CIVIL DEFENCE

THE EFFECTS OF AN ATOMIC BOMB EXPLOSION

ON STRUCTURES AND PERSONNEL

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Part I
EFFECTS OF AN ATOMIC BOMB EXPLOSION

1. Introduction

The effects of an atomic bomb burst on structures and persons can be divided conveniently into

(a) Blast effects
(b) Heat effects
(c) Radiation effects

In this pamphlet the importance of these effects is considered in the case of

(i) an air burst bomb
(ii) a ground burst bomb
(iii) an underground burst bomb
(iv) an underwater burst bomb

It is emphasized that the effects indicated are estimates. The actual effects of an atomic bomb explosion will depend on many factors, such as efficiency of the bomb, height (or depth) of burst, topography, meteorological conditions, etc., and these may cause more or less variation in the extent of damage and injury. Moreover, in the absence of any experimental information on the effects of a ground or underground atomic explosion, no quantitative statements on the effects of such explosions are possible.

2. Assumptions

In the following studies the atomic bomb considered is the so-called "Nagasaki" bomb, a plutonium bomb with an energy release equivalent to that from 20,000 tons of TNT. The air-burst bomb is assumed to be exploded at 2000 feet, a height of burst which is claimed to cause maximum damage. The underground-burst bomb is assumed to be exploded at a depth of 40-50 feet, the depth to which a heavy bomb dropped from an aircraft might be expected to penetrate. The underwater-burst bomb is assumed to be exploded in moderately shallow water (approximately 200 feet deep) under conditions similar to those of Bikini.

3. Sources of Information

These notes are based upon material drawn from unclassified American and British reports, and especially the American publication "The Effects of Atomic Weapons". A list of these reports is given as an Appendix to this pamphlet.

Part II

BLAST EFFECTS OF AN ATOMIC BOMB EXPLOSION ON STRUCTURES

4. General

The blast effects on structures are due mainly to air blast in the case of an air-burst bomb; to air blast and some ground shock in the case of a ground-burst bomb; to ground shock and possibly some air blast after an underground-burst bomb; and to air blast and some underwater shock after an underwater-burst bomb.

Some idea of the magnitude of these blast effects can be obtained from the fact that an air-burst atomic explosion over an average built-up area will cause the complete destruction or collapse of practically all structures within a half mile of ground zero (the point on the ground directly below the explosion). It will also cause serious structural damage to buildings within one mile and partial damage to those within two miles of ground zero. Structures still further away will suffer some plaster damage and window breakage.

In underground and underwater burst atomic explosions the distances at which corresponding damage will be caused will probably be respectively 40% and 50% less than the distances given above. For a ground burst explosion the area affected will probably be between that in an air burst and an underground burst explosion, as indicated in Figure 1 of appended charts.

5. Air Burst Bomb

In Sec. 4 consideration was given to the blast effects of an air-burst atomic explosion on an average built-up area. Figure 2 shows the anticipated effect from blast of an air burst bomb on

(a) multi-storey reinforced concrete and steel frame structures
(b) one-storey heavy steel-frame factory structures
(c) one-storey light steel-frame factory structures
(d) load-bearing brick-wall structures
(e) wood-frame structures and homes.

This shows, for example, that the air blast will cause 100% destruction of ordinary homes within one and a half miles of ground zero. Structural damage sufficient to make part of the floor area unusable will occur up to two miles away and moderate plaster damage and 100% window breakage to two and one-quarter miles from ground zero. Light plaster damage and some window breakage will occur even beyond these distances.

6. Ground Burst Bomb

The explosion of a ground burst bomb may produce a crate approximately 300 feet in radius and may cause appreciab ground shock. Most damage, however, will be caused by a blast. Generally speaking, the effects of the air blast will l somewhat less than those indicated in Figure 2.

7. Underground Burst Bomb

An underground burst bomb may produce a crater approximately 400 feet in radius and 100 feet in depth and will cause ground shock similar to that caused by a strong local earthquake. Close to the bomb this shock may cause cracks in foundations and walls, and some listing of buildings. At greater distances it may cause the fall of chimneys and damage to plaster partitions, and to sewer, gas or water mains. As Figure 3 indicates the extent of damage is expected to vary considerably with the type of soil. For example, an underground explosion in sandy soil may cause considerable damage to walls and foundations of buildings within one-third of a mile of ground zero and some damage to plaster partitions and plumbing up to one-half mile. In the case of an explosion in clay soil it is estimated that damage would extend to about one mile and two miles respectively.

8. Underwater Burst Bomb

The air blast from an underwater burst bomb may be expected to cause corresponding damage to adjacent land structures at approximately one-half the distances shown in Figure 2. In addition, the underwater shock, besides causing serious damage to shipping, will cause damage to piers or breakwaters within a half mile of the point of burst. Moreover, the large waves formed may flood and do serious damage to port facilities and warehouses.

ON PERSONS

9. Air Burst Bomb

Many casualties may be caused indirectly through the collapse of buildings and by flying debris and glass although the actual direct effect of blast from the bomb may be small.

Underground shelters will afford good protection against air blast effects. Basements of structures (especially reinforced concrete or multi-storey steel-frame buildings) some distance from ground zero may afford fair to good protection provided precautions are taken against flying glass, debris, etc. There is,

however, the possibility that people may be trapped in the basement by the collapse of a structure and subsequently burned in fires started in the ruins.

