 335, 339
  cement, Portland 390, 395, 397
    potash, from 78
  concrete blocks 328
  crushed stone 442, 451
  fluorspar 352, 353
    stocks 355
  furnace flux 444
  glass sand 162
  graphite 311
  hones 382
  lime 406, 410, 415
  limestone 435, 442
  marble 434
  mineral waters 116, 119, 129
  natural-gas, gasoline 520, 521, 523, 526
  oilstones 383
  phosphate rock 212, 214
  sand and gravel 157–159
  sandstone 446, 450
  stone 423
Kongo, Belgian, cement, exports to 402
  salt, exports to 247
Korea (Chosen), graphite 182, 197, 314, 316
  salt, exports to 247
Kwantung, asphalt, exports to 286
Labrador, cement, exports to 402
  lime, exports to 416
  salt, exports to 246
  slate, exports to 373
  stone, exports to 424
Lampblack 504
Lanthanum 31
  (*See* Rare-earth minerals.)

Page.

Lehigh district, cement 392–393
Leucite rocks, potash 79
Liberia, cement, exports to 402
Light oils and drip or holder oils 508–510
Lime, by G. F. Loughlin and A. T. Coons. 405–418
  calcareous marl 418
  consumption, by States 416
    interstate shipments 416
    per capita 416
  exports 417
    by countries 417
  hydrated lime 414
    production 414
      by States 414
      by uses 414
      hydrating plants 414
  imports 417
  oyster shell lime 418
  prices 405, 406–407, 414, 418
  rank of States, by quantity 406–407
    by value 406–407
  sold 405–414
    by States 406–407, 408–412
    by uses 407, 408–412
  uses 408, 411–414
    agriculture 408, 411–414
    building 408, 411–414
    chemical works 408, 411–414
    dealers 408, 412–414
    glass factories 408, 411–414
    metallurgy 408, 411
    paper mills 408, 411–414
    sugar factories 408, 411–414
    tanneries 408, 411–414
    other uses 408, 4122–414
  value 405, 407, 412
Limestone (*see also* Stone) 419, 435–445
  Bedford oolitic 420
  furnace flux 420–421, 436, 444
  production, by States 435, 442–4445
  uses, agriculture 436, 442
    alkali works 436
    building 436, 442
    crushed stone 436, 442
    curbing 436, 442
    flagging 436
    flux 436, 442
    glassworks 436, 442
    paper mills 436, 442
    paving 436, 442
    riprap 436, 442
    rubble 436, 442
    sugar factories 436, 442
  value 419
    by States 435, 445
    by uses 435, 445
Lithium minerals, by H. Insley 37–40
  analyses 39
  bibliography 40
  occurrence and distribution 39
  prices and supplies 37–38
  production 37
  properties 38
  sources 38
  uses 38
Lithopone, imports 346
  prices 341, 344
  production 337, 343
Loughlin, G. F., paper on concrete stone and
    blocks 325–333
  lime 405–417
  slate 369–375
  stone 419–455
Louisiana, artificial gas 466,
    471, 473, 484, 487, 493, 498, 501
  cement 395, 397
  concrete block 328
  concrete brick 329
  crushed stone 442
  glass sand 162
  lime, consumption 415
  limestone 435, 442
  mineral waters 116, 119, 130
  natural gas, gasoline 520, 521, 523, 526–527
  salt 240, 241
  sand and gravel 157, 159
  sand-lime brick 238
  stone 423
  sulphur 536

M. Page.

Madagascar, cement, exports to ... 402
graphite ... 182, 203, 312, 314, 316
mica ... 274
thorianite ... 15
Magnesite, by Charles G. Yale and Ralph W. Stone ... 227–235
condition of industry ... 229–230
imports ... 228–229
mines and counties ... 230–234
prices ... 231
producers ... 235
production ... 227–228
tariff ... 230
uses ... 234–235
value ... 227
Maine, artificial gas ... 466, 471, 473, 484, 487, 493, 498, 501, 505
cement ... 395, 397
concrete blocks ... 328
concrete brick ... 329
crushed stone ... 430, 442
feldspar ... 377
granite ... 426, 429
lime ... 406, 410, 413, 415
limestone ... 435, 442
lithium minerals ... 37
mica ... 274
mineral waters ... 116, 119, 130
quartz ... 178, 380
precious stones ... 168, 177, 179
sand and gravel ... 157–159
slate ... 370, 371
stone ... 423
tourmaline ... 197
Makatea Island, phosphate rock ... 218, 224
Malay Peninsula, monazite sand ... 9, 13, 14
Manure salts, imports ... 86
Marble (*see also* Stone) ... 419, 434
exports ... 423–424
imports ... 425
onyx marble ... 425
prices ... 425
production, by States ... 434
value ... 419, 434
by kinds ... 419
by States ... 434
by uses ... 434
Marl, calcareous ... 417
Maryland, artificial gas ... 466, 471, 473, 475, 484, 487, 493, 498, 501
asbestos ... 299, 304
basalt ... 431, 433
cement, Portland ... 390, 395, 397
potash from ... 401
concrete blocks ... 328
crushed stone ... 430, 433, 442, 451
feldspar ... 377
furnace flux ... 444
glass sand ... 167
granite ... 426, 429
lime ... 406, 410, 413, 415
limestone ... 435, 442
lithopone ... 343
marble ... 434
millstones ... 382
mineral waters ... 116, 119, 131
oyster shell lime ... 417
potash ... 81
quartz ... 380
sand and gravel ... 157, 159
sandstone ... 446, 450
slate ... 370–371
stone ... 423
talc ... 265
Marysvale, Utah, alunite ... 79
Massachusetts, architectural stone ... 328
artificial gas ... 466, 471, 473, 484, 487, 493, 498, 501, 505
basalt ... 431, 433
cement ... 390, 395, 397
concrete block ... 328
concrete brick ... 329
crushed stone ... 430, 433, 442, 451, 454
fuller's earth ... 258
furnace flux ... 444
glass sand ... 162
granite ... 426, 429
lime ... 407, 410, 413, 415
limestone ... 435, 442

Page.

