Hints on the Development of Small Water-Power
Leffel Pamphlet "A"

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LEFFEL

PAMPHLET

"A"

THE JAMES LEFFEL & CO.
SPRINGFIELD
OHIO

HINTS ON THE DEVELOPMENT OF SMALL WATER POWERS

This pamphlet has been prepared for those who contemplate the construction of small water power plants on small streams for the purpose of generating electric current for general home use, and it is intended to convey certain information in order that the subject may be grasped by those unacquainted with the general rules and requirements for such developments.

It is generally understood by all that a flowing stream may be made to produce power, but it is not generally understood what information is required by the manufacturer of water power equipment in order that proper advice and recommendations may be given. Therefore we are outlining below the rules and requirements that must be observed when asking for information pertaining to the development of water power. We will add that the subject matter of this pamphlet applies principally to the smaller developments, but, at the same time, the same rules may be applied to the larger developments to a certain extent.

FALL OR HEAD

In order to produce power from a flowing stream there must be a "fall" in the stream. This "fall" is almost always augmented, or increased by the construction of a dam. A dam in the stream is necessary in order to raise the water to a maximum level to create a head, and to divert the water from the stream to the turbine, or water wheel. This head that is created is the vertical distance from the surface of the water at the dam down to the surface of the water in the stream below the dam and at a point where the turbine will be located.

As the useful power that may be produced from any waterpower is the direct product of the "head" and the weight of the water, which weighs 62.34 lbs. per cubic foot, it follows that the "head" available and the amount of water flowing in the stream in cubic feet per minute are absolute factors when it is desired to compute the amount of power that may be developed.

It will be understood that the term "fall" means the natural fall or drop in the course of a stream, and that the term "head" defines the vertical drop resulting from the construction of a dam in the stream. Please note Design 30 illustrating how this term is applied to a turbine installation.

HOW TO DETERMINE THE "HEAD"

When selecting the dam site it is well to remember that the higher the dam is built the more the "head" will be, and the greater the "head" the more power a given amount of water will produce; and the smaller will be the turbine. Therefore, it is well to exercise care in the selection of the dam site so that the highest possible head may be realized. However, consideration must be given to the cost and possible damage to your neighbor's property. Usually the topography of the ground will suggest the logical location for the dam, although there are other determining factors to be taken into consideration, such as character of foundation, property lines, pond area, etc. Space does not permit a more detailed treatment of these subjects. We will say, however, that it may be well to have an engineer or surveyor run out "contour lines" upstream from the dam site representing proposed water levels back of the dam. In this manner the flooded area may be determined before the dam is built, and serious complications avoided if such there may be.

After the height, or elevation, of the water back of the dam has been established, levels may be run downstream with an engineer's level or transit to determine the "fall" or "head" that may be secured below the dam site within a reasonable distance. It follows that the TOTAL HEAD that may be secured is that which is created by the dam plus the "fall or head" that may be secured below the dam. This TOTAL HEAD is represented by the VERTICAL DISTANCE from the surface of the water back of the dam down to the surface of the water below the dam and at the point where the turbine may be located.

If the developed "head" is low; that is, from a few feet up to ten to fifteen feet, the turbine is usually located right at, or very close to the dam, the water being conveyed to the turbine through an open flume or penstock. But, in some cases, where the head is not any greater than mentioned above, the turbine may be quite small and for that reason alone it might be more economical to convey the water to the turbine through a steel pipe line.

In some cases, regardless of the head secured, it is desirable to place the turbine some little distance below the dam to secure additional head due to the fall of the stream below the dam. In such cases a pipe line, or an open flume or open ditch may be used to convey the water to the turbine. However, there are cases where an open tail race may be excavated from the stream to the powerhouse to secure at least part of the fall below the dam; this being less expensive than the above mentioned pipe line or ditch.

MEASUREMENT OF WATER FLOWING IN THE STREAM

The second absolute factor that determines the amount of power that may be developed is the quantity of water available for power purposes flowing in the stream. Quantity of water for power purposes should be expressed in "cubic feet per minute" (C.F.M.).

There are two well known methods of measuring streams; one by the weir method and the other by the float method. Both methods are fully described and illustrated on a leaflet attached to this pamphlet.

There are cases where it is obvious that the water supply is more than adequate for the power to be developed but in most cases it is highly important that the water be carefully measured.

