SurvivalRing

Study Yesterday . . Prepare Today . . Live Tomorrow

This digital document created and presented by Richard Fleetwood. He is the founder, author, producer, and webmaster of the **SurvivalRing** *(http://www.survivalring.org)* and **Civil Defense Now!** *(http://www.survivalring.org/cd-main.htm)* websites.

SurvivalRing has as its goal the ideal of being the leading source of survival, preparedness, and self reliance information on the Internet. Linkage, assistance, and creation of digital content in areas that until now have only been hinted at or impossible to find, is being added to everyday via the SurvivalRing website and email lists.

Thousands of hours of searching, writing, and communications have been spent collecting over 2 gigabytes of digital content, as well as tens of thousands of pages of hard copy original public domain material in the areas of civil defense, survival, training, and preparedness, from all over the globe. As much as possible is being put online at his website at
http://www.survivalring.org

Civil Defense Now!
Part of The SurvivalRing website

The content of THIS file, while created from PUBLIC DOMAIN material, produced by the U.S. (or other) Government at taxpayer expense, is presented in THIS digital format, produced from the ORIGINAL hardcopy document, for the benefit of all mankind, in hoping to help spread the idea of PREPAREDNESS for any and all threats that may come from either natural, extraterrestrial (space based), or manmade sources.

There are too many situations and incidents that can come to pass in everyday life, that when time is taken to learn and skills obtained, can mean the difference between life and death. Sept. 11, 2001 proved to the world that no matter how safe a person thinks they may be, death and injury can come from the most UNLIKELY place, at any time. The documents presented in this series of digitized works, can help the average person with the knowledge within, to know how to save those persons closest to them in REAL disaster. Help spread this idea of sharing SURVIVAL INFORMATION.

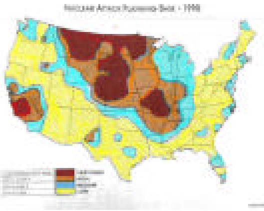
If you have documents from any era, on any disaster or civil defense area, PLEASE contact Richard at his email address of **RAFLEET@AOL.COM**. Check the website for the LATEST additions to the CIVIL DEFENSE NOW online library archive. All data online, and much more, is also available on CD-ROM. Information is available at the website on how to obtain it. Thanks for your support, and enjoy the information contained on the following pages. Share them with those who will learn from them and teach what they know to others.

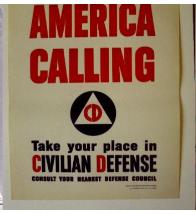
Donations of U.S. or other civil defense documents, articles, books, videos, digitized ephemera, patches, tools, photos, or anything of this nature is appreciated, as well as cash gifts or donations to support the website costs and bills. Address information is available on the homepage of Civil Defense Now! (URL located above)

- Richard Fleetwood – January 2002 — ALL RIGHTS RESERVED –

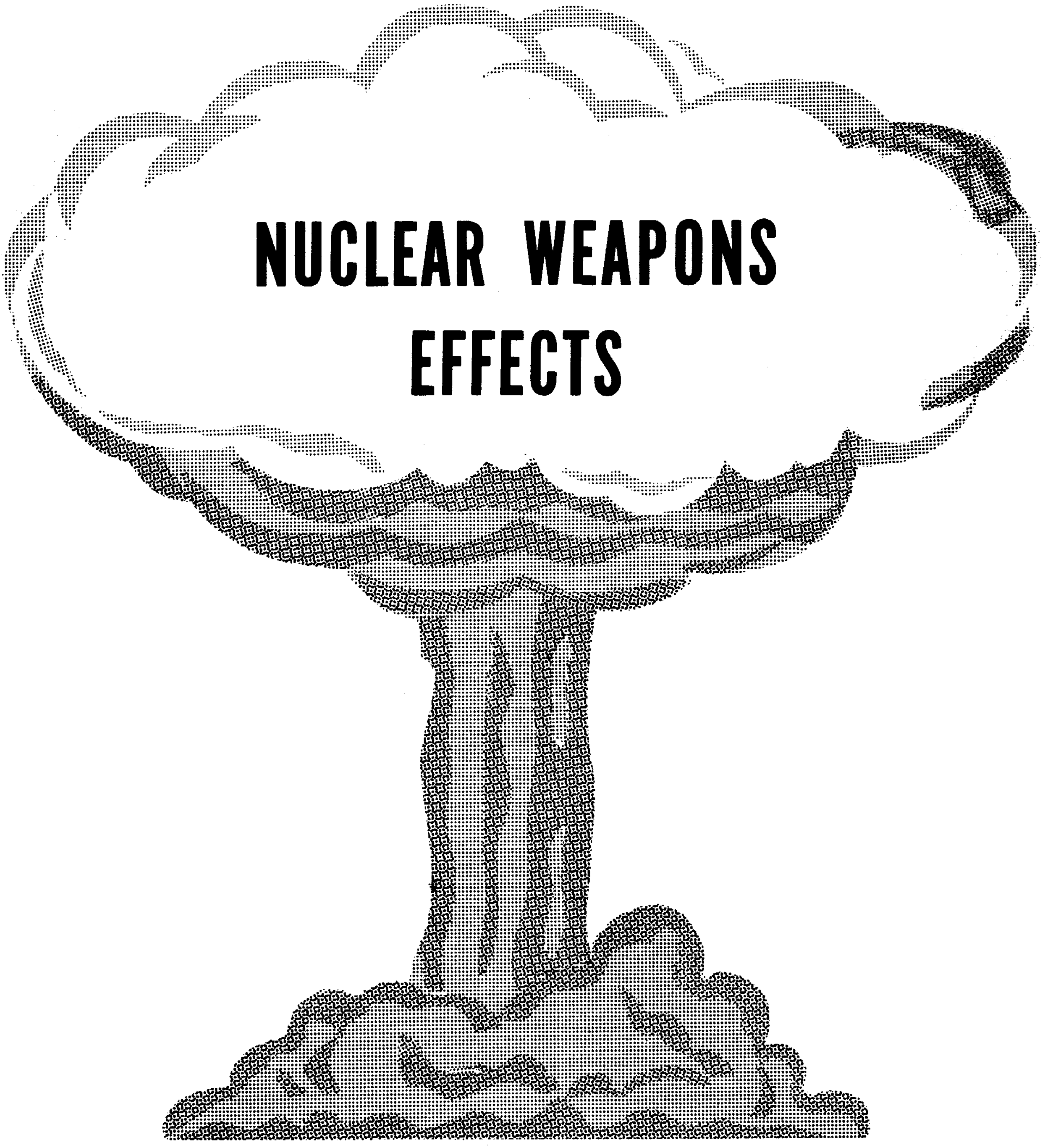
This document may NOT be reproduced commercially on any media WITHOUT EXPRESSLY WRITTEN permission from the creator of this digital presentation. Educational Institutions MAY use this material in any way needed.