Massachusetts, lithium minerals ... 37
marble ... 434
mineral waters ... 116, 119, 132
peat ... 42
peat plants ... 45, 46
potash ... 81
quartz ... 380
sand and gravel ... 157–159
sand-lime brick ... 238
sandstone ... 446, 450
stone ... 423
talc ... 265
McCaslin, M. E., paper on concrete stone and blocks ... 325–333
Mexico, asphalt ... 281–282, 285, 287
cement, exports to ... 402
graphite ... 182, 185, 314, 315, 316
gypsum, exports to ... 107
lime, exports to ... 416
magnesite ... 228
mica ... 273
opal ... 178
phosphate rock, export to ... 217
potash ... 86
salt, exports to ... 246
imports from ... 245
sand and gravel, exports to ... 160
slate, exports to ... 373
sodium compounds, exports to ... 49, 59
stone, exports to ... 424
imports from ... 425
sulphur, exports to ... 539
sulphuric acid, exports to ... 546
Mica, by Herbert Insley ... 267–277
distribution ... 274
exports ... 273
forms and classification ... 275
imports ... 272–273
nature and occurrence ... 273–274
physical properties ... 275
prices ... 271
production ... 269–270
uses ... 277
value ... 269
Michigan, architectural stone ... 328
artificial gas ... 466, 471, 473, 474, 475, 484, 487, 493, 498, 501, 505
basalt ... 431, 433
bromine ... 249
calcium chloride ... 255
cement, Portland ... 390, 395, 397
concrete blocks ... 328
concrete brick ... 329
crushed stone ... 433, 442, 451
furnace flux ... 444
gems and precious stones ... 165
glass sand ... 162
graphite ... 310
grindstones ... 382, 383
gypsum ... 101, 102, 105
lime ... 407, 410, 413, 415
limestone ... 435, 442
marble ... 434
mica ... 274
mineral waters ... 116, 119, 133
potash ... 81
precious stones ... 168
quartz ... 380
salt ... 241
salt and gravel ... 152, 157–159
sand-lime brick ... 238
sandstone ... 446, 450
silo blocks and staves ... 329
stone ... 423
Middleton, Jefferson, paper on fuller's earth ... 257–264
sand-lime brick ... 237–238
Millstones and burrstones ... 382
imports ... 381–382
production ... 382
Mineral waters, by Arthur J. Ellis ... 115–149
condition of trade ... 119–120
exports ... 122
imports ... 122
mineral water trade in 1919 ... 117–122
number of springs ... 116
output and value ... 117–119
percentage of sales, by States ... 118
price per gallon ... 118, 119
production, by States ... 120

Page.
Mineral waters, production, increase or decrease ... 120
range of price ... 120-121
scope of report ... 115
soft drinks ... 121
source of mineral water ... 117
trade, by States ... 123-149
uses of mineral water ... 116
value ... 119-120
Mineral wax, imports ... 283
Minnesota, architectural stone ... 328
artificial gas ... 466, 471, 473, 474, 475, 484, 487, 493, 498, 501, 505
basalt ... 431, 433
cement, natural ... 401
Portland ... 390, 395, 397
concrete blocks ... 328
concrete brick ... 329
crushed stone ... 430, 433, 442, 451
furnace flux ... 444
granite ... 426, 429
lime ... 407, 410, 413, 415
limestone ... 435, 442
mica ... 274
mineral waters ... 116, 119, 133
pebbles for grinding ... 382
sand and gravel ... 157-159
sand-lime brick ... 238
sandstone ... 446, 450
stone ... 423
tube-mill lining ... 382
Miquelon, cement, exports to ... 402
Miscellaneous stone (*see also* Stone) ... 419, 452-454
Mississippi, artificial gas ... 466, 471, 473, 484, 487, 493, 498, 505
cement ... 395, 397
concrete blocks ... 328
lime, consumption ... 415
limestone ... 435, 442
mineral waters ... 116, 119, 134
sand and gravel ... 157-159
stone ... 423
Missouri, architectural stone ... 328
artificial gas ... 466, 471, 473, 474, 475, 484, 487, 493, 498, 501, 505
barytes ... 335, 339
cement, Portland ... 390, 395, 397
potash from ... 401
concrete blocks ... 328
concrete brick ... 329
crushed stone ... 430, 442
fuel briquetting ... 34, 36
furnace flux ... 444
glass sand ... 161, 162
granite ... 426, 429
lime ... 407, 410, 413, 415
limestone ... 435, 442
lithopone ... 343
marble ... 434
mineral waters ... 116, 119, 135
peat ... 46
potash ... 81
pyrites ... 541
sand and gravel ... 157-159
sandstone ... 446
silo blocks and staves ... 329
stone ... 423
tripoli ... 382, 385
Molding sand, production ... 151, 157-158, 163
price ... 160, 163
Molasses, distillery slop, potash from ... 79, 80
Monazite (*see also* Thorium minerals) ... 2-18
Montana, artificial gas ... 466, 471, 473, 484, 487, 493, 498, 501
cement, Portland ... 390, 395, 397
crushed stone ... 430, 442, 451
furnace flux ... 444
granite ... 426, 429
graphite ... 310
gypsum ... 101, 104, 105
lime ... 407, 410, 415
limestone ... 435, 442
mica ... 274
mineral waters ... 116, 119, 135
precious stones ... 168, 170
quartz ... 380
sand and gravel ... 157-159
sandstone ... 446, 450
stone ... 423
Moravia, graphite ... 316
Morocco, phosphate rock ... 222, 223
Mysore, monazite sand ... 9

N.