Because the blast effects are secondary and depend on so many factors, an accurate assessment of the hazards is difficult. Injuries received by unprotected persons within a half mile of ground zero, however, are likely to prove fatal. In addition there will be severe injuries due to flying debris up to 1½ miles away and occasional casualties from flying glass as far as three miles from ground zero.

10. Ground Burst, Underground Burst and Underwater Burst

Similar results will take place in the case of a ground, underground, or underwater burst atomic explosion except that a ground burst explosion may also cause appreciable direct blast injury to unprotected people near the explosion. Generally speaking, however, the radii of injury from such explosions will be smaller than those given in Sec. 9.

Part III

HEAT EFFECTS OF AN ATOMIC BOMB EXPLOSION ON STRUCTURES

11. Air Burst Bomb

Although the thermal radiation from an air burst bomb may start a few fires in combustible material in structures or wreckage near ground zero, most fires will arise from secondary causes such as broken gas mains, electrical short circuits, overturned furnaces, stoves, etc., following the blast. Once started, these fires will spread to combustible structures or material downwind unless checked by fire fighters or wide fire breaks.

Because so many factors are involved in the starting and spreading of fires, a generalization of the expected fire damage caused by an air burst bomb is of little value. Severe fire damage will probably extend to more than one mile from ground zero, but the limit of fire damage in the absence of wind should be about two miles.

12. Ground Burst Bomb

Similar remarks apply to the heat effects to be expected from a ground burst bomb except that the distances from ground zero at which fires are started will be somewhat less than those indicated in Sec. 11.

13. Underground Burst Bomb

Following an underground burst bomb some fires will be started from secondary causes. The distances from ground zero at which these fires will be started, however, will probably be less than those indicated in Sec. 11.

14. Underwater Burst Bomb

The heat effects of an underwater burst bomb on land structures will, of course, be negligible.

ON PERSONS

15. Air Burst Bomb

All persons directly exposed to the thermal radiation from an air burst bomb within approximately two miles from ground zero will receive "flash burns". The severity of these burns will be greater in clear weather than in hazy weather.

Buildings, walls, shelters, etc., will give complete protection against thermal radiation. Clothing, particularly if light coloured, will give partial or complete protection to the parts of the body covered.

Figure 4 indicates the degree of flash burns expected from an air burst atomic explosion over an industrial city, in clear weather. These effects vary from certainly fatal burns at a half mile from ground zero through third degree burns at seven-eighths of a mile, to insignificant burns at two miles. On a hazy day the radii of flash burn will be approximately two-thirds of those given above.

In addition to the flash burns mentioned above, people trapped in burning buildings or otherwise exposed to fires caused by the atomic bomb will receive ordinary flame burns. Though the number of flame burn casualties will be appreciable, this hazard is difficult to assess.

16. Ground Burst Bomb

With a ground burst bomb in a built-up area, the surrounding buildings may be expected to give protection against flash burns. However, because of the very high temperature in the vicinity of the bomb burst, death or serious injury may be expected up to 500 to 1000 feet from the point of burst.

17. Underground Burst Bomb

The heat effects on people may be expected to be somewhat less than those of a ground burst bomb.

18. Underwater Burst Bomb

The heat effects on people will be negligible.

Part IV
RADIATION EFFECTS OF AN ATOMIC BOMB EXPLOSION

ON STRUCTURES

19. Air Burst Bomb

The radiation effects of an air burst atomic bomb on structures will be negligible.

20. Ground Burst, Underground Burst and Underwater Burst

The radiation from such atomic bomb explosions will cause no physical damage to structures. Some structures, however, particularly after an underwater burst explosion, may be so highly contaminated with radioactive fission products that even though they may be otherwise undamaged, safe occupancy may not be possible for some weeks or until they have been decontaminated.

ON PERSONS

21. Air Burst Bomb

The major radiation effects will result from the extremely penetrating radiation (particularly gamma radiation) accompanying the explosion. They may also be some slight secondary effects from the residual radiation emitted by the highly radioactive fission products though, with an air burst, practically all the fission products will be carried high into the air and later scattered harmlessly at considerable distances from ground zero.

Figure 5 shows the probable radiation effects of an air burst bomb on unprotected persons. These effects vary from practically 100% deaths to distances slightly over half a mile, through 50% deaths at approximately three-quarters mile, to 0% deaths but some radiation sickness at about one mile from ground zero. Beyond one and one-eighth miles, the radiation received will be less than that considered as permissible in an emergency.

Some protection against this radiation will be afforded by materials such as concrete or steel or even earth. Figure 5 shows the degree of protection afforded by different thicknesses of the first two mentioned materials. For example, at a distance of three-quarter mile (where radiation would cause 50% deaths among unprotected persons) approximately 10″ of concrete will reduce the radiation effects to no deaths but some radiation sickness; 19″ of concrete will decrease the radiation dose to that considered permissible in an emergency. The thickness of earth required to give corresponding protection will be one and two-third times that of concrete.

22. Ground Burst Bomb

In a ground burst the penetrating radiation accompanying the explosion of the bomb will be effective to slightly greater distances than those shown in Figure 5. In addition, there will be appreciable residual radiation from—

(a) the quantities of highly radioactive fission products which are not carried high into the air,
(b) material made radioactive by neutrons emitted at the time of the bomb explosion, and
(c) unfissioned bomb material.