It will generally be found that the flow of water in any stream will vary greatly with the season of the year and this should be taken into consideration when measurements are taken.

The minimum flow of a stream, in most cases, has a duration of several weeks during the dry season, and this flow, when taken into consideration, represents the amount of water that can be developed continuously, or 100% of the time outside of that period of time the stream may be in flood stage.

As the flow of the stream increases, the amount of power that may be developed increases, although it is true that as the flow increases the actual head on the turbine is decreased somewhat on account of a greater quantity of water being discharged into the tail race which raises the level of the water therein.

As the flow increases beyond the normal, or average stage the head is reduced still further. However, periods of high water and low head are of comparatively short duration and while this condition must be contended with, it should not be allowed to stand in the way of the development of the water power.

It is obvious that a stream should be measured at various times of the year in order that complete data on the flow be established. Daily measurements are ideal and may be made conveniently, especially if the weir method of measuring is used.

It is also obvious that any measurement taken during flood period would be of little value except that such measurements may be used to estimate the size of the flood or waste gate in the dam. It should be noted here that if the stream is subject to floods, provision must be made in the dam to allow the excess water to escape; thereby preventing damage to the dam and powerhouse structure.

EFFECT OF PONDAGE

When a dam is built in a stream there is created back of the dam a pond that is really a storage reservoir that may be used to very good advantage to conserve the supply of water during times when the turbine is consuming less water than is flowing in the stream, and to supply water over and above that flowing in the stream when it is needed. If the pond is of sufficient area the above feature is of much benefit during times when the stream is at minimum flow.

In further explanation it may be stated that the load on any plan is seldom, if ever, fixed as it may and will vary with the needs of the power consumer. For example: Let us assume that the maximum capacity of the turbine is 600 cubic feet of water per minute, and that the load on the turbine at the moment requires all of this water to develop the power required by the load. Assume also, that the flow of water in the stream at the same time is only 300 cubic feet per minute. It will be seen that the turbine will consume the 300 cubic feet of water flowing in the stream plus 300 cubic feet more per minute which will be drawn from the pond. Now assume that in a short time the load changes to the extent that the turbine only requires 100 cubic feet of water per minute. Inasmuch as there are 300 cubic feet of water flowing in the stream and the turbine only requires 100 cubic feet of it, the difference, or 200 cubic feet of water per minute, will be stored in the pond to replace that which was drawn out.

A great many water-power feed and flour mills depend a great deal on pondage as they operate during the day, drawing on the pond for excess water not supplied by the normal flow of the stream. At night they shut down and the flow of the stream refills the pond which allows them to start the next morning with a full pond.

From the above we believe it will be seen how important and necessary the pond is to the successful operation of a water power plant during times when the normal flow of the stream is not great enough to supply the maximum capacity of the turbine installed. In other words one may take advantage of the existence of a pond and install a larger turbine than he could otherwise, and, thereby, be able to carry a greater momentary, or peak load for short times.

Therefore, the area of the pond created by the dam should be given along with the information regarding the head and the quantity of water. The area of the pond may be given approximately and in terms of acres.

ESTIMATING THE POWER REQUIRED

As this pamphlet is principally for those who desire to install water power equipment to drive generators for furnishing electric current for home and farm use, we will confine our remarks to that type of load.

It may be your wish to furnish electricity to only a small cottage, a group of cottages, a group of farm buildings, or perhaps, to a private estate including all the buildings thereon. But, whatever it is, there are certain items of information we should have to be able to advise you regarding the amount of power required to accomplish the results you desire.

A list of the total number of electrical outlets in all of the buildings should be made, and this list should include only the outlets for electric lights.

Then, in addition, list all of the electrical appliances that may be used, including heaters, flat irons, radios, television sets, electrical ranges, milking machines, cream separators, etc. With such a list at hand we can then estimate the approximate peak load that would have to be carried by the turbine and helps us to decide on the proper size of turbine and accessory equipment.

TYPES OF ELECTRIC GENERATORS

There are two types of electric generators that may be used, and we are referring to their electrical characteristics in this instance. One type generates Alternating Current and the other type generates Direct Current. The type to be selected depends on a number of factors which must be given consideration. Alternating Current may be transmitted much greater distances than Direct Current without undue loss and with smaller wires. Therefore, the distance from the power plant to the place where the current will be used is a very important factor and should be stated in your inquiry.

The size of the generator is another factor, but that is determined when the power of the turbine is determined, and, therefore, this will be taken into account when the recommendations are made.