Naphthalene ... 510-511
Natal, asbestos ... 306
diamond ... 171
Natural cement. (*See* Cement.)
Natural-gas gasoline, E. G. Sievers ... 519-534
economic aspects ... 521-524
diagram showing quantity and value of natural-gas gasoline produced in the United States, 1911-1919 ... 422
diagram showing natural-gas gasoline production in the United States, by States, 1911-1919 ... 423
industry, by States ... 524-534
California ... 524
Illinois ... 525
Kansas ... 525
Kentucky ... 526
Louisiana ... 526-527
New York ... 527
Ohio ... 527-528
Oklahoma ... 529-530
Pennsylvania ... 530-531
Texas ... 532
West Virginia ... 533-534
Wyoming ... 534
prices ... 520, 521
production ... 519-521
by principal methods of manufacture, by States ... 521
by compression and vacuum ... 521
by absorption ... 520
statistics of natural-gas gasoline produced, 1911-1919 ... 520
unblended natural-gas gasoline produced, by States ... 520
Nauru Island, phosphate rock ... 218, 223-224
Nebraska, architectural stone ... 328
artificial gas ... 466, 471, 473, 484, 487, 493, 498, 501
cement, Portland ... 390, 395, 397
concrete stone ... 328
concrete blocks ... 329
crushed stone ... 442, 451
furnace flux ... 444
lime, consumption ... 415
limestone ... 435, 442
mineral waters ... 116, 119, 136
natural soda ... 62
potash ... 78, 80, 81
pumice ... 382
sand and gravel ... 157-159
sandstone ... 446, 450
silo blocks and staves ... 329
stone ... 423
Netherlands, asphalt, exports to ... 285
cement, exports to ... 402
diamonds, imports from ... 169
gypsum, exports to ... 107
mineral waters, imports ... 122
phosphate rock, exports to ... 216-217
potash ... 86
salt ... 248
stone, exports to ... 424
imports from ... 425
sulphur, exports to ... 539
Nevada, artificial gas ... 466, 474
barytes ... 335, 340
cement ... 395, 397
crushed stone ... 442
diatomaceous earth ... 382, 385
fluorspar ... 353
stocks ... 355
fuller's earth ... 258
graphite ... 310, 312
gypsum ... 101, 104, 105
lime ... 407, 410, 413, 415
limestone ... 435, 442
marble ... 434
mineral waters ... 116, 119, 136
natural sodium sulphate ... 73
opal ... 177
pebbles for grinding ... 382
precious stones ... 168
salt ... 241
sand and gravel ... 157-159
stone ... 423

Page.

Nevada, sulphur........ 536
New Brunswick, gypsum........ 105, 108
New Caledonia, phosphate rock........ 218
Newfoundland, asphalt........ 285
cement, exports to........ 402
gypsum, exports to........ 107
lime, exports to........ 416
salt, exports to........ 246
sand and gravel, exports to........ 160
slate, exports to........ 373
stone, exports to........ 424
sulphur, exports to........ 539
New Hampshire, artificial gas........ 466
471, 473, 474, 484, 487, 493, 498, 501, 505
cement........ 395, 397
concrete blocks........ 328
crushed stone........ 430
fluorspar........ 352, 353
garnet........ 382
granite........ 426, 429
lime, consumption........ 415
mica........ 269–270, 274
mineral waters........ 116, 119, 136
peat plants........ 45, 46
precious stones........ 168
sand and gravel........ 157–159
scythestones........ 382
stone........ 423
New Jersey, architectural stone........ 328
artificial gas........ 466,
471, 473, 475, 484, 487, 493, 498, 501, 505
barium chemicals........ 344
basalt........ 431, 433
building sand........ 163
cement, Portland........ 390, 395, 397
concrete blocks........ 328
concrete brick........ 329
crushed stone........ 430, 433, 442, 451, 454
fuel briquetting........ 34, 36
furnace flux........ 444
glass sand........ 161, 162
granite........ 426, 429
graphite........ 311
lime........ 407, 410, 413, 415
limestone........ 435, 442
mineral waters........ 116, 119, 136
molding sand........ 163
oyster shell lime........ 417
peat plants........ 45, 46
potash, from greensand........ 79
sand and gravel........ 157–159
sandstone........ 446, 450
slate........ 370, 371
stone........ 423
talc........ 265
zircon........ 21–22
New Mexico, artificial gas. 466, 471, 474, 484, 493, 498
barytes........ 340
cement........ 395, 397
crushed stone........ 442, 451
fluorspar........ 352, 353
stocks........ 355
granite........ 426
gypsum........ 101, 105
lime........ 407, 410, 413, 415
limestone........ 435, 442
magnesite........ 234
marble........ 434
mica........ 269, 274
mineral waters........ 116, 119, 137
natural sodium sulphate........ 73
precious stones........ 168
salt........ 241
sand and gravel........ 157–159
sandstone........ 446, 450
stone........ 423
New South Wales, fluorspar........ 360, 366
opal........ 178
New York, architectural stone........ 328
artificial gas........ 466, 471,
473, 475, 484, 487, 493, 498, 501, 505
barium chemicals........ 344
basalts........ 431, 433
bluestone........ 452
building sand........ 163
cement, natural........ 401
Portland........ 390, 395, 397
potash from........ 401
puzzolan........ 401

Page.

New York, concrete blocks........ 328
concrete brick........ 329
crushed stone........ 430, 433, 442, 451, 454
diatomaceous earth........ 382, 385
emery........ 382
feldspar........ 377
furnace flux........ 444
garnet........ 382
granite........ 426, 429
graphite........ 310–311, 313
gypsum........ 101, 103, 104, 105
lime........ 407, 410, 413, 415
limestone........ 435, 442
lithopone........ 343
marble........ 434
mica........ 274
millstones........ 382
mineral waters........ 116, 119, 137
molding sand........ 163
natural-gas gasoline........ 520, 521, 527
peat........ 45, 46
potash........ 81
pyrites........ 541
quartz........ 380
salt........ 241
sand and gravel........ 152, 157–159
sand-lime brick........ 238
sandstone........ 446, 450
silo blocks and staves........ 329
slate........ 370, 371
stone........ 423
talc........ 265
New Zealand, asphalt........ 286
cement, exports to........ 402
graphite........ 206, 315
lime, exports to........ 416
phosphate rock........ 218
salt, exports to........ 247
sodium compounds, exports to........ 51
stone, exports to........ 424
sulphur, exports to........ 539
Nicaragua, asphalt, exports to........ 285
cement, exports to........ 402
lime, exports to........ 416
salt, exports to........ 246
sodium compounds, exports to........ 49
North Carolina, asbestos........ 299, 304
artificial gas........ 466, 471, 473,
484, 487, 493, 498, 501, 505
auerlite........ 15
calcareous marl........ 417
cement........ 395, 397
crushed stone........ 430, 442, 451
feldspar........ 377
furnace flux........ 444
garnet........ 382
granite........ 426, 429
graphite........ 310
lime........ 407, 410, 413, 415
limestone........ 435, 442
marble........ 434
mica........ 269–270, 274
millstones........ 382
mineral waters........ 116, 117, 138
monazite sand........ 6, 12
peat plants........ 45
quartz........ 380
sand and gravel........ 157–159
sandstone........ 446, 450
stone........ 423
talc........ 265
zircon........ 18, 19
North Dakota, artificial gas........ 466, 471, 473,
484, 487, 493, 498, 501, 505
cement........ 395, 397
concrete blocks........ 328
fuel briquetting........ 34, 36
lime, consumption........ 415
mineral waters........ 116, 119, 139
sand and gravel........ 157–159
sand-lime brick........ 238
Norway, asphalt, exports to........ 285
cement, exports to........ 402
fluorspar........ 366
gadolinite........ 30
graphite........ 195
gypsum, exports to........ 107
mica........ 273
monazite........ 10

