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PART 4: SECTION 1

CHAPTER 4

NUCLEAR WEAPONS

**Introduction**

1. The fact that a single aircraft can now carry a missile which can cause essentially the same damage as a weight of conventional bombs requiring half a million or more aircraft for their delivery has opened up a new era in offensive warfare. The following paragraphs discuss, in broad outline, some basic considerations of these weapons.

**Release of Nuclear Energy—Comparison of Atomic and Conventional Explosives**

2. The destructive effect of a nuclear weapon, like that of a conventional high explosive weapon, is due mainly to the blast or shock waves which follow the explosion. While in this respect nuclear weapons are similar to, although immensely more powerful than, the weapons which are familiar to us, there are some fundamental differences in other respects.

3. In general the nuclear explosion results from the release of a large amount of energy in a short interval of time within a limited space. The liberation of this energy is accompanied by a rise in temperature, so that the products of the explosion become extremely hot gases. These gases, at high temperature and pressure, move outward rapidly. In doing so they push away with considerable force the surrounding medium—air, water, or earth—thus causing the destructive effects of the explosion.

4. In a conventional or chemical explosion the energy is produced as a result of a rapid chemical reaction, namely, the decomposition of the explosive material. The atoms of the elements forming the chemical compound undergo a rearrangement leading to the formation of a number of new substances. This particular change in arrangement of the atoms is accompanied by the release of large amounts of energy.

5. An atomic or nuclear explosion resembles a chemical explosion in that it is due to the rapid release of a large amount of energy. The difference is that in the nuclear explosion the energy results from rearrangement of the central portion, or nucleus, of the atom itself, rather than of the atoms as in a chemical explosion.

Since the energy changes accompanying nuclear rearrangement are very much larger than those associated with chemical reactions, the force of the explosion is correspondingly greater. The release of this nuclear energy can be accomplished by two diametrically opposed methods—fission or fusion.

**Fission**

6. The materials which have been used to produce nuclear explosions are certain forms (isotopes) of the heavy elements uranium and plutonium. When a neutron, which is an uncharged atomic particle, enters the nucleus of the appropriate atom, it can cause the nucleus to break into two almost equal fragments. Each of these fragments is the nucleus of another lighter element (see Fig. 1). Two or more neutrons

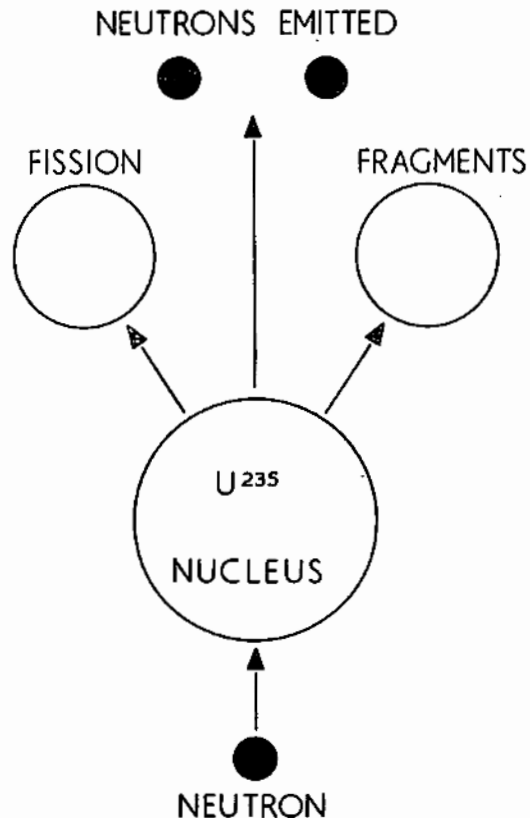


Fig. 1. Fission of Uranium 235 by a Neutron.

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are also emitted. These split further atoms and so a chain reaction, which is necessary for the explosion, is built up. However, unless the material used is of sufficient mass this reaction will not sustain itself. Therefore the mass of the material used in an atomic missile must not be less than this critical mass. Conversely it cannot be greater than a certain mass or the missile will explode spontaneously. When this occurs the total mass of the fission fragments (and the atomic particles which may be formed simultaneously) is less than the total mass of the nucleus undergoing fission plus that of the neutron initiating the process. It is the mass which is "lost" in the fission process which appears as an equivalent amount of energy. Although the actual loss of mass is only 0.1 per cent. of the total, the fission of all atomic nuclei in a pound of uranium or plutonium would produce the same amount of energy as the explosion of over 9,000 tons (9 megatons) of T.N.T.