The type of equipment to be operated by the electrical current is, also, a factor, and it is well to remember in this connection that any electrical apparatus having heating elements, such as light bulbs and heaters, may be operated by either Alternating or Direct Current. On the other hand, any apparatus operated by electric motors must be equipped with either Alternating Current motors or Direct Current motors as it is substantially true that it is impossible to have a motor that will operate on both A.C. and D.C. current.

If your buildings are already furnished with Alternating Current equipment it is a very deciding factor in the selection of the generator, irrespective of the distance the current must be transmitted. But, if this apparatus is yet to be purchased, consideration may be given to the selection of a Direct Current generator and equipment to suit. Direct Current generators are generally less expensive than the A.C. type, and, if wound in a certain specific manner for constant voltage, expensive governing equipment for the turbine equipment may be omitted.

For additional information on this subject please write to any of the principal electrical manufacturers, or confer with your local electrician.

TYPES AND STYLES OF TURBINES

THE JAMES LEFFEL & COMPANY, with main office and factory located at Springfield, Ohio, having manufactured turbine water wheels since 1862, have many lines of patterns from which a selection may be made to fit practically every condition of installation. We are prepared to furnish turbines developing fractional horsepower up to thousands of horsepower, and these are made in many different styles to meet the requirements of our customers.

No inquiry is neglected regardless of the size of the equipment involved, and each and every inquiry is given prompt and careful attention. We earnestly desire that the party making inquiry correspond with us freely, and we will do everything within our power to advise and counsel him to the end that when the plant is completed it will be a thing of usefulness and not a failure. We urge you to accept our advice and suggestions BEFORE work is started. Altogether too many people have come to us for advice AFTER they have attempted to make an installation, relying on their own limited knowledge of an art that is highly specialized. They have nothing to their credit but failure, loss of time and much money which, if properly directed in the beginning, would have spelled success.

The successful completion of a waterpower plant is not a difficult problem if it is properly engineered in the beginning. If the owner will realize that the problems confronting him are of an unusual nature and that to solve them properly requires special training, he will not start construction or expend his resources without proper advice.

We have endeavored to show in this pamphlet what information we must have in order to properly advise those who are contemplating the construction of small water power plants, and, on receipt of this information, we will promptly advise the amount of power that may be developed, together with a suggestion as to the type and size of turbine that would best suit the conditions. Quotations on the equipment will also be given at the proper time.

At this point we might describe in detail the various types and styles of turbines which we are in position to furnish, but to do so would have a tendency to confuse and we would, therefore, prefer to dwell on this matter at length after the first preliminary information is at hand which is covered in this pamphlet. We will, however, describe briefly a few of the more common types of turbines and their application.

A turbine water wheel is a device for transforming the energy of falling water to power in a form which may be applied to the driving of machinery, electrical or otherwise. The empounded water back of the dam flows into a flume or penstock which is built into the dam, and from thence, it flows through the turbine and into what is known as a discharge pit, or tail race, eventually reaching the stream again below the dam.

Attached to this pamphlet is a special, illustrative page entitled "IMPROVED VERTICAL SAMSON TURBINES" and if this page is referred to it will be noted that a turbine consists of three principal parts; the runner and shaft, which are the parts that rotate; the gate or guide casing which contains the adjustable gates for guiding the water into the runner; and the discharge cylinder, or draft tube, which conveys the water to the discharge pit, or tail race, after it has left the runner.

A turbine may be installed in a vertical or horizontal position, but the vertical position (like Design 30) is to be preferred as it is usually more economical and efficient. The illustrative page referred to above shows a typical, vertical, open flume turbine When this type of turbine is installed an extension shaft is attached to the coupling on the top end of the turbine shaft, and on this extension shaft is mounted a pulley for driving a generator by means of a quarter turn belt. Necessary bearings are also mounted on this extension shaft. Examples of quarter turn belt drives may be found in our bulletin No. 38, copy of which will be sent on request.

The flume in which the turbine is installed is usually built of concrete, but sometimes wood or steel is used. An open flume or penstock is one that is open at the top to the atmosphere, and a closed flume is closed at the top which is below headwater level. In this case (closed flume) the extension turbine shaft and the gate operating shaft pass through suitable packing boxes in the top of the flume.

When turbines of small capacity are used under heads of water of about fifteen feet or more, they are often installed in steel or cast iron cases and the water is conveyed to the turbine by means of a pipe made from steel or wood.