Page.
Norway, peat ... 42
pebbles, imports from ... 386
phosphate rock, exports to ... 216–217, 218
potash, imports from ... 86
salt, exports to ... 246
stone, exports to ... 424
sulphur, exports to ... 539
sodium compounds, exports to ... 49
thorite ... 14–15
Nourse, M. R., and Hicks, W. B., paper on potash ... 77–94
Nova Scotia, gypsum ... 105–108
Nyassaland, mica ... 274

O.

Ocean Island, phosphate rock ... 218
Oceania, phosphate rock, exports to ... 217
salt, exports to ... 247
sulphur, exports to ... 539
Ohio, architectural stone ... 328
artificial gas ... 466, 471, 473, 474, 475, 484, 487, 493, 498, 501, 505
bromine ... 249
building sand ... 163
calcium chloride ... 255
cement, natural ... 401
Portland ... 390, 395, 397
potash from ... 401
puzzolan ... 401
concrete blocks ... 328
concrete brick ... 329
crushed stone ... 442, 451
furnace flux ... 444
glass sand ... 161, 162
grindstones ... 382
gypsum ... 101, 103, 104, 105
lime ... 407, 410, 413, 415
limestone ... 435, 442
millstones ... 383
mineral waters ... 116, 119, 139, 383
molding sand ... 163
natural-gas gasoline ... 520, 521, 523, 527–528
oilstones ... 382
peat ... 46
potash ... 81
salt ... 241
sand and gravel ... 152, 157–159
sand-lime brick ... 238
sandstone ... 446, 450
silo blocks and staves ... 329
stone ... 423
whetstones ... 382
Oilstones and scythestones ... 381
imports ... 381, 384
production ... 383
Oklahoma, artificial gas ... 466, 471, 473, 484, 487, 493, 498
asphalt ... 281
cement, Portland ... 390, 395, 397
concrete blocks ... 328
concrete brick ... 329
crushed stone ... 430, 442, 451
glass sand ... 162
granite ... 426, 429
gypsum ... 101, 105
lime ... 407, 410, 413, 415
limestone ... 435, 442
mineral waters ... 116, 119, 140
natural-gas gasoline ... 520, 521, 523, 529–530
salt ... 241
sand and gravel ... 157–159
sandstone ... 446, 450
stone ... 423
tripoli ... 382, 385
zircon ... 22–23
Onyx marble, imports ... 425
opal ... 177–178
Oregon, architectural stone ... 328
artificial gas ... 466, 471, 473, 474, 484, 487, 493, 498
basalt ... 431, 433
cement ... 390, 395, 397
concrete blocks ... 328
crushed stone ... 430, 433, 442, 454
diatomaceous earth ... 382, 385
fuel briquetting ... 34, 36
granite ... 426, 429
gypsum ... 101, 105
lime ... 407, 415
limestone ... 435, 442
Oregon marble ... 434
mineral waters ... 116, 119, 141
precious stones ... 168
sand and gravel ... 157–159
sandstone ... 446
stone ... 423
Oyster-shell lime ... 417
Ozokerite ... 283

P.

Panama, asphalt ... 285
cement, exports to ... 402
imports from ... 403
diamonds, imports from ... 169
gypsum, exports to ... 107
lime, exports to ... 416
potash ... 86
salt, exports to ... 246
imports from ... 245
sand and gravel, exports to ... 160
slate, exports to ... 373
sodium compounds, exports to ... 49
stone, exports to ... 424
Paraguay, cement, exports to ... 402
sodium compounds, exports to ... 50
sulphur, exports to ... 539
Paving sand, production ... 151, 158–159
Pearl, imports ... 169, 170
Peat, K. W. Cottrell ... 41–46
analyses ... 44
consumption ... 45
distribution of plants ... 45–46
imports ... 45
prices ... 41, 44, 45
producers ... 46
production ... 41, 45
fertilizer and fertilizer filler ... 41
stock food ... 43–44
fuel ... 42–43
source of alcohol ... 44–45
summary ... 45
Pebbles for grinding (*see also* Abrasive materials) ... 379
imports ... 379, 386
in the United States ... 385
Pennsylvania, architectural stone ... 328
artificial gas ... 466, 471, 473, 475, 484, 487, 493, 498, 501, 505
barium chemicals ... 344
basalt ... 431, 433
bluestone ... 452
building sand ... 163
calcareous marl ... 417
cement, natural ... 401
Portland ... 390, 395, 397
potash from ... 401
puzzolan ... 401
concrete blocks ... 328
crushed stone ... 430, 433, 442, 451, 454
feldspar ... 377
fuel briquetting ... 34, 36
furnace flux ... 444
glass sand ... 161, 162
granite ... 426, 429
graphite ... 310–311, 318–322
lime ... 407, 410, 413, 415
limestone ... 435, 442
lithopone ... 343
marble ... 434
millstones ... 382
mineral waters ... 116, 119, 141
molding sand ... 163
natural-gas gasoline ... 520, 521, 523, 530–531
oyster-shell lime ... 417
potash ... 81
pyrites ... 541
quartz ... 380
rottenstone ... 382
salt ... 241
sand and gravel ... 152, 158–159
sand-lime brick ... 238
sandstone ... 446, 450
silo blocks and staves ... 329
slate ... 370, 371, 372
stone ... 423
talc ... 265
tripoli ... 385
Peru, asphalt ... 285
cement, exports to ... 402