### Fusion

7. Whereas the fission process for the release of nuclear energy entails the splitting of large atomic nuclei into smaller particles, the fusion process involves the making of one atomic nucleus from two lighter nuclei. According to the generally accepted hypothesis, the fusion process is the basis of solar energy. The method employed is to fuse two atoms of deuterium (heavy hydrogen) into one atom of helium. The mass of the helium atom is less than that of the two deuterium atoms and once again this lost mass appears as energy. As tremendous heat is required to bring about this fusion it is necessary to use a fission explosion as an initiator.

### Products of Explosion

8. The products of nuclear explosion are :—

- (a) Blast or shock waves.
- (b) Highly penetrating and deleterious invisible rays, in addition to intense heat and light.
- (c) Radio-active substances which remain after the explosion, emitting radiations capable of producing harmful consequences in living organisms.

9. Atomic missiles can be exploded in the air, on the surface and below the surface of the ground or water. The effects produced by each of these vary, as shown in Table 1.

## CHARACTERISTICS OF ATOMIC BLASTS

### Characteristics of an Air Burst

10. The air burst of an atomic missile is accompanied by the formation of an intensely hot, luminous sphere of compressed gas called the ball of fire. As this ascends and cools, an expanding column of smoke forms and rises to a height of from 5 to 8 miles before spreading.

11. The explosion is followed by the formation of a shock wave moving outward at high speed. The overpressure of the shock wave (the amount by which it exceeds atmospheric pressure) and the accompanying wind are responsible for the blast damage to structures. At a certain distance from ground zero (G.Z.) the direct shock wave fuses with the wave reflected from the surface causing a coalescent effect which greatly increases the overpressure at the surface.

12. Thermal radiation is emitted from the ball of fire in two pulses. The first lasts for little more than 0.01 second and contains a large proportion of ultra-violet radiation. The second pulse, lasting up to 3 seconds and carrying most of the thermal

TABLE 1

Type of Burst	Heat	Blast	Radio-Activity	
			Immediate	Residual
High Air Burst ...	Extensive ...	Extensive ...	Extensive ...	None.
Low Air Burst ...	Extensive ...	Concentrated ...	Extensive ...	Considerable fallout.
Underground Burst ...	Practically none...	Concentrated earth shock. Some air blast.	Almost none	Considerably more. Crater. Base surge and fallout. (See paras. 18, 19, and 23.)
Underwater Burst ...	Practically none...	Concentrated wave formation. Some air blast.	Almost none	Considerably more base surge and fallout.

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energy emitted, consists mainly of visible and infra-red rays. The second radiation pulse causes skin burns and some incendiary action.

13. The immediate nuclear radiation which reaches the ground from the ball of fire at the time of the explosion, and the subsequent atomic cloud, consist of gamma rays and neutrons. The lethal range of the neutron is small in comparison with that of the gamma rays and may be ignored.

14. The residual radio-activity, consisting mainly of gamma rays and beta particles from the fission products, and alpha particles from the uranium and plutonium that has not undergone fission, is that which remains on the ground after the explosion. In the case of the air burst it is usually negligible.

15. Increasing the power of the missile increases the effective range of the shock wave, the thermal radiation, and the immediate nuclear radiation ; but the area of damage always increases less rapidly than the energy release. The effect of the immediate nuclear radiation becomes relatively less important with respect to blast and thermal radiation as the energy is increased.

#### Characteristics of Sub-Surface or Surface Bursts

16. In an underwater explosion of an atomic missile a high, hollow column of water and spray is thrown up. The gases from the ball of fire are vented through the column, and form the normal atomic cloud. As the water from the column falls back to the surface, a base surge is produced. The explosion is accompanied by the transmission of a strong shock wave through the water. Some of the energy of the bomb also appears as air blast.