Permission granted to individuals for PERSONAL USE ONLY.





NUCLEAR WEAPONS EFFECTS



PREPARED FOR
EMERGENCY MEASURES ORGANIZATION
PRIVY COUNCIL OFFICE, OTTAWA
BY
DR. E. E. MASSEY
DEFENCE RESEARCH BOARD

EMO MANUAL No 3

NUCLEAR WEAPONS EFFECTS

PRODUCED FOR

EMERGENCY MEASURES ORGANIZATION

BY

DR. E.E. MASSEY

DEFENCE RESEARCH BOARD

(THE DATA CONTAINED HEREIN ARE TAKEN
MAINLY FROM "THE EFFECTS OF NUCLEAR
WEAPONS" WASHINGTON 1962 EDITION.)

MAY 1963

Cat. No: S83—2/3

ROGER DUHAMEL, F.R.S.C.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1963

NUCLEAR WEAPONS EFFECTS

INTRODUCTION

A considerable need has existed for an authoritative publication on nuclear weapons effects that could be read and understood by non-technical emergency measures and civil defence planning officials. Existing publications in this field may have been too vague or too complicated for the average reader.

This manual was prepared by the Defence Research Board at the request of the Emergency Measures Organization to fill this need. While it is not intended that this manual be a substitute for such publications as the "Effects of Nuclear Weapons" which is published by the U.S. Atomic Energy Commission for highly qualified technical readers, it is hoped that it will provide sufficient up-to-date and accurate information for those engaged in emergency planning.

Ottawa, Ontario
March, 1963.

Privy Council Office (EMO)

NUCLEAR WEAPONS EFFECTS

Table of Contents

TABLES

NUCLEAR WEAPONS EFFECTS

Dr. E.E. Massey

DEFENCE RESEARCH BOARD

(The data contained herein are taken mainly from "The Effects of Nuclear Weapons",
Washington, 1962 Edition)

1. Nuclear explosions range in energy release (or "yield") from a few tons, through kilotons (1 kiloton = 1,000 tons) to many megatons (1 megaton = 1,000,000 tons) equivalent of TNT. One kiloton is arbitrarily defined as being equal to

10^{12} calories

which equals

4.2×10^{19} ergs
= 3.1×10^{12} ft. lbs.
= 1.15×10^{6} kwh
= 1.8×10^{9} b.t.u.
= energy of 350 tons coal, and comes from the fission of
1.45×10^{23} nuclei

or about 2 ounces of U or Pu.

2. To those who have not seen one of these explosions, figures and units mean very little. The Nagasaki bomb was rated at 20 kilotons. How much energy is 20 kilotons? Perhaps one of the more meaningfull statements is to say that this amount of energy suitably applied could raise a ship the size of the Queen Mary to a height of seventy miles. A 20 kt bomb releases ten times as much energy as the explosion of the ammunition ship Mont Blanc, which was carrying 2000 tons of TNT, and which all but destroyed Halifax in 1917.

3. Extending this analogy, one megaton would be represented by the explosion of a line of such ships stem to stem and extending for twenty miles. Even so, this is small compared with the energy released in some natural phenomena. It has been calculated that this is sufficient energy to keep a hurricane in business for about twenty seconds. The Operation Ivy test of November 1952 lifted 1/80 cubic miles of coral sand – the Krakatoa (East Indies) volcano, in 1883, lifted 13 cubic miles. Much larger quantities of material have been ejected in some less well known volcanic eruptions.

4. It must be understood that there are always uncertainties in any quantitative data given for specific weapons effects. Firstly, there are inherent difficulties in making exact measurements because, even in tests, all conditions cannot be controlled. Then, two weapons of the same yield may have different effects, because of differences in design. Uncertainties are introduced by the conditions of burst: height, ground type, terrain, weather; and by the nature of the attack, as well as by the characteristics of the target complex: kind and density of buildings, distribution of people. Hence, only very approximate data should be used in planning. With this limitation, it is possible, knowing what one size weapon will do, to estimate the effects of a different size weapon. This process is called "scaling".

5. It is convenient to consider weapons effects under four headings:

Blast
Thermal Radiation
Initial Nuclear Radiation
Residual Nuclear Radiation

6. These will be discussed in turn. Their relative effectiveness for various types of burst is indicated in Table I of the Appendix.

Air Blast

7. The high temperature of the fireball of the explosion heats the adjacent air to such a degree that its rate of expansion produces a shock wave which travels in all directions from the point of burst.

8. The damage resulting from the air blast of the shock wave may be brought about in two ways. First there is the sudden increase in pressure when the blast wave arrives. The pressure rises almost instantaneously to a value called the "peak overpressure" and then gradually falls off, the time taken for the pressure to return to atmospheric being longer at greater distances from the explosion, and for larger yield explosions.

9. The peak overpressure in the blast wave before it strikes anything is described as the "incident peak overpressure". When it meets a surface reflection occurs, and the pressure, now called the "reflected overpressure", is increased as indicated in Table VII. This occurs with each reflection.

10. As the blast wave engulfs a structure, pressure differences act upon it to crush or deform it. This is called the "diffraction effect" or "diffraction loading" and the degree of damage depends on the magnitude of the peak overpressure (See Appendix, Tables II, VIII).

11. Secondly, immediately following the shock front of the blast wave there is a strong wind (Appendix, Table IV) which lasts as long as the pressure is above atmospheric. This results in the application of a dynamic pressure (Table III) for as long as the wind blows. The long duration (Table VI) of this wind is one of the important differences between large nuclear blasts and smaller high explosive blasts. The effect on structures is called the "drag" effect. Whether the diffraction or drag effect dominates in causing damage to a particular structure depends on the size and shape of the structure and whether it is anchored down. Anything which is not anchored down, or which has relatively slender structural members, will respond predominantly to drag; such targets are poles, towers, truss bridges, steel frame buildings with frangible walls, vehicles and people. Houses, as well as more massive structures, respond mainly to the diffraction effect.