These highly radioactive materials will be scattered by the explosion and will contaminate the ground up to a mile or so from the bomb, depending on wind speed and direction. Though passage over the greater part of the contaminated ground may be possible shortly after the explosion, contamination will be very heavy in and near the bomb crater and the radiation emitted by the material will prevent safe occupancy of this area for weeks or months. From the results of the Los Alamos bomb test in 1945, an area within approximately one-quarter mile from the crater will be hazardous for continuous occupancy by personnel not previously exposed to radiation who may enter the area one hour after the explosion. As the Los Alamos bomb was not a ground burst bomb, however, but was exploded at about 75′ above ground, the size of the area may be somewhat in doubt.

23. Underground Burst Bomb

It is probable that the primary radiation effects of an underground burst bomb will be negligible. The earth from the crater, however, heavily contaminated by a high percentage of the fission products and also by material made radioactive by neutrons, etc., will be scattered to a mile or more from ground zero, as explained in Sec. 22. The residual radiation from this radioactive material will be so great in the vicinity of the crater that it will be impossible to approach the crater for weeks or months without serious risk of casualties. The hazard will fall off with distance and probably the area unsafe for continuous occupancy one hour after the explosion will be considerably smaller than after an underwater burst bomb. (See Sec. 24)

24. Underwater Burst Bomb

The primary radiation from an underwater burst bomb will probably be negligible. Most of the fission products, however, together with the radioactive isotopes produced by the action of neutrons will be retained in the water. Many tons of this water will be blasted high into the air in a huge hollow column and as this water falls back the spray will contaminate land areas, structures, etc., within a radius of several thousand feet from the point of explosion.

Under certain conditions, moreover, a highly radioactive cloud or mist some 200 to 300 feet high may be formed at the base of the column. As this cloud or mist (usually called the "base surge") spreads out, unprotected persons will receive heavy doses of radiation. Some of the radioactive material in the cloud may also be precipitated in the form of rain, adding to the contamination of adjacent land areas. The residual radiation from this contamination will cause further radiation injury to exposed persons. The occupancy of highly contaminated areas will be impossible except at the risk of casualties.

The size and shape of the area affected by the passage of the base surge and/or contaminated by radioactive fall-out (rain) will depend on many factors such as depth of burst, depth of water, nature of harbour bottom, wind speed, wind direction, etc. Opinion is not unanimous that the base surge will be formed in temperate regions where conditions differ from those at Bikini.

Figure 6 gives an estimate of the radiation effects on unprotected persons under conditions similar to those at Bikini, where a 5 mph. wind was blowing at the time of the explosion. The left side of the Figure indicates the hazards due to radiation received during the passage of the base surge and that received in the first hour from the radioactive fall-out on the ground. The radiation from the fall-out will, of course, continue after the first hour and will increase the hazard to people remaining longer in the area. The right side of the Figure indicates the residual radiation hazards and the area safe for continuous occupancy by previously unexposed persons who enter the area one hour after the explosion.

APPENDIX I

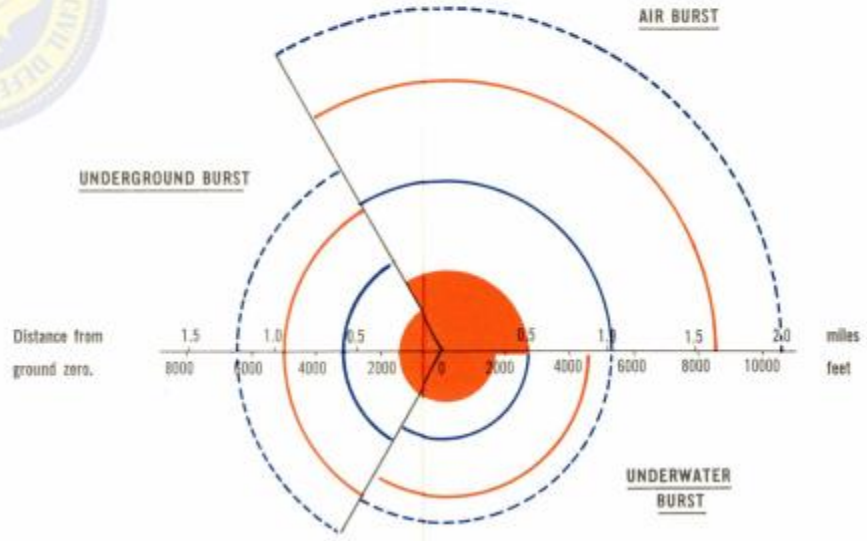
References

1. The Effects of Atomic Weapons — U.S. Government Printing Office, 1950.
2. Medical Aspects of Atomic Weapons — U.S. Government Printing Office, 1950.
3. The Effects of the Atomic Bombs at Hiroshima and Nagasaki — Report of the British Mission to Japan, 1946.
4. The Effects of the Atomic Bombings of Hiroshima and Nagasaki — The United States Strategic Bombing Survey — June, 1946.
5. The Atomic Bombings of Hiroshima and Nagasaki — The Manhattan Engineer District.
6. Blast Effects of Atomic Bombs on Buildings, USAEC Press Release — March 17, 1950.
7. Damage from Atomic Explosion and Design of Protective Structures — U.S. Government Printing Office, 1950.
8. Radiation Safety Measures in an Atomic Energy Plant — Eng. J. *31* 154, 1948.