In all cases the turbine is fitted with a set of adjustable gates of the wicket type that may be open or closed to any degree from closed position to open position, and they are located in the gate, or guide casing mentioned above. These gates are used to regulate the flow of water through the turbine runner, and thus regulate the power and speed of the turbine.

In many cases the adjustment of the turbine gates is accomplished by means of a suitable handwheel located at a convenient place in the powerhouse, and connected to the turbine gate operating mechanism by suitable shafting. In other cases the adjustment of the turbine gates is accomplished by an automatic governor, which automatically adjusts the turbine gates to maintain a constant speed on the turbine when the load is diminishing or increasing. When used this governor is located in the powerhouse and is arranged in such a manner that the turbine gates may be operated by hand if desired.

Whether or not a governor is needed depends on the size of the turbine, type of load on the plant, type of generator used, and the desirability for good speed regulation. It is also a factor in the cost of the equipment as the governor cost is sometimes as much as that of the turbine equipment if the turbine is small. These as well as related questions are covered in detail when the quotation is made.

In instances where the turbine is installed in concrete or wooden flumes, we consider it our duty and a part of our business to furnish information showing the proper size, or the internal dimensions of such flumes, as it is of the utmost importance that these flumes be built sufficient in size to handle the water without undue loss in head. It is well to note here that the water flowing in the flume flows at a velocity determined by the size or area of the flume, and, as it requires a certain amount of head to produce a given velocity, it follows that the higher the velocity the more head is required to produce that velocity. This head is lost to the turbine and, therefore, does not produce power. It is highly important, therefore, that the flume, pipe line or penstock, as well as all the water passages conveying water to the turbine be designed with ample dimensions, and we do all that is possible to see that this type of construction is carried out. But, all too frequently, we find flumes and penstocks designed and built altogether too small for the size of the turbine installed. The result is that the turbine does not operate under the head expected and the owner is sorely disappointed with the performance of the plant.

TRASH RACKS AND HEAD GATES

To prevent trash and floating material from getting into the turbine and plugging up the water passages with a resultant reduction in power and efficiency, and, also, possible damage to the turbine, it is highly desirable to install at the head of the flume or penstock a suitable trash rack made from steel bars set on edge to the flow of the water and properly spaced according to the size of the turbine. It is usual to design trash racks so that the maximum water velocity does not exceed one and one-half feet per second.

Just back of the trash rack should be installed suitable head gates that may be operated easily to close the water out of the flume or penstock to allow the turbine equipment to be inspected, cleaned, or repaired as the case may be.

We manufacture both trash racks and head gate hoisting equipment and we will furnish further information regarding these items on request.

OLD WATER-POWER PLANTS REMODELED

It often happens that an old, abandoned water-power plant is purchased and it is desired to have it remodeled and brought up to date. In such cases it is well for us to know this in the beginning, as we have records of many of these sites, and such information means a saving not only to the customer but to ourselves as well. Quite often existing structures may be saved, and if the old flumes or penstocks are to be used we should have full information regarding them. In most instances of this kind it is desirable to have one of our engineers visit the site in order to get first hand information and data.

SERVICES OF AN ENGINEER

As mentioned in the above paragraphs, we are prepared to have one of our expert engineers visit the water power site to collect the necessary information and data on existing water power structures to assist in the planning of the application of new turbine equipment. This engineer would also be competent to take measurements of the head and to go over the ground in a preliminary manner, advising to the best of his ability and experience, whether or not the project is practical.

Arrangements for the services of such an engineer may be made on written application to The James Leffel & Company, Engineering Department, Springfield, Ohio.

IN CONCLUSION

We have discussed in a general way in this pamphlet several items of information that should be given us when inquiry is made regarding the possibilities of small water powers and, in conclusion, we will group these items in condensed form on the following page in order that they may be readily taken into consideration and proper reply made.

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Please fill out the attached perforated sheet completely — tear it out and return to —

THE JAMES LEFFEL AND COMPANY
SPRINGFIELD
OHIO

TO:

THE JAMES LEFFEL AND COMPANY
SPRINGFIELD
OHIO

1. Give Head or Fall of water in feet...

2. Give quantity of water available in cubic feet per minute...
....

3. Estimation of number of electrical outlets and electrical appliances to be used...
....
....

4. Give approximate area of pond above dam in acres...

5. Give distance from powerhouse to where electric current will be used...
....

6. Give approximate distance from dam to powerhouse...

7. Will plant be all new or will an old plant be remodeled?...
....

REMARKS AND SKETCHES:

(Signed)...