12. The following shows how the distance to produce a particular effect scales with the yield of the weapon.

Structure **	Degree of Damage	Range of effects for airburst* weapons of		
		1 Kt	1 Mt	8 Mt
1. Wood frame houses	Moderate (wall framing cracked, roof badly damaged, interior partitions blown down)	3500 ft (⅔ mile)	35,000 ft (7 miles)	70,000 ft (14 miles)
2. Multistorey wall-bearing bldgs, apartment house type	Moderate (walls badly cracked, interior partitions badly cracked or blown down)	2500 ft (½ mile)	25,000 ft (5 miles)	50,000 ft (10 miles)
3. Multistorey steel frame office bldgs with light curtain walls	Severe frame distortion, incipient collapse	600 ft (1/10 mile)	10,000 ft (2 miles)	22,000 ft (4 miles)
4. Vehicles	Need major repairs	1200 ft (¼ mile)	18,000 ft (3½ miles)	40,000 ft (8 miles)
5. Telephone lines (transverse to direction of blast.)	Blown down	1300 ft (¼ mile)	21,000 ft (4 miles)	50,000 ft (10 miles)

* For ground burst weapons multiply these ranges by ¾.

** Numbers 1 and 2 are diffraction type targets, while 3, 4 and 5 are drag type targets.

13. The distance at which a specific peak overpressure is produced is proportional to the cube root of the weapon yield. This is shown in the damage distance for a "diffraction" target. Drag damage depends not only on the pressure but upon the length of time the pressure is applied. This duration also scales according to a cube root law so that for larger yields damage distances are greater than would be predicted by scaling pressure alone. This is reflected in the damage distances given.

14. Air blast, as such, is not an important direct cause of casualties. Blast casualties result indirectly by collapsing buildings, flying debris, or by bodily displacement. Table XII compares the expected biological effect of various overpressures with structural damage for the same pressure levels.

15. The probable effects of flying debris (missiles) may be deduced from Tables XIII and XIV.

16. For translational injuries the evidence indicates that impact with a hard object at less than 10 feet per second is unlikely to produce a significant number of serious injuries; between 10 and 20 feet per second some fatalities may occur, and above 20 feet per second the probability of fatal injury increases rapidly with increasing velocity. At 5 miles from an air burst 1 mt weapon a 165 lb man attains a velocity of just over 20 feet per second after a displacement of 10 feet.

17. From a consideration of the mechanisms by which casualties are caused, it follows that, even where structural damage may be considerable, blast casualties can be greatly reduced by taking cover against collapse of buildings, flying debris and high winds.

18. There is some delay between the explosion and the arrival of the blast for the same reason that there is a delay between a lightning flash and its thunderclap. The shock wave travels somewhat faster than the speed of sound. It is thus possible under many conditions for people in the open to increase their chances of survival in the interval between the explosion and the arrival of the blast wave.

Ground Shock

19. A weapon burst near the ground surface will cause some ground shock and produce a crater. The ground shock may cause some damage to below ground installations as shown in Table XI. Crater dimensions for surface burst are given in Table X.

Explosions in Water

20. Bursts in water will generate a shock wave which travels through the water, and is called a "water shock". It can cause damage to the hulls of vessels and to their contents. In addition water waves are started which travel considerable distances and may cause damage by flooding. Heights of waves are difficult to predict. They depend, not only on the size of the weapon but, in addition, to the depth of water and the depth of burst. Waves are smaller for bursts in shallower water. The depth of flooding they cause depends on the composition and contour of the bottom near the shore, and the angle of incidence of the approaching wave, but under the worst conditions flooding depth can be twice the height of the approaching wave. Wave heights resulting from underwater nuclear bursts are given in Table XXVI.

Thermal Radiation

21. Starting at the moment of the explosion, considerable heat is given off. This thermal radiation travels with the speed of light; indeed it behaves essentially like light in all respects. The length of the effective thermal pulse increases with energy yield.

For 1 kiloton it is roughly 0.3 seconds.
10 megatons it is roughly 30 seconds.

22. Because the thermal radiation is so similar to light in behaviour it can be stopped by any opaque material. Moreover, variations in atmospheric conditions – clouds, haze, fog – will modify the heat radiation in exactly the same way they modify sunlight. Because of this it is impossible to predict exactly what will happen in any particular city if attacked.

23. As might be expected, the larger the weapon the greater the thermal energy emitted, and at a point at any specified distance from the point of burst the total quantity of heat delivered is roughly proportional to the yield of the weapon for the same atmospheric conditions. Hence, if a 1 kt bomb delivers 1 calorie per square centimeter at 1 mile from the point of burst, a 100 kt bomb would deliver 100 calories per square centimeter at the same distance under the same conditions. What happens to a surface which receives thermal radiation depends upon how much thermal radiation it receives and how fast it receives it.

24. The sun delivers roughly about 2 calories per square centimeter per minute to the earth. The four calories delivered in two minutes by the sun have a decidedly warm feeling, but that is all. Delivered in 30 seconds by a 10 mt explosion 4 calories per square centimeter causes a first degree burn, and delivered in 0.3 seconds by a 1 kt explosion it causes a second degree burn.

25. Distances to which burns can be expected from various yield weapons are given in Table XVI. The heat of the sun starts few fires, but 4 calories per square centimeter from a 10 mt explosion ignites shredded newspaper, and from a 1 kt explosion it will ignite dry rotted wood (Table XVII). The potentialities for starting fires will be apparent from Table XVIII. All fires start as small fires, and, if unchecked within a few minutes, many fires may merge to produce larger fires. If building densities are sufficiently high, large fires may merge into mass fires of fire storm or conflagration proportions. With large weapons, a considerable fraction of a target area is potentially more vulnerable to fire than to serious blast damage (see Table XV), and the possibility of dealing with incipient fires is very real in these areas.

26. Calculations of ranges for thermal effects of very large weapons on ground targets lead to overestimates of damage and casualties, because the atmospheric transmission data available are reliable only up to distances as great as half the visibility (see Table XXV).

27. It is important to remember that the thermal radiation is stopped by any opaque material, because the application of this fact can reduce fires and physical injuries very markedly. Fires in inflammable material in building interiors can be prevented by shading the windows with venetian blinds or white-wash, even though the subsequent blast blows out the windows. Many fires can be prevented by removing inflammable trash from back yards – plain ordinary "good housekeeping" in fact. The prevention aspect of defence against thermal effects cannot be emphasized too strongly.