FIGURE 1

FIGURE 1

BLAST EFFECTS OF AIR BURST, UNDERGROUND BURST AND UNDERWATER BURST ATOMIC EXPLOSION ON A BUILT-UP AREA



LEGEND

Complete destruction or collapse of all structures other than earthquake-resistant reinforced concrete buildings.

Severe damage—major structural damage.

Moderate damage—sufficient to render unusable until repaired.

Partial damage—more severe than merely plaster damage or window breakage.

Light damage (mainly plaster damage and window breakage) will extend some distance beyond radii shown depending on conditions.

FIGURE 2

FIGURE 9

BLAST EFFECTS OF AIR BURST ATOMIC EXPLOSION ON DIFFERENT TYPES OF STRUCTURES

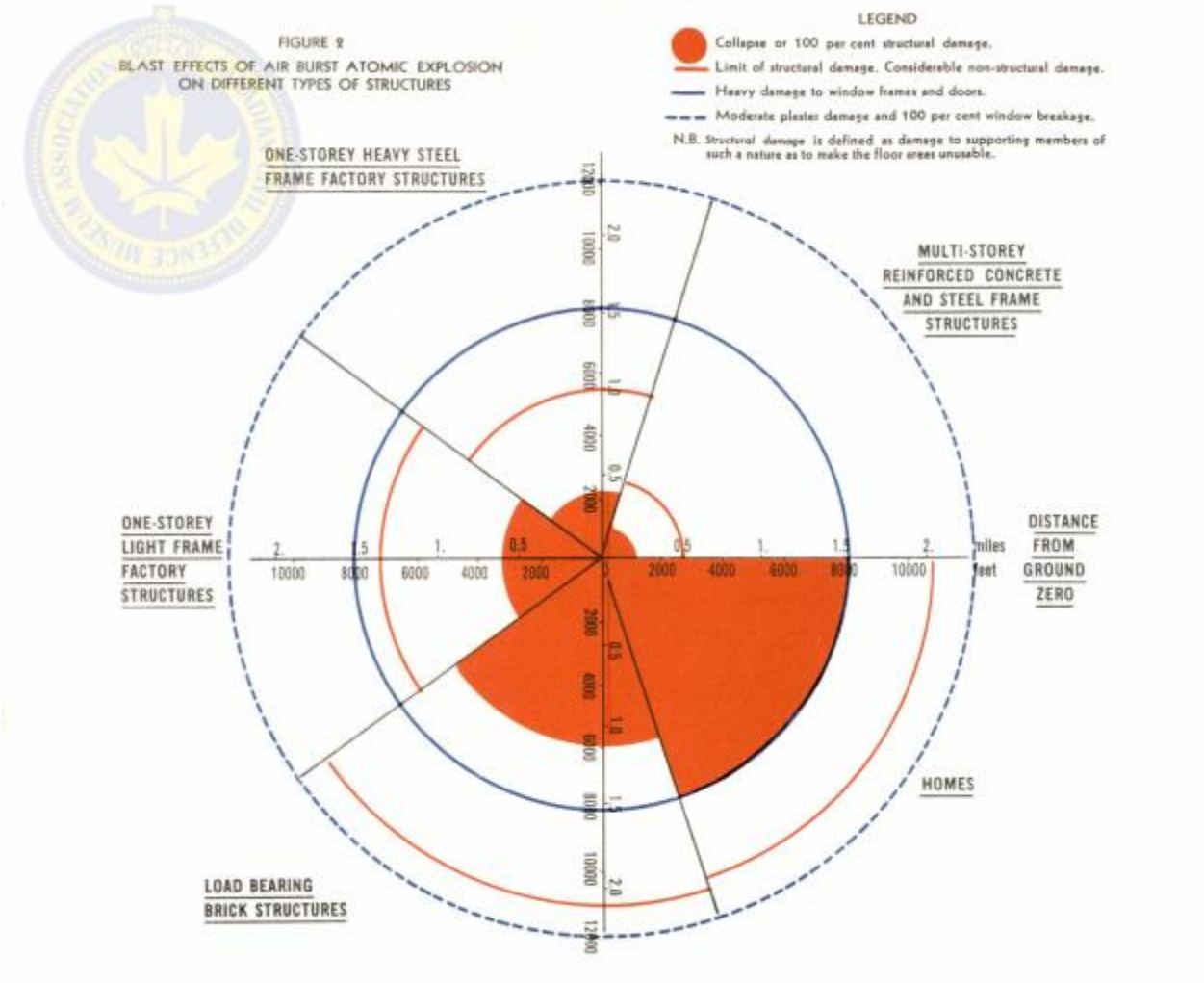
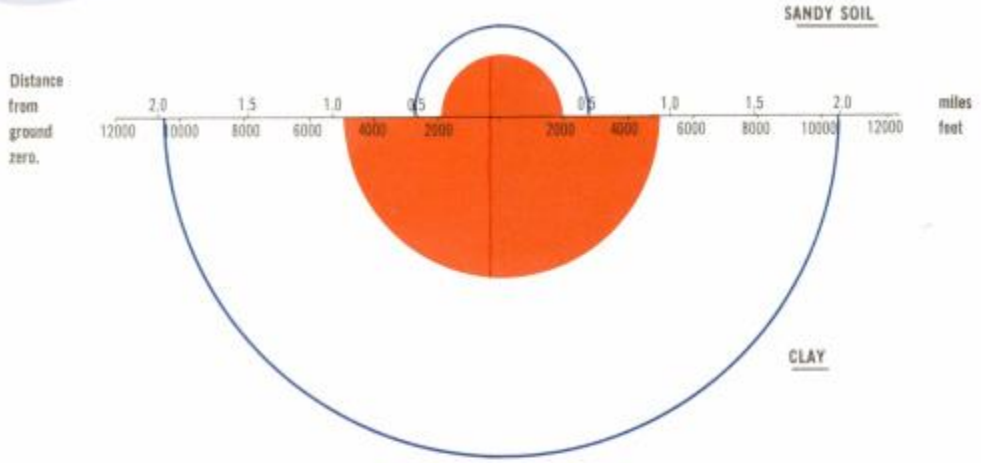