	Page.
Peru, graphite	315
lime, exports to	416
potash	86
salt, exports to	247
sodium compounds, exports to	50
stone, exports to	424
sulphur, exports to	539
Petroleum. See note, p. iv.	
Philippine Islands, asbestos	305
asphalt	286
cement, exports to	402
graphite	315
gypsum, exports to	107–108
lime, exports to	406
potash	86
salt, exports to	247
sodium compounds, exports to	51
stone, exports to	424
sulphur, exports to	539
Phosphate rock, by R. W. Stone	211–225
exports	215–217
foreign phsophate deposits	219–225
Africa	220–223
Algeria	220–221
Morocco	222–223
Tunis	221
Europe	219
Belgium	219
France	219
Russia	219
Spain	219
Pacific Islands	223–225
Makatea Island	224–225
Nauru Island	223–224
mined, by States	211
prices	212–215
production, marketed	211–215
by States and kinds	212–215
stocks	212
value	211–212
world's production	218
Poland, salt	249
Portland cement, production, by States (*see also* Cement)	388–397
Porto Rico, cement	395, 397
crushed stone	443
furnace flux	444
lime	407, 410, 415
limestone	435, 443
potash	81
salt	241
stone	423
Portugal, pebbles	386
potash	86
salt	248
imports from	245
stone, exports to	424
imports from	425
sulphur, exports to	539
Portuguese Africa, asbestos, imports from	305
cement, exports to	402
gypsum, exports to	107
lime, exports to	416
potash	86
salt, imports from	245
sulphur, exports to	539
Potash, by W. B. Hicks and M. R. Nourse	77–94
bibliography	89–94
exports	81
imports	81–86
for consumption	82–85
general imports, by countries	86
introduction	77
potash from alunite	79, 80
in Marysvale district, Utah	79
blast furnace dust	79, 80
brines	78–79, 80
cement dust	79, 80
kelp	79, 80
plant of Department of Agriculture	79
molasses distillery slop	79–80
salines	78–80
Utah	79
Great Salt Lake, Utah	79
Nebraska lakes	78, 80
Salduro marsh, Utah	79
Searles Lake, Calif	78
Potash, potash from silicate rocks	79, 80
patents for processes of extracting potash from silicate rocks	87–89
Leucite Hills	79
Steffins waste water in beet sugar manufacture	80
wood ashes	79, 80
wool washings and other industrial wastes	79
prices	77
production	78, 80–81
according to material marketed	80
to sources	80
to States	81
in Germany, 1880–1919	87
sales	78
value	78, 80–81
Prices, architectural stone	328, 330
artificial gas	481–483
asbestos	299, 304–305
asphalt	279, 281–282
barytes	335, 337, 341, 343, 346–347
blanc fixe	345
bromine	249, 250, 252
building sand	160, 163
calcium chloride	255
cement	390, 398
concrete blocks	328
concrete brick	329, 332
crushed stone	455
cryolite	367
diamond	171, 172, 176
engine sand	160
filter sand	160
feldspar	377
fire or furnace sand	160
fluorspar	349, 352, 355, 357
fuel briquets	35
fuller's earth	258–259, 260
gasoline	520–521
glass sand	160, 162
graphite	315–316
gravel	160
grinding and polishing sand	160
gypsum	102
ichthyol	283
lime	405, 406–407, 413, 416–417
lithium minerals	37–38
lithopone	341, 346
magnesite	231
marble	434
mica	271
mineral waters	118–121
molding sand	160, 163
monazite	7, 9
natural-gas gasoline	520, 521
ozokerite	283
paving sand	160
peat	41, 44, 45
phosphate rock	212–215
potash	77
pumice	385
pyrites	541, 542
railroad ballast	160
salt	239, 243–244
sand-lime brick	238
silo blocks and staves	332, 392
salte	370, 371, 372
sodium salts	59, 65, 75
strontium	96
salts	97
sulphur	536, 538
sulphuric acid	543, 545
talc	265–267
thorianite	16
thorium nitrate	4
Pulpstones (*see also* Grindstones)	381, 383
Pumice, imports	381, 385
production	385
Puzzolan cement. (*See* Cement.)	
Pyrites (*see also* Sulphur, pyrites, and sulphuric acid)	541–543
imports	542
prices	541, 542
production, by States	541
1915–1919	542
tariff	543
world's pyrites industry	543

Q. Page.

Quartz (*see also* Silica) 178
imports, flint 379
industry, by States 379-380
production, by States 178
Queensland, fluorspar 366

R.

Railroad ballast, sand 151, 158-159
stone 430, 442, 451, 454, 455
Rare-earth minerals (*see also* Thorium) 28-32
bibliography 31-32
cerium (allanite, monazite) 28-30
occurrence 28-29
uses 29-30
introduction 28
lanthanum (didymium) 31
occurrence 31
uses 31
yttrium (gadolinite, thorium) 30-31
occurrence 30-31
uses 30
Retort carbon 503
Rhode Island, architectural stone 328
artificial gas 466, 471, 473, 484, 487, 493, 498, 501, 505
cement 395, 397
concrete blocks 328
crushed stone 430, 443, 454
furnace flux 444
granite 426, 429
graphite 310, 312
lime 407, 410, 413, 415
limestone 435, 443
mineral waters 116, 119, 142
sand and gravel 158-159
stone 423
Road metal 430, 442, 451, 454, 455
Rhodesia, asbestos 306
Rottenstone. (*See also* Diatomaceous earth and tripoli.)
Rumania, asbestos 306
sodium compounds, exports to 49
Russia, asphalt 287
phosphate rock 218, 219
salt, exports to 246-247
sodium compounds, exports to 49, 51
stone, exports to 424
thorianite 15

S.