17. The thermal and instantaneous nuclear radiations in an underwater burst are absorbed in the water and have a negligible effect. The radio-activity carried by the base surge is important. The radiation dosage received consists of two parts—the transit dose during the short time the base surge cloud is in transit, and the deposit (or contamination) dose due to the deposition of radio-active matter. Additional radio-active contamination arises from the fallout from the column and cloud.

18. An underground burst will result in the formation of a large crater. The earth and rocks hurled upwards may weigh over a million tons and a base surge of radio-active dust particles

will form when the dirt, etc., falls to the ground. There will be a strong ground shock wave similar to an earthquake of moderate intensity, and some of the energy of the bomb will also be propagated as blast.

19. The thermal and instantaneous nuclear radiations are absorbed by the soil, but the base surge will contribute a transit dose and a deposit dose of radiation, as in the underwater explosion. Because of the large amount of dust raised a considerable amount of fallout is expected.

20. The characteristics of a surface burst will be between those of an air burst and a sub-surface burst. Energy will go into both air blast and ground shock. The thermal and immediate nuclear radiations will be similar to those in an air burst. The base surge and fallout will be less than for the sub-surface burst.

#### Effects of Atomic Explosions on Structures and Material

21. Damage to structures and material in an atomic explosion is due to blast and shock, and heat and fire (see Table 2). Fires may be started by thermal radiation, but most of these will be extinguished by the blast. Most fires will be secondary in nature due to indirect blast effects.

22. While radio-active contamination does not cause any material damage, it can render a building uninhabitable, or equipment unusable, for some time, because of the hazard to personnel. An air burst is non-contaminating and the only important radiological effect would be to an aircraft flying through the atomic cloud.

23. The base surge and the fallout accompanying a sub-surface or surface burst will produce considerable radio-active contamination. In general, rough, worn, and porous surfaces will be more susceptible than smooth, non-porous surfaces. Clean metal and well-painted articles are least vulnerable to contamination.

24. Reinforced concrete buildings are resistant to blast, shock, and fire ; heavy steel-framed structures withstand blast and shock, but fire weakens the steel members and may cause collapse. Light steel-framed, wooden, and brick buildings are vulnerable. Bridges are very resistant to blast. Underground shock will cause sewers, gas and water mains to suffer severely, but electric mains will not be greatly affected. The rupture of gas mains may cause fires.

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25. Vehicles are easily damaged and so are lightly constructed electrical and electronic devices of all kinds. Heavy equipment such as machine tools, motors, and generators, will be affected by debris and fire. Medium and heavy tanks and armoured cars are very resistant to blast. Heavy weapons also will stand up well. In all cases, however, exposed parts and equipment will suffer.

26. Naval craft are, on the whole, not very vulnerable to blast or shock. Fairly close to surface zero, hulls may be damaged by underwater shock. Topside equipment is likely to suffer from blast, and antennae are especially sensitive. No serious damage to machinery results from the blast, but rupture of foundations due to shock renders it useless. Main feed and main steam lines, and boiler brickwork, are also sensitive to shock.

27. Because of their design, aircraft, especially the fighter type, can withstand moderate blast and shock. Large aircraft have a considerable surface area exposed to blast and are, therefore, more liable to damage. The power plant, armament, oxygen, hydraulic, fuel, and other systems, are resistant to blast. Interior equipment will be protected if the exterior of the aircraft is intact.