FIGURE 3

FIGURE 3

ESTIMATED BLAST EFFECTS OF UNDERGROUND BURST
ATOMIC EXPLOSION ON STRUCTURES



LEGEND

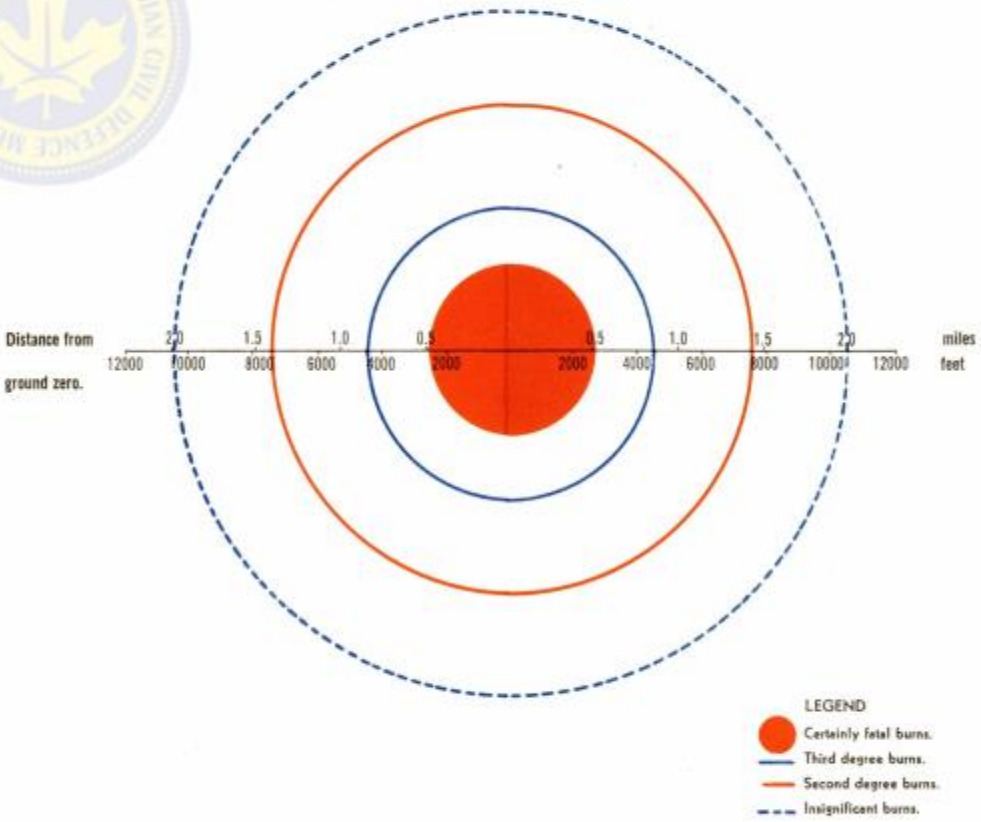
Appreciable damage to walls and foundations.

Light damage—occasional fall of chimneys, damage to plaster partitions and plumbing.

FIGURE 4

FIGURE 4

HEAT (Flash burn) EFFECTS OF AIR BURST ATOMIC EXPLOSION ON UNPROTECTED PERSONS ON CLEAR DAY



Note re Fig. 5

To determine approximate thickness of concrete required to reduce radiation to a lower intensity at any distance from ground zero using Figure 5.

1. Measure off the known distance on the left side of the horizontal scale.
2. Draw a vertical line from this point upwards continuing until it meets the curved line representing the desired radiation level.
3. The figure on the left side of the vertical scale opposite the point where the line drawn (para. 2) cuts the intensity curve is the required thickness of concrete.

Example —

To find the thickness of concrete required to reduce radiation to 25r at 4000 feet from ground zero.

Starting from A (4000 ft.) draw AB vertically till it cuts the 25r curve (B). Read the figure (C) horizontally opposite B, i.e., about 15 inches.