Salduro salt marsh, potash 79
Salt, bromine, and calcium chloride, by Herbert Insley 239-256
Salt (*see also* Salt, bromine, and calcium chloride) 239-249
domestic consumption 244
diagram showing production, consumption, imports, and exports, 1900-1919 240
domestic deposits 248
exports 246-248
foreign deposits 248-249
imports 244-246
poison gases 241
prices 239, 243-244
production and trade conditions 239-243
by States 241
of brine salt 239, 242
of evaporated salt 239, 242-243
of rock salt 239, 241-242
value 239, 241
Salvador, cement, exports to 402
salt, exports to 246
sodium compounds, exports to 49
Saltpeter. (*See* Potash salts.)
Sand and gravel, by R. W. Stone 151-164
exports 160
filter sand 151, 158
gravel 151, 157
imports 160
prices 160-161
producers, associations of 164
production 151-159
by States 157-157

Page.
Sand and gravel, sand, building 151, 157
engine 151, 157
fire or furnace 151, 157
glass 151, 157
grinding 151, 157
molding 151, 157
paving 151, 158
railroad ballast 151, 158
technical journals 164
value 151, 159
Sand and sandstone. (*See* Silica.)
Sand-lime brick, by Jefferson Middleton 237-238
prices 238
production, by States 238
value 238
Sandstone (*see also* Stone) 419, 446-451
ganister 446, 450
value, by States 423, 446
by uses 420, 451
Schaller, W. T., paper on thorium, zirconium, and rare-earth minerals 1-32
Scotland, asbestos, imports from 305
asphalt 285
magnesite 228
diamond 176
phosphate rock, exports to 217
Scythestone 382
Serpentine 435
Siam, asphalt, exports to 286
Siberia, salt 249
thorianite 16
Sievers, E. G., paper on natural-gas gasoline 519-534
Silica (quartz), by L. M. Beach 379-380
diatomaceous earth 379
flint or chert 379
imports 379
production 379
quartz 379-380
by States 380
sand and sandstone 379
tripoli 379
Silica rocks, potash from 79-80
patents for processes of extraction 87-89
Silo blocks and staves 329, 337
Slate, by G. F. Loughlin and A. T. Coons 369-375
colored slates 370
conditions of industry 369
exports 373-734
general statistics 369
imports into Canada 375
mill stock 370, 371, 372
prices per square 370, 371
per square foot 370
production, by States 370, 371
roofing 370, 371, 372
value, by States 370
Smith, P. S., paper on sulphur, pyrites, and sulphuric acid 535-546
Soapstone (*see also* Talc and Soapstone) 268
production 268
Sodium nitrate 67
Sodium compounds, by Roger C. Wells 47-76
effect of the war on sodium compounds 52-53
exports, by countries 49-51
by classes 52
imports 48
introduction and summary 47-48
miscellaneous sodium compounds 76
prices 59
production 47
sodium (metal) 55
acetate 56
benzoate 56
bicarbonate 56
bichromate 57
bisulphite 57-58
bromide 58
carbonate 58-62
soda ash 58
marketed production 58-59
imports and exports 59
prices 59
uses 60
manufacture 60
monohydrate and sesquicarbonate 60

Page.

Sodium compounde, carbonate, soda ash, sal soda 60-61
natural soda 61-62
localities of commercial production 62
Owens Lake 62
citrate 63
cyanide 63-64
ferrocyanide 64-65
fluoride 65
hydroxide 65-66
production 65
exports and imports 65
producers 66
uses 66
manufacture 65-66
hypochlorite 67
iodide 67
nitrate 67
nitrite 68
perborate 68
permanganate 68
peroxide 68
phosphate 69
silicate 69-70
sulphate 70-73
salt cake 70-71
manufacturers of 71
Glauber's salt 71
manufacturers of 71
niter cake 71-72
manufacturers of 72
natural sodium sulphate 72-73
sulphide 73-74
manufacturers 74
tartrate 74
tetraborate (borax) 74-76
description and uses 74-75
production and prices 75
sources of domestic borax 75
imports and exports 76
thiosulphate 76
manufacturers 76
trade names for various sodium compounds 54-55
value and uses 47, 53
South Africa, asbestos 306
imports from 305
cement, exports to 402
diamond 169, 171-175
imports from 169
gypsum, exports to 107
graphite 182, 205, 315, 316
mica 272, 274
potash 86
slate, exports to 373, 374
sodium compounds, exports to 51
stone, exports to 424
South America, stone, exports to 424
South Australia, phosphate rock 218
South Carolina, artificial gas 466, 471, 473, 484, 487, 493, 498, 501
calcareous marl 417
cement 395, 397
crushed stone 430
granite 426, 429
lime, consumption 415
limestone 435
marble 434
mica 274
mineral waters 116, 119, 143
monazite sand 6, 12
phosphate rock 212, 214
sand and gravel 158-159
stone 423
South Dakota, artificial gas 466, 471, 473, 484, 487, 493, 498, 501
cement 395, 397
concrete blocks 328
crushed stone 430, 443, 451, 454
granite 426, 429
gypsum 101, 105
lime 407, 410, 413, 415
limestone 435
lithium minerals 37, 39
mica 269-270, 274
mineral waters 116, 119, 143
precious stones 168

Page.

South Dakota, sand and gravel 158-159
sand-lime brick 238
sandstone 446, 450
silo blocks and staves 329
stone 423
Spain, asphalt 285, 288
cement, exports to 402
diamonds, imports from 169
fluorspar 366
graphite 182, 196, 315, 316
lime, exports to 416
lithium minerals 37
mineral waters, imports from 122
phosphate rock, exports to 216-217, 218, 219
potash 86
precious stones 168
pyrites 542
salt 248
imports from 245
sand and gravel 158-159
sand-lime brick 238
sandstone 446, 450
silo blocks and staves 329
sodium compounds, exports to 49
stone, exports to 424
imports from 425
sulphur, exports to 539
Steffens waste water, potash from 78, 80
Stoddard, B. H., paper on gems and precious stone 165-180
Stone, R. W., paper on gypsum 99-113
magnesite 227-235
phosphate rock 211-225
sand and gravel 151-164
salt, bromine, and calcium chloride .. 239-256
Stone, by G. F. Loughlin and A. T. Coons. 419-455
basalt and related rocks (trap rock) 419, 431-433
bluestone 446, 452
building 420-421, 426, 429, 431, 433, 434, 436, 442, 446, 450, 452, 454
concrete 325-333, 429, 451, 454, 455
crushed stone 420-421, 426, 429, 431, 433, 436, 442, 446, 451, 452, 454, 455
curbstone 420-421, 426, 429, 436, 442, 446, 450
exports 423-424
flagstone 420-421, 429, 436, 446, 450
furnace flux 420-421, 436, 444
ganister 446, 450
general conditions 419
granite 419, 425, 426-430
imports 425
limestone 419, 435-445
marble 419, 425, 434
prices 434
miscellaneous 419, 452-454
monumental stone 420-421, 426, 429, 434
onyx marble 425
paving 420-421, 426, 429, 431, 433, 436, 442, 446, 450
production 419-423, 426
by kinds and uses 419-421
by States 422-423
railroad ballast 430, 451, 454, 455
refractory 420-421, 452
riprap 420, 426, 430, 431, 433, 436, 442, 446, 451, 452, 454
road metal 430, 451, 454, 455
rubble 420, 426, 430, 431, 433, 436, 442, 446, 451, 452, 454
sandstone 419, 446-451
serpentine 435
value, by kind 419
by States 423
by uses 420
Stose, G. W., paper on strontium 95-98
barytes and barium products 335-347
Straits Settlements, asphalt, exports to 286
cement 402
graphite 315
lime, exports to 416
salt, exports to 247
sodium compounds, exports to 50
sulphur, exports to 539
Strontium, by George W. Stose 95-98
deposits in United States 98
imports 96
general conditions 95