Post Office...

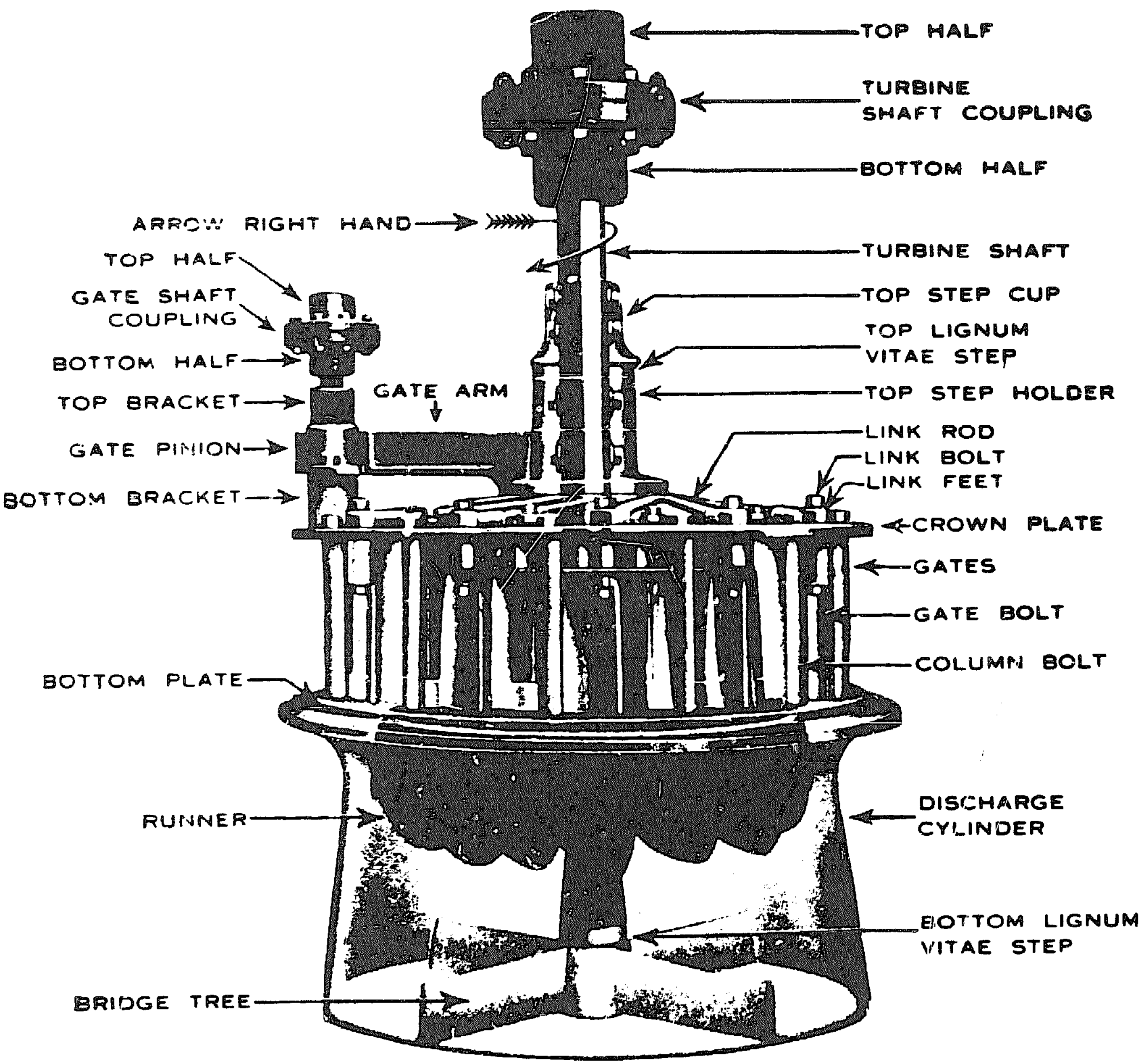
....

Date...