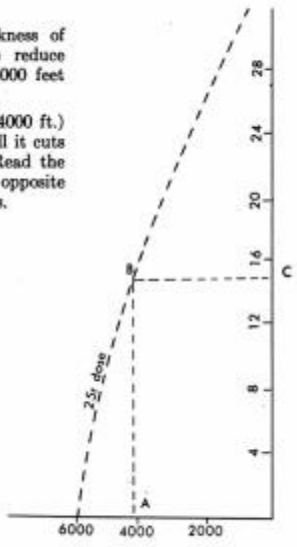
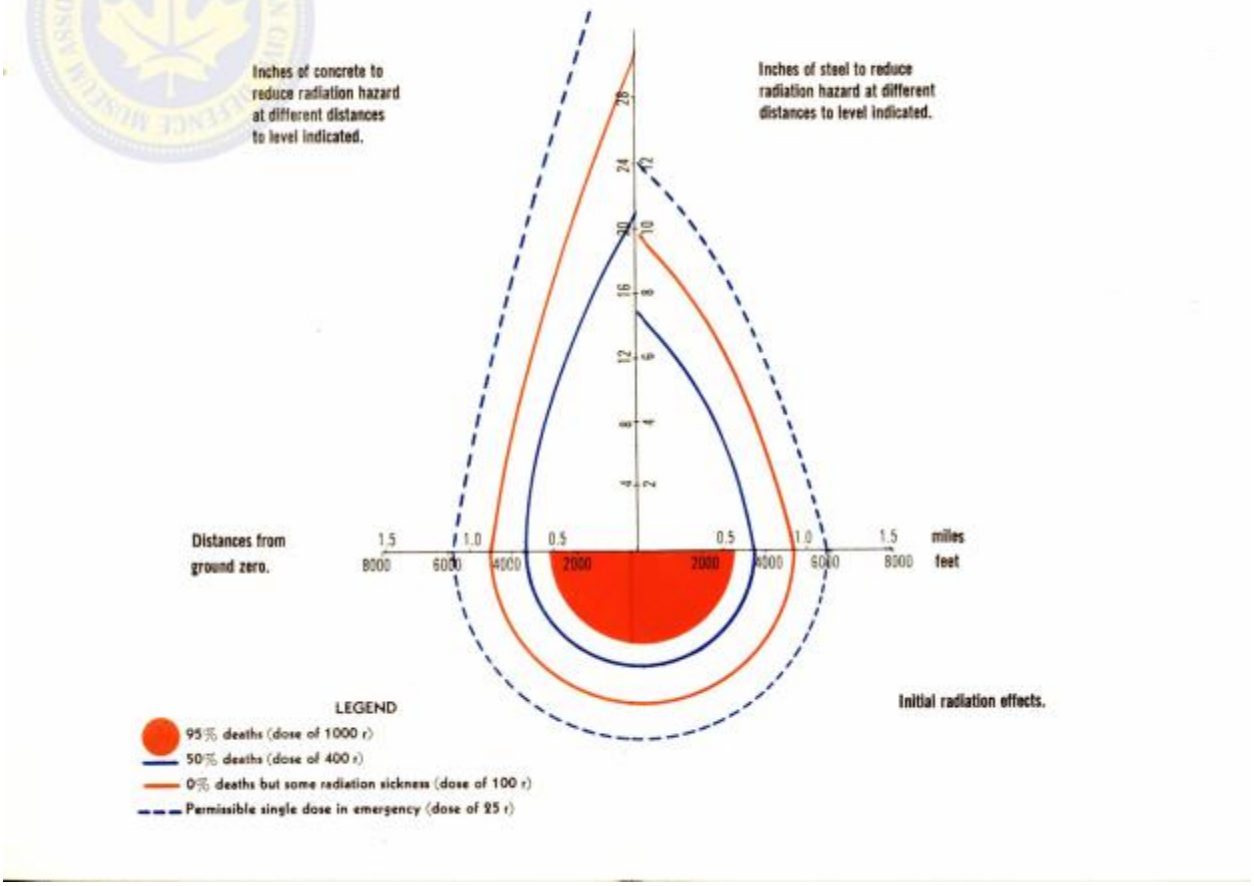


FIGURE 5

FIGURE 5

INITIAL RADIATION EFFECTS OF AIR BURST ATOMIC EXPLOSION ON UNPROTECTED PERSONS (AND PROTECTION AFFORDED BY CONCRETE OR STEEL)