28. Clothing affords some protection against thermal injury. At least two layers of clothing are desirable. Clothing should be loose, the outer layer should preferably be of light colour, and flame retardant treatment is advantageous.

Radiation Effects

29. The particular kind of radiation which is of most concern to emergency planners is gamma radiation. This is much like very powerful X-rays. It travels in straight lines with the speed of light and will readily penetrate opaque materials.

30. When a nuclear device is detonated, gamma radiation is emitted. It is this which is largely responsible for the INITIAL NUCLEAR RADIATION hazard. If people receive enough gamma radiation, they may get sick or even die, but it is important to remember that this gamma radiation does NOT make anything or anybody radioactive. For a 1 mt weapon the gamma dose at 1¾ miles from the explosion would be insufficient to cause sickness in exposed people (Table XIX). With larger and larger weapons the importance of initial radiation becomes less and less by comparison with the blast and thermal effects (See Table XV).

31. Simultaneously with the emission of the initial radiation a large number of radioactive elements are produced by the fission of uranium or plutonium. These compounds are collectively called fission products. At the high temperature of the fireball it can be assumed that all these are vapourized and that as the fireball cools many (but not all) of these substances condense selectively to a fine dust. These dust particles might be comparable in size to the water droplets in the cloud that issues from the spout of a boiling kettle, and, but for other intervention, would fall to the ground just as fast.

32. If larger particles to which the fine dust can adhere become incorporated into the cloud, as, for example, the dirt raised when the explosion occurs near the ground (Table XX), then, because the larger particles fall more rapidly, "early fallout" may occur. This takes place within 24 hours. The area of most serious hazard after a ground surface burst generally results from the fallout of visible particles. Their sizes range from that of fine sand in the more distant parts to that of small marbles, with the biggest ones falling near to ground zero.

33. The dirt raised by a ground surface burst may bring down up to 50 to 70% of the radioactive material in the cloud. The remaining dust may be brought down by rain, weeks, months or years later, almost anywhere on the earth's surface. This is "delayed fallout", and because of the changes it has undergone in the meantime it is not true to say "what goes up must come down". Where early radioactive fallout lands on anything, that thing is said to be contaminated. It is important to distinguish between "being irradiated" and "being contaminated". Survival operations are concerned only with the early fallout, and any further reference in this manual to "fallout" will mean "early fallout".

34. The gamma radiation given off by the radioactive dirt has a range of several hundred feet in air. Therefore, it is not necessary to come into direct contact with the dirt to be subjected to the external hazard from its radiation. It has been estimated that 50% of the dose that a person would receive, if he were standing in a fallout area, would come from more than 50 feet away and 25% from distances in excess of 200 feet.

35. Stopping gamma radiation is not as simple as stopping thermal radiation. More massive amounts of shielding are necessary. A term frequently encountered in discussing radiation shielding is "half thickness layer". This means the thickness of material which reduces the intensity of radiation passing through it to 50% or ½. Two half thickness layers (whether in contact or not) reduce intensity to $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$; n layers reduce to $(\frac{1}{2})^n$.

36. The half value layer of concrete for initial radiation is about 4 inches, and for radiation of similar energy to that from fallout about 2 inches. To be strictly accurate the half thickness layer applies only to a narrow radiation beam from a point source. With residual radiation the major problem is protection from the radiation of scattered dirt over a very extensive surface. It is, therefore, more appropriate to give shielding factors for various structures when the roof and the surrounding ground are contaminated. A number of these factors are given in Table XXI.

37. In addition to gamma radiation, neutrons are emitted at the time of explosion, and fission products emit beta particles. Unfissioned bomb material will emit alpha particles. Neutrons have a somewhat shorter range than gamma radiation, but have similar effects on people, and have the power to make certain substances radioactive. Thus, neutrons contribute to initial radiation, and may contribute to residual radiation if the target is within neutron range of the burst.

38. The range of beta particles is only a few yards in air. Therefore, they contribute mainly to residual activity. There is a risk of burns if beta emitting materials are allowed to remain in contact with body tissue. Alpha particles do not penetrate the skin so they constitute a hazard only when alpha emitters are taken into the body.

39. The protective clothing used in survival operations is to prevent beta emitting dirt from coming into contact with the skin. Since this clothing is made of closely woven cloth it does not protect against gamma radiation. Protective clothing is simply overalls, headgear, gloves and footwear.

40. One prominent feature of radioactivity, which comes about from its very activity, is that it gradually decays. Every radioactive substance has its own rate of decay, which is invariable, and is expressed as the time required to lose half of its activity. This is called the "half life". Examples showing how half lives vary widely from one radioisotope to another are given in Table XXIV.

41. Fission products, being a mixture of many radioisotopes, have no definite half life. The half life increases with age. The decay is more complicated and can, in general, be expressed by the statement: for a sevenfold increase in age the activity of fission products is decreased tenfold. This is a simplification of what is expressed mathematically by the equation:

$$I_t = I_1 \, t^{-1.2}$$

where I_t is intensity at time t_1 and
I_1 is intensity 1 hour after explosion.

42. Putting this into specific values, it means, for example, that if the activity at a certain place at

H + 1 hour is	100	roentgens	per	hour
then at H + 7 hours it will be	10	"	"	"
then at H + 49 hours it will be	1	"	"	"
then at H + 2 weeks it will be	0.1	"	"	"
then at H + 3 months it will be	0.01	"	"	"

This relationship is valid within 25% for times after the explosion between 30 minutes and 200 days, provided there is no change in the quantity of fallout during the time interval under consideration. The formula cannot be used while fallout is still descending, or in overlapping fallout from bursts at different times, or if much weathering has occurred. Hence, in an actual situation the decay rate must be verified by measurement as frequently as possible.

43. It can be seen that the radioactivity falls off during its early life compared to later, hence the relative benefit of only a few hours protection during the early life of the fission products. Fortunately, some of this protection is automatic – much decay occurs before fallout starts, and the further downwind, the greater the delay is before fallout begins.