THE JAMES LEFFEL & CO

Improved Vertical Samson Turbines

These turbines are built strong and substantial, and equipped with our exclusive design double steel bucket runners fitted on steel shafts. Large top and bottom lignumvitae step bearings for carrying the revolving parts of these turbines, including the weight of extra upright shafting and gearing. Also, balanced swing-type gates with separate adjustable steel connections. Each gate removable independently. All bearings of large dimensions and special material. Bolted couplings.



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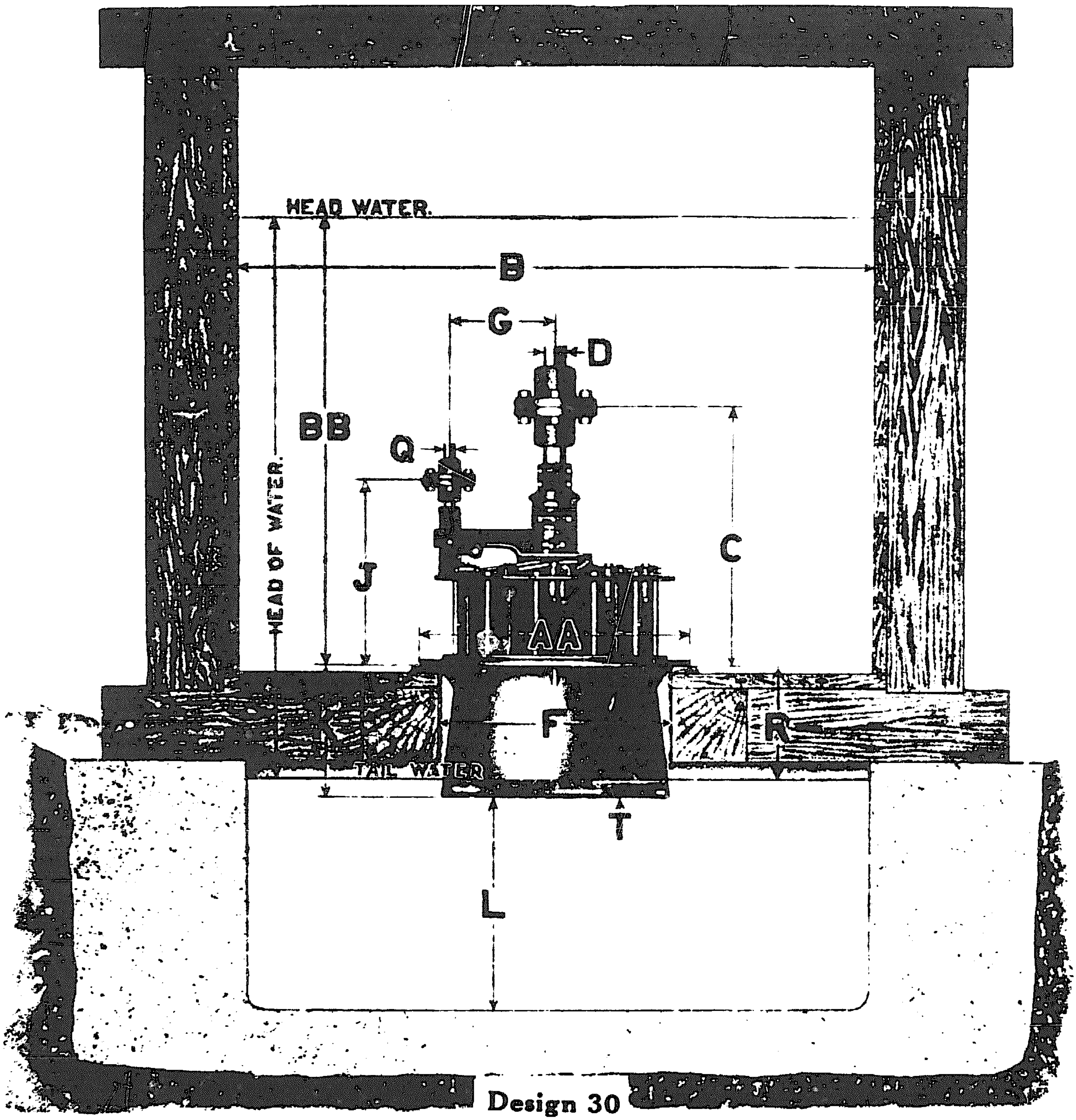

Design 30

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Different Methods With Instructions For Measuring Water

Measuring Flow of Water by Weir Method

After deciding upon suitable location for the new power plant, the following preliminary measurements must be obtained:

FIRST, obtain in feet the head of water. This is the vertical distance from the surface of water above dam down to the tail water surface below dam at the place where turbines will be located.