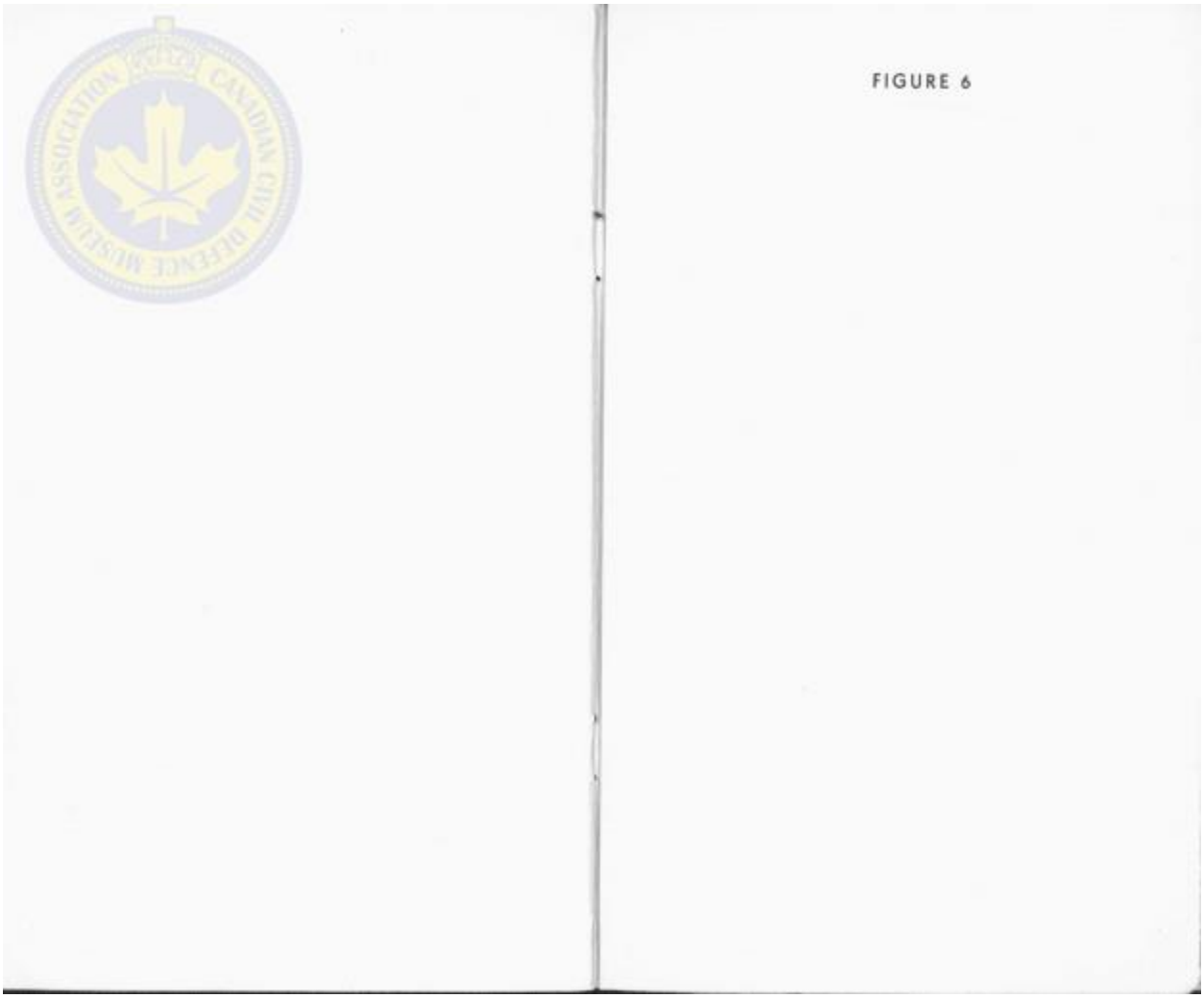


FIGURE 6

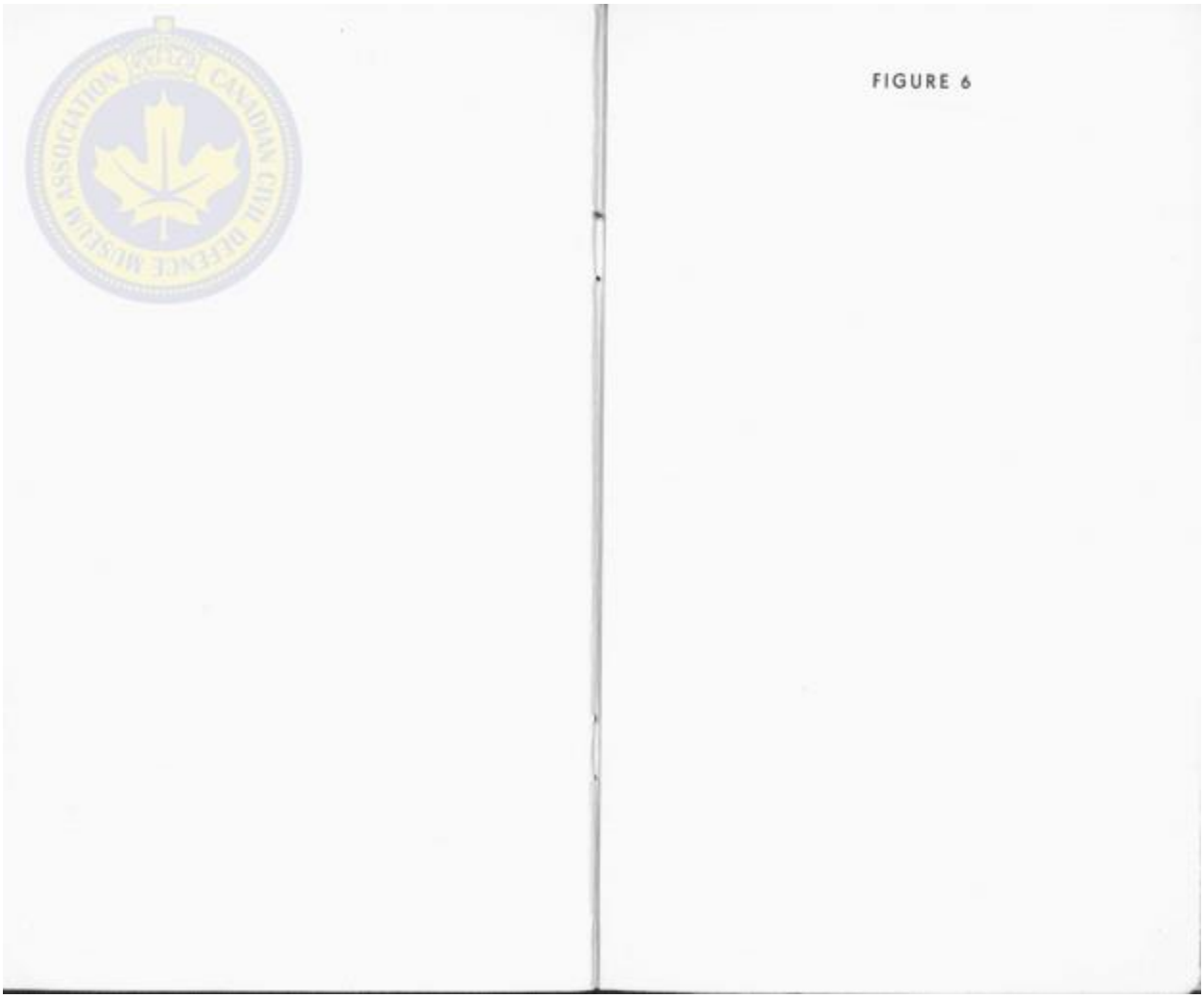


FIGURE 6

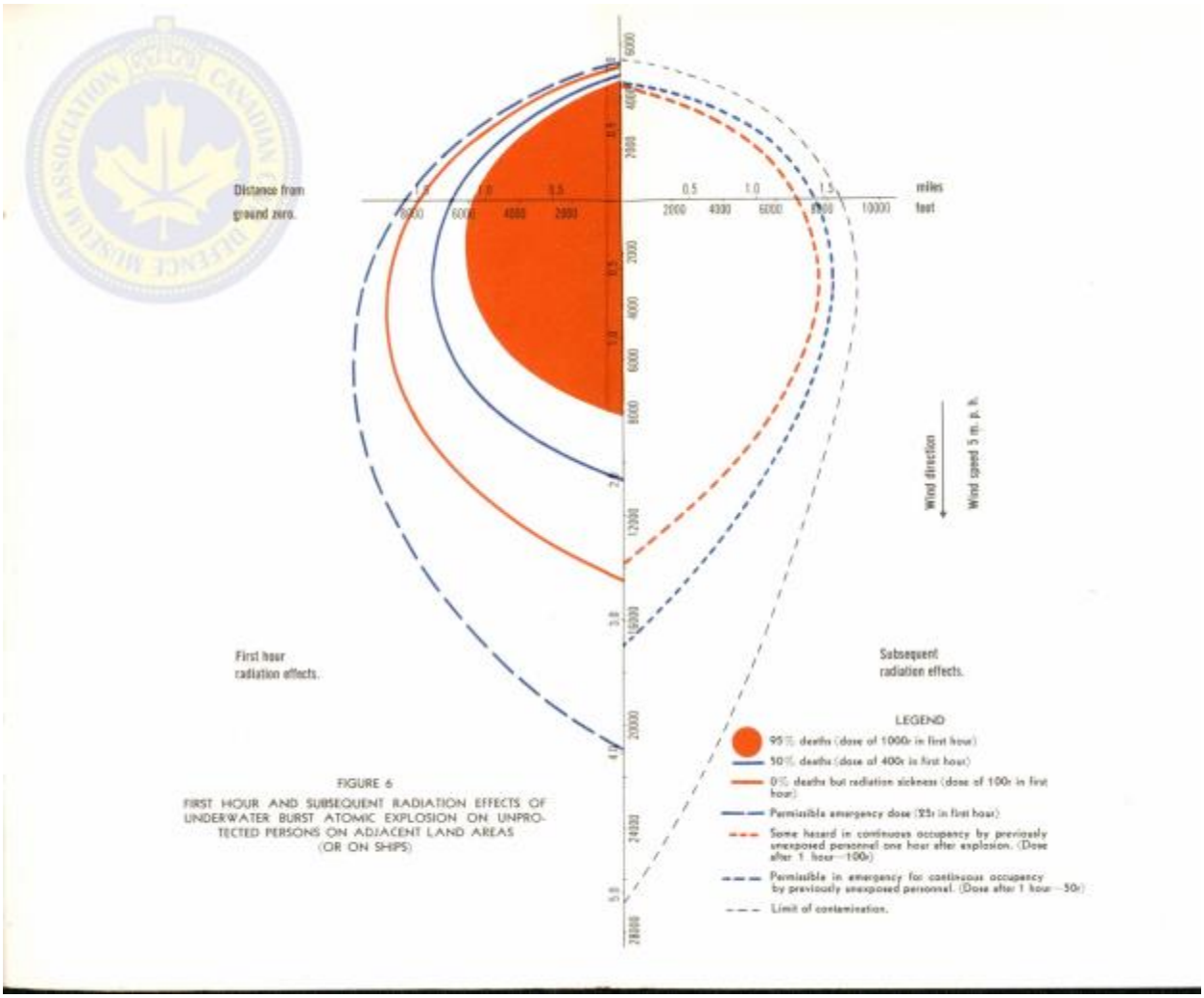


FIGURE 6

FIRST HOUR AND SUBSEQUENT RADIATION EFFECTS OF UNDERWATER BURST ATOMIC EXPLOSION ON UNPROTECTED PERSONS ON ADJACENT LAND AREAS (OR ON SHIPS)

OTTAWA
Edmond Cloutier, C.M.G., O.A., D.S.P.
Queen's Printer and Controller of Stationery,
1953