44. It follows from the decay equation that the dose received by remaining indefinitely at a place where the intensity is I_t at time t will be 5 t I_t. For example, if the activity at a place 3 hours after the burst is 15 roentgens per hour, the dose received between 3 hours and infinity would be

$$5 \times 3 \times 15 = 225 \text{ roentgens}$$

45. In order to determine the hazard at any contaminated place it will be apparent that it is not sufficient to know the dose rate only; one must know, too, the time since zero. This applies whether it is a question of staying where one is, or of going into a contaminated area either to work or to live. To illustrate this point, take the example given above of a dose rate of 15 roentgens per hour at 3 hours after burst. If, at other times of reading, this same dose rate were obtained (at different places, of course) the following lifetime doses would be obtained:

for 15 r/hr at 1 hr	"Lifetime" dose is	75 r
15 r/hr at 3 hrs	" " "	225 r
15 r/hr at 24 hrs	" " "	1800 r

The difference here is rather striking, though perhaps not as realistic as the dose accumulated in say, the next 24 hours. This works out to

15 r/hr at 1 hr	24 hour dose is	37 r
15 r/hr at 3 hrs	" " " "	80 r
15 r/hr at 24 hrs	" " " "	200 r

46. Dosage is accumulated as follows from H + 1 hour onward (in terms of lifetime dose):

From H + 1	to H + 3 hrs	20% of lifetime dose
H + 3	to H + 12 hrs	20% " " "
H + 12	to H + 72 hrs (3 days)	20% " " "
H + 3 days	to H + 6 months	20% " " "
H + 6 months	to Lifetime	20% " " "

Here again the value of protection during the early hours is clearly demonstrated.

47. Protection against the radiation from early fallout can be summed up under three headings:

Distance – The further away the fallout deposit the less is the exposure.
Shielding – The greater the amount of material between oneself and the fallout the less is the exposure.
Time – (a) Duration – The shorter the exposure to radiation the less will be the radiation absorbed.
– (b) Delay – The longer the delay in exposing oneself to fallout radiation the less will be the radiation absorbed for equal duration exposure.

March 1963.

TABLE I

Relative degrees of effects for various burst conditions

(E.N.W. 1962, p. 635)

Burst Conditions *	Air Blast	Ground or water shock	Thermal		Initial nuclear radiation	Early Fallout
			Light	Heat		
High altitude	*		****	**	*	
Air..................	****	*	***	****	****	
Ground surface	***	**	**	***	***	****
Water surface.........	***	**	***	***	***	****
Confined subsurface. . .		****				
Relative importance is indicated by the number of asterisks. A blank means the effect is negligible.						

* *Burst conditions:*

High Altitude: An explosion at an altitude above 100,000 ft.

Airburst: A burst below 100,000 ft. but at such a height that the fireball does not touch the surface of the earth.

Surface burst: A burst at, or slightly above, the surface of water or ground. (Between an air burst and a surface burst there is a transition zone where effects are intermediate between the two).

Subsurface burst: A burst with centre below ground or water.

Confined subsurface: A burst in a subterranean chamber.

TABLE II

Peak overpressures near ground surface

Distance (Miles)	Yield				
	100 Kt	1 Mt	5 Mt	10 Mt	20 Mt
		(overpressure in p.s.i.)			
		Air Burst			
1	15	52	150	>200	≫200
2	5	16	40	60	95
3	2.8	8.5	20	30	44
5	1.4	4	9	13	19
7	<1	2.5	5.5	8	11
10		1.5	3.2	4.6	6
20		<1	1.2	1.7	2.3
30			<1	1	1.3
		Surface Burst			
1	8	38	120	>200	≫200
2	2.3	9	27	44	75
3	1.2	4.3	12	19	30
5	.6	1.8	4.5	7	11
7	<.5	1.1	2.5	3.7	5.5
10		.65	1.4	2.1	3
20		.3	.5	.7	1
30			.3	<.5	.6

TABLE III

Maximum dynamic pressures

Distance (Miles)	Yield				
	100 Kt	1 Mt	5 Mt	10 Mt	20 Mt
		(dynamic pressure in p.s.i.)			
		Air Burst			
1	4	150	≫200	≫200	–
2	.6	5	50	200	>200
3	.2	1.6	7	18	80
5	.05	.4	1.6	3	6
7	.025	.15	.7	1.2	2.4
10		.05	.25	.5	.9
20		<.025	.035	.07	.13
30			–	.025	.045
		Surface Burst			
1	1.3	25	>200	≫200	–
2	.12	1.7	13	35	100
3	.037	.4	3	6.5	18
5	<.025	.08	.4	1	2.2
7		.03	.15	.3	.7
10		<.025	.05	.1	.2
20			<.025	<.025	.025
30			–	–	–

TABLE IV

Maximum wind speed

Distance (Miles)	Yield				
	100 Kt	1 Mt	5 Mt	10 Mt	20 Mt
		(wind in miles per hour)			
		Air Burst			
1	360	2000	≫2000	≫2000	-
2	160	400	1100	>2000	≫2000
3	90	260	450	700	1400
5	48	130	260	340	450
7	34	80	170	240	300
10	<30	51	100	150	200
20			45	60	80
30			30	37	47
		Surface Burst			
1	230	800	1900	>2000	≫2000
2	80	260	600	900	1400
3	45	140	300	450	650
5	<30	63	140	200	300
7		40	85	120	170
10		<30	50	70	100
20			<30	<30	37
30					<30

TABLE V

Times of arrival of peak overpressure

(E.N.W. Table 12.29)

Distance (Miles)	Yield				
	100 Kt	1 Mt	5 Mt	10 Mt	20 Mt
			(Time in seconds)		
			Air Burst		
1	3	2.5	2.0	1.5	<1.5
2	8	6.5	5.5	5.0	5
3	12	11	10	9	9
5	22	20	17	16	15
7		30	27	25	24
10		45	42	40	39
20			95	90	80
30				130	130
			Surface Burst		
1	2.4	1.3	<1	<1	<1
2	7	4.5	3	2.5	1.7
3	12	9	7	5	4.5
5	20	18	14	12	11
7	30	26	25	24	20
10		40	40	35	35
20			90	80	75
30			>100	130	130

TABLE VI

Duration of positive phase

Distance (Miles)	Yield				
	100 Kt	1 Mt	5 Mt	10 Mt	20 Mt
		(Time in seconds)			
		Air Burst			
1	1.1	1.4	1.4	1.4	–
2	1.5	2.3	2.6	2.7	2.7
3	1.8	2.8	3.5	3.5	3.5
5	2.2	3.5	4.5	5	5
7	>2.3	4.0	5.5	6	6
10		4.5	6.5	7	8
20		>5	8	9.5	11
30			>9	11	14
		Surface Burst			
1	1.2	1.4	1.6	1.6	–
2	1.8	2.5	3	3	3
3	2.5	3.3	4	4.5	4.5
5	>3	4.5	5.5	6	6
7		5.5	7	8	8
10		>6	8.5	9	10
20			>10	>14	>16
30				–	–