### Effects of Atomic Explosions on Personnel

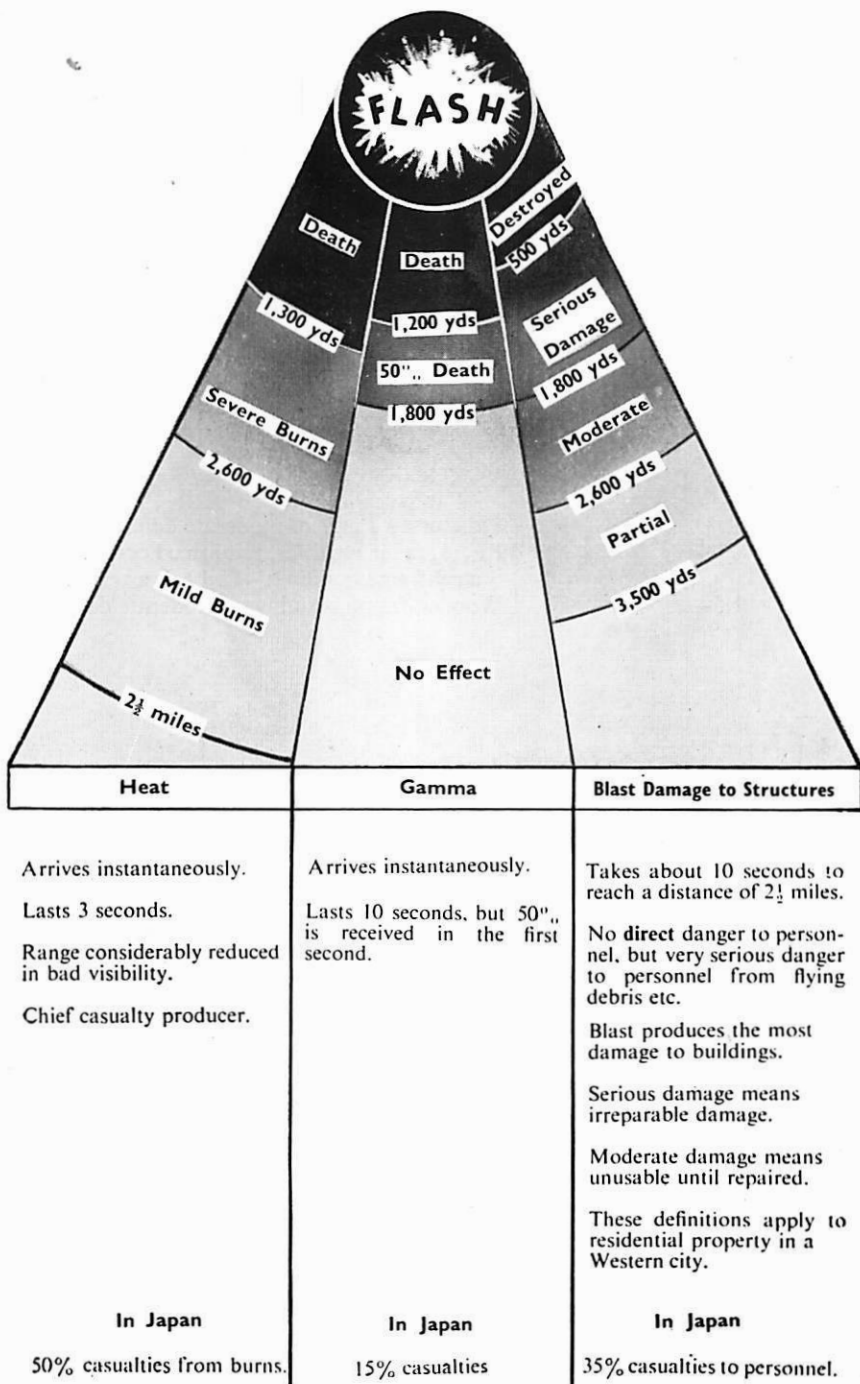
28. Fig. 2 gives a general idea of the effects of the air burst of a nominal bomb on exposed personnel.

### Use of Atomic Missiles

29. It will be clear that atomic missiles can be used in many ways against a variety of targets. As a general rule inanimate objects are best attacked by air blast from an air burst bomb, although very tough elements may require the earth disruption effects of a surface or sub-surface burst. Personnel in the open are most vulnerable to thermal radiations, in a shelter to gamma radiations, and in a city to all three effects, although blast injuries would normally be of an indirect nature.

30. When planning an atomic attack, therefore, it is first necessary to consider the nature of the most important elements of the target; the appropriate effect and level to give the required result against these elements; and the position of burst, relative to the ground, necessary to obtain this effect at the maximum possible range. The power of the weapons required will be chosen after consideration of target size, bombing error, the required assurance of success, and the radii of the appropriate level of effect for the destruction potential of the bomb.