SECOND, obtain minute cubic feet of water. Several methods may be used, the easiest and most commonly used methods are as follows:

If the stream is large, select place where water flows slowly for some distance between parallel banks and where the bottom of stream is fairly even. Then carefully space and measure the cross sectional area of water in square feet. Then place a float that sinks well down into the water in the center of stream and accurately measure the distance in feet the float travels in one minute. Then multiply this distance by the cross sectional square feet area, and eighty-three per cent of this result will be approximately the minute cubic feet of water flowing in the stream. Or,

If the stream is small the water can be measured by weir. (See the above illustration.) Select first a suitable location in stream where water flows slowly, then place a board with notch in same, forming a weir dam; the down stream edge of weir notch beveled almost to a sharp edge; the width B must be about six times the greatest depth of water flowing over weir. The bottom edge of weir not less than one foot above

Table Giving Minute Cubic Feet of Water 1 Inch Wide Flowing Over Weir

Inches Depth C Over Stake		1/8 Inch	1/4 Inch	3/8 Inch	1/2 Inch	5/8 Inch	3/4 Inch	7/8 Inch
1 Inch	.40	.47	.55	.65	.74	.83	.93	1.03
2 "	1.14	1.24	1.36	1.47	1.59	1.71	1.83	1.96
3 "	2.09	2.23	2.36	2.50	2.63	2.78	2.92	3.07
4 "	3.22	3.37	3.52	3.68	3.83	3.99	4.16	4.32
5 "	4.50	4.67	4.84	5.01	5.18	5.36	5.54	5.72
6 "	5.90	6.09	6.28	6.47	6.65	6.85	7.05	7.25
7 "	7.44	7.64	7.84	8.05	8.25	8.45	8.66	8.86
8 "	9.10	9.31	9.52	9.74	9.96	10.18	10.40	10.62
9 "	10.86	11.08	11.31	11.54	11.77	12.00	12.23	12.47
10 "	12.71	12.95	13.19	13.43	13.67	13.93	14.16	14.42
11 "	14.67	14.92	15.18	15.43	15.67	15.96	16.20	16.46
12 "	16.73	16.99	17.26	17.52	17.78	18.05	18.32	18.58
13 "	18.87	19.14	19.42	19.69	19.97	20.24	20.52	20.80
14 "	21.09	21.37	21.65	21.94	22.22	22.51	22.79	23.08
15 "	23.38	23.67	23.97	24.26	24.56	24.86	25.16	25.46
16 "	25.76	26.06	26.36	26.66	26.97	27.27	27.58	27.89
17 "	28.20	28.51	28.82	29.14	29.45	29.76	30.08	30.39
18 "	30.70	31.02	31.34	31.66	31.98	32.31	32.63	32.96
19 "	33.29	33.61	33.94	34.27	34.60	34.94	35.27	35.60
20 "	35.94	36.27	36.60	36.94	37.28	37.62	37.96	38.31
21 "	38.65	39.00	39.34	39.69	40.04	40.39	40.73	41.09
22 "	41.43	41.78	42.13	42.49	42.84	43.20	43.56	43.92
23 "	44.28	44.64	45.00	45.38	45.71	46.08	46.43	46.81
24 "	47.18	47.55	47.91	48.28	48.65	49.02	49.39	49.76

the surface of water below the down-stream side of weir. Then drive a stake up stream several feet above weir. The top of stake must be exactly level with bottom edge of weir. When all water is flowing over weir, measure the depth C over top of stake, then read above weir table which gives the minute cubic feet of water 1 inch wide flowing over weir. Example: Assume width B of weir as 70 inches, depth C as 12½ inches. Look down the first column in weir table to 12 inches, then horizontally to column under ½ inch. The minute cubic feet flowing over weir 1 inch wide, 12½ inches deep will be 17.78 multiplied by 70 inches, the result is 1244.60 minute cubic feet flowing over weir.

The horsepower of the minute cubic feet of water thus obtained for any head up to 50 feet given in power tables, pages 10 to 13, inclusive.

If water is measured by miner's inch method, give us the number of miner's inches of water per minute, together with the head of water. We then will advise the horsepower that can be developed by our turbines.

Send us full measurements and particulars regarding proposed new turbine installment. We will reply promptly with full information.