TABLE VII

Incident & reflected overpressure

Incident p.s.i.	Reflected p.s.i.
200	1200
150	800
100	500
80	370
60	250
40	145
30	100
20	60
10	25
5	13
4	9
3	6.5
2	4.2
1.5	3.2
1	2.1

TABLE VIII

Relations between peak overpressures and structural failure

(E.N.W. Tables 4.39; 12.19 and 4.45)

Structure or structural element	Damage	Approx. overpressure p.s.i.
Glass windows	Shattering; occasional frame failures	0.5 to 1
Corrugated asbestos siding	Shattering	1 to 2
Corrugated steel or aluminum panel	Connection failure followed by buckling	1 to 2
Brick wall panel 8" or 12" thick (not reinforced)	Shearing and flexure failures	7 to 8
Wood siding panels, standard house construction	Usually failure occurs at the main connections allowing a whole panel to be blown in	1 to 2
Concrete or cinder block walls 8" or 12" thick (not reinforced)	Shattering of wall	2 to 3
Wood frame building, residential type	*Moderate:* Wall framing cracked; roof badly damaged; interior partitions blown down.	2 to 3
	Severe: Frame shattered so that for the most part collapsed.	3 to 4
Wall-bearing masonry building apartment house type	*Moderate:* Exterior walls badly cracked, interior partitions badly cracked or blown down.	3 to 4
	Severe: Total collapse of structure.	5 to 6
Multistory wall-bearing building monumental type	*Moderate:* Exterior walls facing blast badly cracked, interior partitions badly cracked.	6 to 7
	Severe: Some of bearing walls collapse.	8 to 11
Reinforced concrete building, concrete walls, small window area	*Moderate:* Exterior walls badly cracked, interior partitions badly cracked or blown down, frame distorted, spalling of concrete.	8 to 10
	Severe: Walls shattered, incipient collapse.	11 to 15
Ten guage corrugated steel arch with 5 feet of earth cover, 20 – 25 foot span.	Collapse	45 to 60
	Deformation and entrance damage	40 to 50
	Damage to ventilation and entrance door	30 to 40
Buried 8" thick concrete arch, 16 foot span, 4 ft. of earth cover	Collapse	220 to 280
	Deformation, cracking or spalling	160 to 220
	Cracking of panels, possible entrance door damage.	120 to 160

TABLE IX

Maximum ranges from ground zero for structural damage from air bursts (Note 1)

(E.N.W. Table 12.21)

Structure type	Damage (Note 2)	Yield				
		100 Kt	1 Mt	5 Mt	10 Mt	50 Mt
			(Distance in miles)			(Note 3)
Wood frame bldgs. residential type	Moderate	3.2	6.6	12	14	25
	Severe	2.4	5.5	9.5	12	22
Wall bearing masonry bldg. apartment house type	Moderate	2.4	4.7	8	10	17
	Severe	1.7	3.5	6.5	8.7	15
Multistory wall bearing monumental type	Moderate	1.6	3.5	6	7.4	13
	Severe	1.3	2.8	5	6.1	11
Reinforced concrete (NOT earthquake resistant)	Moderate	1.5	3.4	6	7.2	13
	Severe	1.1	2.5	4.5	5.9	10

Note 1 For a surface burst the respective distances are three quarters of those for an air burst of the same yield.

Note 2 For explanation of "moderate" and "severe" see Table VIII.

Note 3 The figures given for 50 Mt are extrapolations, and they are less reliable, therefore, than the other figures given.

TABLE X

Crater dimensions for surface burst in dry soil

(E.N.W. Fig. 6.48)

Dimension (apparent)	Yield				
	100 Kt	1 Mt	5 Mt	10 Mt	50 Mt
		(feet)			
Radius............................	300	600	1100	1400	*2300
Depth............................	140	300	500	600	*1100

*These are extrapolated values.

TABLE XI

Damage criteria for moderately deep underground structures

(E.N.W. Table 6.69)

Structural type	Damage	Distance	Nature of damage
Relatively small, heavy, well-designed underground structures	Severe	1¼ app. crater radii	Collapse
	Light	2½ apparent crater radii	Slight cracking severance of brittle connections
Relatively long, flexible structures e.g. buried pipelines, tanks, etc.	Severe	1½ app. crater radii	Deformation and rupture
	Moderate	2 app. crater radii	Slight deformation and rupture
	Light	2½ or 3 app. crater radii	Failure of connections

TABLE XII

Estimated overpressures for direct blast casualties

Peak Overpressure	Biological Effect	Structural Effect
p.s.i.		
5 – 45	1 – 99% ruptured eardrums	Houses collapse at 5 p.s.i.
15 – 25	Threshold lung haemorrhage	Damages reinforced concrete structure
35 – 45	1% Probability of Fatality	Heavy damage to earthquake-proof structures.
45 – 55	50%	
55 – 65	99%	

TABLE XIII

Velocities, masses and densities of fragments

(E.N.W. Table 11.37)

Missile	Peak Overpressure p.s.i.	Median Velocity f.p.s.	Median Mass grams	Max no. per sq. ft.
Glass	1.9	108	1.45	4.3
"	3.8	168	0.58	159
"	3.9	140	0.32	108
"	5.0	170	0.13	388
Stones	8.5	286	0.22	40

TABLE XIV

Probabilities of glass fragments penetrating abdominal cavity

(E.N.W. Table 11.39)

Mass of glass fragments (grams)	Probability of penetration %		
	1	50	99
	Impact Velocity f.p.s.		
0.1	235	410	730
0.5	160	275	485
1.0	140	245	430
10.0	115	180	355

TABLE XV

Weapon effects for air bursts with maximized ranges

(E.N.W. Table 12.18)

Distances from ground zero	Yield				
	100 Kt	1 Mt	5 Mt	10 Mt	20 Mt
½ mile:		*	*	*	*
overpressure (p.s.i.) . . .	46				
thermal radiation (cal/cm^2).	380				
initial nuclear rad^n (rems)	7.6×10^4				
1 mile:		*	*	*	*
overpressure	14				
thermal radiation	91				
initial nuclear radiation	1100				
2 miles:				*	*
overpressure	5.0	16	40		
thermal radiation	21	210	1000		
initial nuclear radiation	1.9	35	300		
3 miles:					
overpressure	2.8	8.6	20	29	44
thermal radiation	9.0	90	500	900	2000
initial nuclear radiation		<1	1	2.6	10
5 miles:					
overpressure	1.4	4.1	9	13	19
thermal radiation	3.0	30	150	300	600
10 miles:					
overpressure	<1	1.5	3.2	4.5	6.5
thermal radiation	<1	6.6	30	66	120
20 miles:					
overpressure		<1	1.2	1.7	2.4
thermal radiation		1.4	7	14	30
50 miles:					
overpressure		–	<1	<1	<1
thermal radiation		<1	<1	1.7	3

* An asterisk means this distance is within or close to the fireball.