Page.
Strontium, prices ... 97
production ... 95
strontium salts ... 96
uses and market ... 97
Styria, graphite ... 316
Sulphur, pyrite, and sulphuric acid, by P. S. Smith ... 535–546
general situation ... 535–536
Sulphur ... 536–540
cost of production ... 540
exports ... 538–539
imports, by countries ... 537–538
by customs districts ... 537–538
prices ... 536, 538
production ... 536–537
world's sulphur industry ... 539–540
Sulphuric-acid industry in United States (*see also* Sulphur, pyrite, and sulphuric acid) ... 543–546
exports ... 545–546
imports ... 545
prices ... 543, 545
production ... 543–545
by industries ... 544
from smelter gases ... 544
sulphur used in making sulphuric acid .. 545
Sweden, asphalt ... 285
graphite ... 182, 196, 316
gypsum, exports to ... 107
peat ... 45
pebbles, imports ... 386
phosphate rock, exports to ... 216–217
potash ... 86
sodium compounds, exports to ... 49, 59
stone, exports to ... 424
sulphur, exports to ... 539
Switzerland, asphalt ... 285
diamonds, imports from ... 169
phosphate rock, exports to ... 216
sodium compounds, enports to ... 49
stone, exports to ... 424

T.

Talc and soapstone, by J. S. Diller ... 265–268
Talc ... 265–268
conditions in which marketed ... 266
imports ... 267–268
occurrence ... 265–266
prices ... 265, 266, 267
production ... 265
uses ... 266–267
analyses ... 267
Tar ... 496, 508
Tariff, thorium minerals ... 5
pyrites ... 543
Tennessee, artificial gas ... 466, 471, 473, 475, 484, 487, 493, 498, 501, 505
barytes ... 335, 340
cement, Portland ... 390, 395, 397
potash from ... 401
concrete blocks ... 328
crushed stone ... 443, 451
furnace flux ... 444
glass sand ... 162
lime ... 407, 410, 413, 415
limestone ... 435, 443
marble ... 434
mineral waters ... 116, 119, 144
phosphate rock ... 212–214
potash ... 81
pyrites ... 541
quartz ... 380
sand and gravel ... 158–159
sandstone ... 446, 450
slate ... 370, 371
stone ... 423
Texas, architectural stone ... 328
artificial gas ... 466, 471, 473, 474, 484, 487, 493, 498, 501, 505
asphalt ... 281
basalt ... 431, 433
cement, Portland ... 390, 395, 397
concrete blocks ... 328
concrete brick ... 329
crushed stone ... 430, 433, 443
fuller's earth ... 258
furnace flux ... 444
gadolinite ... 30

Page.
Texas, glass sand ... 162
granite ... 426, 429
graphite ... 310, 312
gypsum ... 101, 105
ichthyol ... 284
lime ... 406, 410, 414, 415
limestone ... 435, 443
mackintoshite ... 16
marble ... 434
meerschaum ... 165
mica ... 274
mineral waters ... 116, 119, 145
natural-gas gasoline ... 520, 521, 523, 532
precious stones ... 165, 168
salt ... 241
sand and gravel ... 158–159
sand-lime brick ... 238
sandstone ... 446
silo blocks and staves ... 329
stone ... 423
strontium ... 95, 98
sulphur ... 536–537
throgummite ... 16
Thorium minerals ... 2–18
analyses ... 12–13, 14–15
bibliography ... 16–18
condition of industry ... 2–3
imports ... 3–5
localities ... 6–10
mines and counties ... 6
prices ... 4, 7, 9, 16
production ... 3–4
sources ... 11–16
auerlite ... 15
mackintoshite ... 16
monazite ... 11–14
pilbarite ... 16
thorianite ... 15–16
thorite ... 14–15
thorogummite ... 16
tariff ... 5
uses ... 10–11
world's production ... 5–6
Tobago, asphalt ... 282
cement, exports to ... 402
slate, exports to ... 373
Toluol ... 506–508
Tourmaline, Maine ... 179
Topaz, Idaho ... 179
Transvaal, asbestos ... 306
Trap Rock. (*See* Basalt and related rocks.). 419
Travancore, monazite sand ... 8–9
Trinidad, asphalt ... 282, 285, 288
cement, exports to ... 402
slate, exports to ... 373
sodium compounds, exports to ... 49
Tripoli (*see also* Abrasives *and* Silica) ... 379
imports ... 385
production ... 379, 384
Tryon, F. G., paper on fuel briquetting ... 33–36
Tunis, phosphate rock ... 218, 221
Turkey, cement, exports to ... 402
diamonds, imports from ... 169
potash ... 86
salt, exports to ... 246
sodium compounds, exports to ... 49

U.

United Kingdom, asphalt, exports to ... 285
cement, exports to ... 402
graphite ... 315
gypsum, exports to ... 107–108
magnesite ... 228
mica ... 273
potash ... 86
sodium compounds, exports to ... 49
stone, exports to ... 424
imports from ... 425
sulphur, exports to ... 539
Uruguay, asphalt ... 285
graphite ... 186, 315
gypsum, exports to ... 107
sodium, compounds, exports to ... 50
sulphur, exports to ... 539
Utah, alunite ... 79
artificial gas ... 466, 471, 473, 484, 487, 493, 498, 505
asphalt ... 281

Page.