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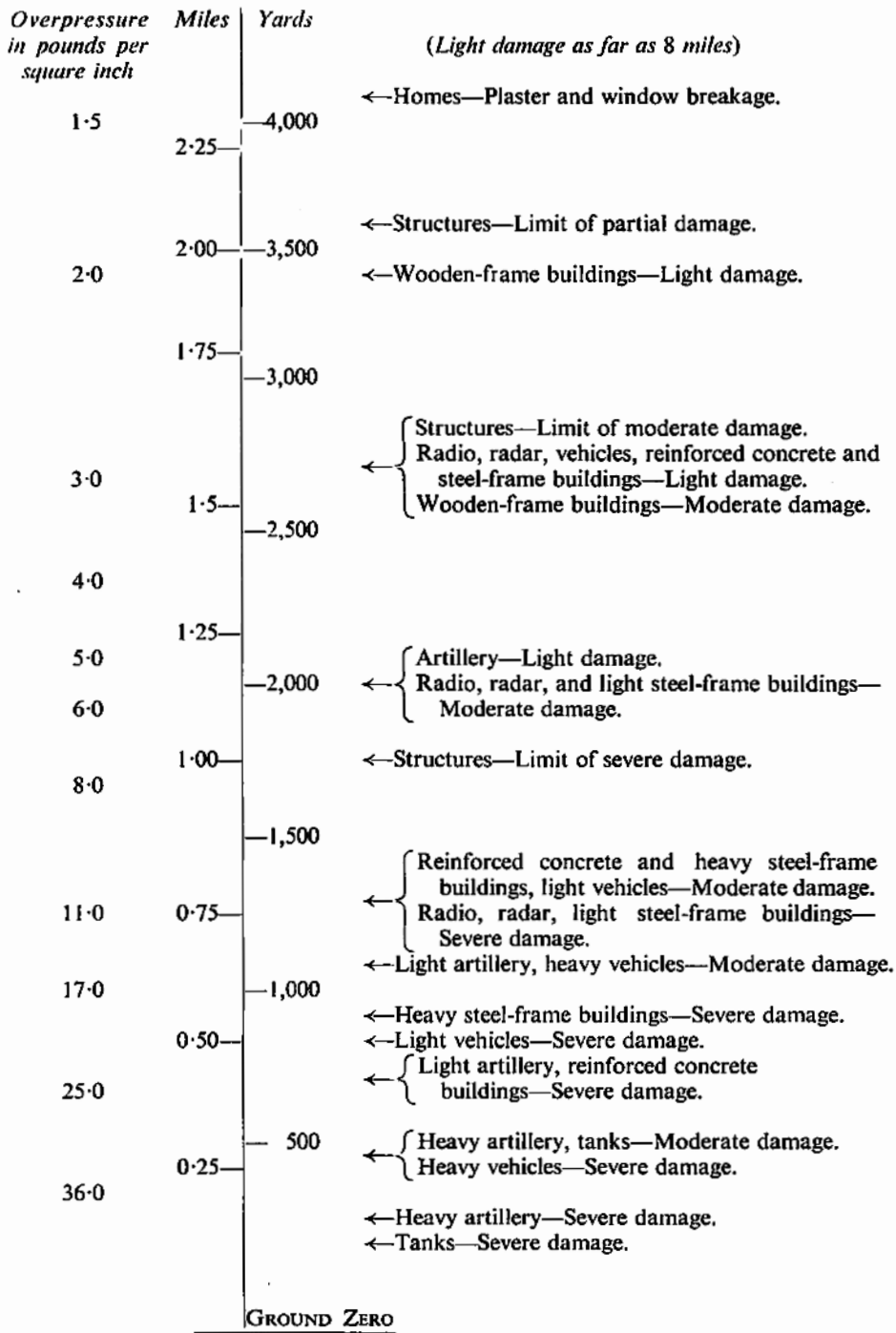


Note:—Distance figures refer to exposed personnel standing in the open.  
 Japanese figures refer to estimates of casualties under actual conditions at Hiroshima and Nagasaki.

Fig. 2. Air Burst Atomic Explosion (Nominal Bomb)—Immediate Effects (2,000-ft. Burst).

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TABLE 2  
EFFECTS OF ATOMIC EXPLOSIONS



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