TABLE XVI

Thermal effects

(E.N.W. Fig. 11.61; Tables 12.31, 12.34)

Effect	Yield			
	100 Kt	1 Mt	5 Mt	10 Mt
Radiant exposure				
for 1st degree burns (cals/cm²)	2.6	3	3.4	3.6
for 2nd degree burns (cals/cm²)	5	6.5	8	9
Range from ground zero for burns to bare skin from airbursts*:				
for 1st degree burns (miles)	5.3	14	27	>30
for 2nd degree burns (miles)	4.0	11	20	24
Time to second thermal maximum (seconds)	0.3	1.0	2.2	3.2

* For a surface burst the distances are about 4/5 those for an air burst of the same yield.

TABLE XVII

Ignition energv for various materials

(Colour given in brackets)
(E.N.W. Tables 7.40; 7.44)

Material	Ignition Energy	
	20 Kt	10 Mt
Rayon Acetate (wine) 3 oz.	2 cal/sq cm	3 cal/sq cm
Doped fabric aluminized cellulose acetate	18	35
Cotton muslin oiled window shade (green) 8 oz.	5	11
Cotton awning (green) 12 oz.	5	9
Cotton sheeting unbleached (cream) 3 oz.	15	30
Cotton denim (blue) used	8	13
Cotton denim (blue) new	9	14
Burlap heavy woven (brown)	8	16
Newspaper single sheet	3	6
weathered crumpled	3	6
crumpled	4	8
shredded	2	4
Matches paper book heads exposed	5	9
Kraft paper carton (brown)	8	15
Dust mop (oily gray)	3	5
Cotton waste (oily gray)	5	8
Excelsior	5	12
Dry rotted wood punk	4	9
Fine grass	5	10
Fallen leaves	6	12
Pine needles	6	14
Spruce needles	8	17

TABLE XVIII

Frequency of exterior ignition points in a city

(E.N.W. Fig. 7.55, p. 341)

Based on survey of prevalence of ignitable materials found in different districts of a city which will indicate chance of fires starting under ideal weather conditions (3 to 5 cals per sq cm)

Type of Area	Number of Exterior Ignition Points Per Acre
Wholesale district	27
Slum residence	20
Neighbourhood retail	11
Poor residential	9
Small manufacturing	7
Downtown retail	4
Good residential	3
Large manufacturing	2.5

TABLE XIX

Ranges from ground zero for various initial nuclear radiation doses from air bursts (Note 1)

(E.N.W. Table 12.44)

Effect	Yield				
	100 Kt	1 Mt	5 Mt	10 Mt	20 Mt
			(Distances in Miles)		
Radiation dose:					
100 rems	1.3	1.8	2.1	2.4	2.6
500 rems	1.1	1.5	1.9	2.1	2.4
1000 rems	1.0	1.4	1.8	2.0	2.3
Other effects:					
5 p.s.i. overpressure	2.0	4.3	7.5	9.2	12
Second degree burns	4.0	11	19	22	30

Note 1. The distances for a specified radiation dose are slightly less for a surface burst.

TABLE XX

Heights of burst above which negligible early fallout is produced

Yield	Height (feet)
1 Kt	200
10 Kt	500
100 Kt	1,200
1 Mt	3,000
5 Mt	6,000
10 Mt	7,500
20 Mt	10,000

TABLE XXI

Radiation protection factors

(E.N.W. Table 9.139)

Location	Protection Factor*
Above ground areas of light residential structures	2 or less
Partially exposed basements of small 1 or 2 storey houses	2 to 10
Central areas on ground floor in 1 or 2 storey bldgs. with heavy masonry walls.	
Basements without exposed walls of small 1 or 2 storey bldgs.	10 to 50
Central areas of upper floors (but not top floor) of multi-storey bldgs. with light floors and exterior walls	
Basement fallout shelters (frame and brick veneer residences).	50 to 250
Central areas of basements with partially exposed walls in multi-storey (3 to 10) bldgs.	
Central areas of upper floors (but not top floor) of multi-storey bldgs. with heavy floors and exterior walls.	
Basement fallout shelters (heavy masonry residences). Basements without exposed walls of multi-storey masonry bldgs.	250 to 1000
Central areas of upper floors (excluding top 3 floors) of high rise (over 10 stories) bldgs. with heavy floors and exterior walls.	
Underground shelters (3 feet of earth or equivalent). Sub-basements of multi-storey bldgs.	1000 or more

* The "protection factor" is the ratio of the dose which would be received outdoors, without any protection, to that received in the location indicated.