Utah, cement, Portland ... 390, 395, 397
  potash from ... 401
 concrete blocks ... 328
 crushed stone ... 443, 451
 diatomaceous earth ... 382, 385
 fluorspar ... 352, 353
  stocks ... 355
 furnace flux ... 444
 granite ... 426
 gypsum ... 101, 105
 jet ... 165
 lime ... 407, 410, 413, 415
 limestone ... 435, 443
 marble ... 434
 phosphate rock ... 212, 215
 potash ... 79, 81
 precious stones ... 165, 168
 salt ... 241
 sand and gravel ... 158-159
 sandstone ... 446, 450
 slate ... 370, 371
 stone ... 423
 strontium ... 95
 sulphur ... 536

V.

Venezuela, asphalt ... 282, 285, 288
 cement, exports to ... 402
 natural soda ... 62
 sodium compounds, exports to ... 50
 stone, exports to ... 424
 sulphur, exports to ... 539
Vermont, artificial gas. 466, 471, 473, 484, 487, 493, 498
 cement ... 395, 397
 crushed stone ... 430, 443
 furnace flux ... 444
 granite ... 426, 429
 lime ... 407, 410, 413, 415
 limestone ... 435, 443
 marble ... 434
 mineral waters ... 116, 119, 145
 sand and gravel ... 158-159
 scythestones ... 382
 slate ... 370, 371
 stone ... 423
 talc ... 265-266
Virgin Islands, cement, exports to ... 402
 lime, exports to ... 416
 salt, exports to ... 247
  imports from ... 245
 stone, exports to ... 424
Virginia, artificial gas ... 466, 471, 473, 484, 487, 493, 498, 501, 505
 barytes ... 335, 341
 calcareous marl ... 417
 calcium chloride ... 255
 cement, Portland ... 390, 395, 397
 cerium (allanite) ... 28
 concrete blocks ... 328
 crushed stone ... 430, 433, 443, 451
 emery ... 328
 fuel briquetting ... 34
 furnace flux ... 444
 granite ... 426, 429
 gypsum ... 101, 103, 105
 lime ... 407, 410, 413, 415
 limestone ... 435, 443
 marble ... 434
 mica ... 269-270, 274
 millstones ... 382
 mineral waters ... 116, 119, 146
 oyster-shell lime ... 417
 peat ... 46
 pyrites ... 541
 salt ... 241
 sand and gravel ... 158-159
 sandstone ... 446, 450
 slate ... 370, 371
 soapstone ... 268
 stone ... 423
 talc ... 265-266
 zircon ... 20-21

W.

Washington, architectural stone ... 328
 artificial gas ... 466, 471, 473, 475, 484, 487, 493, 498, 501, 505
 asbestos ... 299, 304
 basalt ... 431, 433
 cement, Portland ... 390, 395, 397
 concrete blocks ... 328
 crushed stone ... 430, 433, 443, 451
 diatomaceous earth ... 382, 385
 fluorspar ... 353
  stocks ... 355
 fuel briquetting ... 34, 36
 furnace flux ... 444
 granite ... 426, 429
 gypsum ... 105
 lime ... 407, 410, 413, 415
 limestone ... 435, 443
 magnesite ... 227, 233-234, 235
 marble ... 434
 mineral waters ... 116, 119, 147
 natural-gas gasoline ... 521, 523
 potash ... 81
 precious stones ... 168
 sand and gravel ... 158-159
 sandstone ... 446, 450
 silo blocks and staves ... 329
 stone ... 423
 strontium ... 95, 98
 talc ... 265-266
Wells, Roger C., paper on sodium compounds. 47-76
West Indies, cement, exports to ... 402
 salt, exports to ... 246-247
  imports from ... 245
 slate, exports to ... 373-374
 sodium compounds, exports to ... 50
 stone, exports to ... 424
 sulphur, exports to ... 539
West Virginia, architectural stone ... 328
 artificial gas ... 466, 471, 473, 475, 484, 487, 493, 498, 501
 barium chemicals ... 344
 bromine ... 249
 calcareous marl ... 417
 calcium chloride ... 255
 cement, Portland ... 390, 395, 397
 concrete blocks ... 328
 crushed stone ... 443
 furnace flux ... 444
 glass sand ... 161, 162
 grindstones ... 382, 383
 lime ... 407, 410, 413, 415
 limestone ... 435, 443
 mineral waters ... 116, 119, 147
 natural-gas gasoline ... 520, 521, 523, 523-524
 salt ... 241
 sand and gravel ... 158-159
 sandstone ... 446, 450
 stone ... 423
Whetstones, imports ... 384
 production ... 383
Wisconsin, architectural stone ... 328
 artificial gas ... 466, 471, 473, 474, 475, 484, 487, 493, 498, 501, 505
 barytes ... 335, 341
 basalt ... 431, 433
 cement ... 395, 397
 concrete blocks ... 328
 concrete brick ... 329
 crushed stone ... 430, 433, 443, 451
 fuel briquetting ... 34, 36
 furnace flux ... 444
 glass sand ... 162
 granite ... 426, 427
 lime ... 407, 410, 413, 415
 limestone ... 435, 443
 mica ... 274
 mineral waters ... 116, 119, 148
 potash ... 81
 pyrites ... 541
 quartz ... 380
 sand and gravel ... 158-159
 sand-lime brick ... 238
 sandstone ... 446, 450
 silo blocks and staves ... 329
 stone ... 423
Wood ashes, potash from ... 78-80
Wool washings, potash from ... 79
World's production, fluorspar ... 366
 graphite ... 316
 monazite sand ... 5-6
 phosphate rock ... 218

Page.
Wyoming, artificial gas........ 466, 471, 484, 493, 498
asbestos........ 299, 304
cement........ 395, 397
crushed stone........ 443
gypsum........ 101, 105
lime........ 407, 410, 415
limestone........ 435, 443
mineral waters........ 116, 119, 149
natural-gas gasoline........ 520, 521, 523, 534
natural sodium sulphate........ 73
phosphate rock........ 212, 215
potash........ 77, 81
precious stones........ 168
sand and gravel........ 158–159
sandstone........ 446, 450
stone........ 423

Y. Page.

Yale, Charles G., paper on magnesite........ 227–235
Yttrium........ 30–31

Z.

Zirconium minerals........ 18–28
analyses........ 18–19, 26
baddeleyite........ 18–19
imports........ 28
occurrence........ 19–24
mines and counties........ 19–23
production........ 27
uses........ 24–27
zirconia........ 25–26
zirkite........ 26–27

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