TABLE XXII

Dose rate reduction factors related to dose rate at H + 7 hrs

Time (t)	Factor (f_t)	Time (t)	Factor (f_t)	Time (t)	Factor (f_t)
15 min	0.0196				
30 min	0.0444	7 hours	1.00	2 days	10.0
45 min	0.0750	8 hours	1.18	3 days	16.0
1 hr	0.100	9 hours	1.35	4 days	23.3
1¼ hrs	0.130	10 hours	1.54	5 days	30.0
1½ hrs	0.162	12 hours	1.91	6 days	37.
1¾ hrs	0.196	14 hours	2.29	1 week	45
2 hrs	0.228	16 hours	2.70	2 weeks	100
2½ hrs	0.298	18 hours	3.10	3 weeks	167
3 hrs	0.370	20 hours	3.52	1 month	250
4 hrs	0.519	22 hours	3.92	3 months	1000
5 hrs	0.676	24 hours	4.39	6 months	2170
6 hrs	0.833	36 hours	7.15		

To find dose rate at 7 hours, when dose rate at some other specified time is known, multiply known dose rate by factor for that time.

i.e. $I_7 = I_t \times f_t$

e.g., if dose rate at H + 3 hours is 30 r/hr dose rate at H + 7 will be 30 × 0.37 = 11.1 r/hr

To find dose rate at some other time when I_7 is known, divide I_7 dose rate by factor for required time i.e.

$$I_t = \frac{I_7}{f_t}$$

e.g., if I_7 is 10 r/hr dose rate at 20 hours will be

$$\frac{10}{3.52} = 2.8 \text{ r/hr}$$

To find time by which a required dose rate will be reached find the time factor by dividing H + 7 dose rate by required dose rate i.e. $f_t = \frac{I_7}{I_t}$ then read off from the Table the time corresponding to the factor found e.g. to find when the dose rate will be 3 r/hr if I_7 is 12 r/hr nearest factor in Table is

$$\frac{12}{3} = 4$$

3.92 *corresponding to 22 hours*

TABLE XXIII

Lifetime dose factors related to H + 7 dose rate (I_7 value)

Time of Start of Exposure	Factor	Time of Start of Exposure	Factor	Time of Start of Exposure	Factor
15 min	66.0	7 hrs	34	2 days	23
30 min	57.	8 hrs	33	3 days	22
45 min	53.	9 hrs	32	4 days	21
1 hr	50.	10 hrs	31	5 days	20
1¼ hrs	48.	12 hrs	30	6 days	19
1½ hrs	46.2	14 hrs	29	1 week	18
1¾ hrs	44.8	16 hrs	28	2 weeks	16
2 hrs	43.5	18 hrs	27.5	3 weeks	15
2½ hrs	41.5	20 hrs	27	1 month	13
3 hrs	40.	22 hrs	26.5	3 months	11.0
4 hrs	38.	24 hrs	26	6 months	10.0
5 hrs	36.	36 hrs	25		
6 hrs	35				

To find lifetime dose multiply I_7 value by the factor given for particular start of exposure.

e.g. Lifetime dose for exposure starting at H + 18 in an area where the I_7 value is 3 r/hr is
3 × 27.5 roentgen
= 82.5 r

To find dose accumulated in a specific interval of time subtract lifetime dose for end of exposure from lifetime dose for start of exposure.

e.g. Dose accumulated between H + 18 and H + 24 hours where I_7 is 3 r/hr
Lifetime dose from H + 18 = 82.5 r
" " " H + 24 = 78 r
dose accumulated between H + 18 and H + 24 = 82.5-78
= 4.5 r

TABLE XXIV

Half lives of some radioisotopes

In fission products:	
Krypton – 90	33 secs
Rubidium – 90	2.74 min
Strontium – 90	25 years
Strontium – 89	51 days
Iodine – 131	8 days
Cesium – 137	30 years
Barium – 140	13 days
Others:	
Cobalt – 60	5 years
Tritium	12 years
Carbon – 14	5,700 years
Plutonium – 239	24,100 years
Uranium – 233	1.6 x 10^5 years
Uranium – 235	7 x 10^6 years
Uranium – 238	4.5 x 10^9 years

TABLE XXV

Data for high yield weapons

(U.S. AEC Release Dec 1961)

Effect	Yield (Mt)					
	5	10	20	30	50	100
Severe blast damage from surface burst:						
to residential structures (miles)	6	8	10	12	14	17
to reinforced concrete structures (miles)	4	5	6	7	8	10
Height of detonation above which BLAST damage is insignificant to ground structures (miles)	35	44	50	60	75	100
Thermal effects on clear day of burst below 50,000 ft. (Note 1)						
1° burn exposed skin (miles)	25	35	45	55	70	100
2° " " " "	17	25	32	40	50	70
Height of burst above which thermal effects are negligible to ground targets (miles)	–	–	50	60	75	110
Thermal pulse time to second maximum (secs) (Note 2)	2.2	3.2	4.5	5.5	7.4	10.1
Time for specified fraction of thermal energy emitted: (Fig. 7.91 ENW):						
10% (secs)	2.2	3	4.5	5.5	7.5	10
50% (secs)	6	7.5	10.5	12	17	23
70% (secs)	12	16	22	28	37	50
82% (secs)	25	32	45	55	74	100
Average maximum fireball radius (miles) (E.N.W. p. 77)	1.3	1.7	2.3	2.7	3.3	4.5

Note 1. These distances are most certainly overestimates. The available data on transmission of thermal radiation are unreliable at distances greater than half the atmospheric visibility.

Note 2. Calculated from the equation $t_{max} \approx 0.032 W^{1/2}$ seconds

TABLE XXVI

The wave heights shown in the following table were derived for underwater bursts of various yield weapons when exploded at 85 feet below the sea surface in water which is 100 feet deep.

Wave heights produced by nuclear weapons at specified distances from surface zero

Weapon Size	1 Mile	2 Miles	3 Miles	4 Miles	5 Miles	10 Miles	15 Miles	20 Miles
1 MT..........	21	12	8.7	6.6	5.5	2.9	2	1.6
2 MT..........	25.5	14.3	10.4	7.9	6.7	3.6	2.4	2
3 MT..........	28.5	16.1	11.7	8.9	7.6	4	2.7	2.2
4 MT..........	30	16.9	12.2	9.3	8.0	4.2	2.8	2.3
5 MT..........	32.5	18.3	13.1	10.2	8.6	4.6	3	2.5
10 MT..........	37.7	21.1	15.3	11.8	10	5.3	3.5	2.9
15 MT..........	40.7	22.8	16.6	12.6	11	5.7	3.8	3.2
20 MT..........	45.5	25.5	18.2	14.2	12	6.3	4.2	3.5

Wave heights produced by very high yield weapons

Yield	Water Depth	Depth of Burst	Distance of Burst from Shore	Wave Height at Shore
50 MT.....	1 mile	2700 feet	100 miles	20-50 feet
50 MT.....	1 mile	2700 feet	400 miles	5-12 feet
100 MT.....	over 1 mile	4000 feet	100 miles	28-70 feet
100 MT.....	over 1 mile	4000 feet	1000 miles	3-7 feet
50 MT.....	Very deep	surface	100 miles	1-10 feet
50 MT.....	Very deep	surface	400 miles	3 in –.2½ feet