HIGH EXPLOSIVE BOMBS

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In this World War II, civilian populations as well as military objectives are targets for aerial attack. The problem of active defense belongs to the military. This includes the use of interceptor planes, such protective measures as anti-aircraft fire, and balloon barrages. Every civilian should understand the methods of air raids and the probable ratio of hits to misses. Everyone should have a general idea of various kinds of aerial missiles and their destructive power, and what is most important, a specific knowledge of methods tending to reduce the effectiveness of aerial attack. A direct hit by a high explosive bomb will demolish a residence or partially destroy a massive building. However, it is well to remember that a city—especially one which is spread out—has a large proportion of its area in streets and vacant lots.

Principles of Explosives

An explosion is caused by a sudden liberation of gas. Explosives are mixtures, or chemical compounds, which on ignition or detonation produce large quantities of heated gases.

Mechanical Explosive Mixtures

Dust of a combustible nature suspended in air may form an explosive mixture. Every internal combustion engine utilizes an explosive mixture of volatile hydrocarbons and air. Black gunpowder consisting of a finely ground mixture of saltpetre (potassium nitrate), sulphur and charcoal was the chief military explosive for more than 500 years. When black gunpowder burns, the saltpetre breaks down, furnishing oxygen for the combustion of the carbon and sulphur. Rate of burning is relatively slow since it proceeds from particle to particle. An explosion takes place only when this burning with its product of heated gases is confined in a gun barrel or tight container like a firecracker. Some mechanical mixtures such as those including chlorate of potassium, are sensitive to percussion and are suitable for caps and primers. In these mixtures the chlorate of potassium breaks down easily and provides the necessary oxygen for the combustion of the other ingredients of the mixture.

Explosive Chemical Compounds

High Explosives. Guncotton (nitrocellulose), nitroglycerine, TNT (trinitrotoluene) are nitrated products of cellulose, glycerine, and toluene. They are chemically unstable. Under the impact of a sudden shock they detonate or explode with extreme rapidity. The oxygen, hydrogen and carbon atoms produce an inter-atomic rather than inter-particle combustion. The gaseous products of this rapid reaction produce a volume increase some 15,000 times the volume of the original material. The rate of detonation of TNT cast or compressed in bombs is 25,000 feet per second, that is, if you had a stick of TNT 25,000 feet long and detonated one end, it would take one second for the explosion to travel to the other end. The gases move away from the explosion at the rate of about 6,500 feet per second.

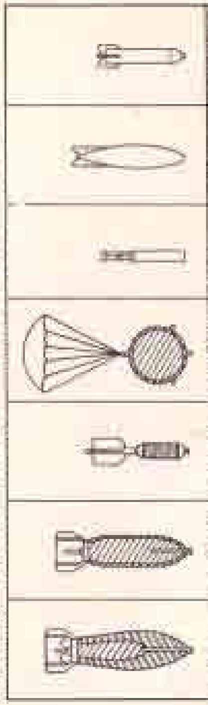
Nitroglycerine is far too sensitive to shock to be of value as a military explosive. Its sensitivity is reduced by mixing it with less-explosive or non-explosive materials as is done in the various grades of dynamite. TNT is an ideal military explosive because it will not explode by an ordinary shock, but must have a powerful detonator. Mercury fulminate aided by a "*booster*" charge is used for this purpose. This mercury salt is so extremely unstable that in a pure dry state it will detonate on slight shock. In a cap or detonator it is mixed with other materials to reduce its sensitivity. In a bomb, fulminate of mercury usually fires a booster charge of a relatively easily detonated explosive, which in turn detonates the main charge of TNT.

Bombs

Bombs are merely devices for using explosives in warfare. The old fashioned spherical bomb-shell fired from a smooth-bored cannon had its fuse lighted by the burning of the propelling charge of black powder. Modern artillery shells fired from rifled pieces have complicated mechanical fuses set in action by the movement of the shell. Aerial bombs from planes are of various types depending upon the purpose for which they are to be used. Figure 1, taken from a recent article by Sherwood B. Smith, shows various kinds of aerial missiles.[1]

In this figure the term sectional pressure means the weight of the bomb in pounds divided by the maximum cross sectional area (in square inches). "*Terminal velocity*" is the

[1] Sherwood B. Smith, "Air Raids and Protective Construction," *The Military Engineer*, July-August, 1941, pp. 287-293.



	ARMOR PIERCING	DEMOLITION	FRAGMENTATION	AERIAL MINE	INCENDIARY LIGHT	INCENDIARY SCATTER	GAS
Usual weight	1100 lbs.	550 lbs.	30 lbs.	2000 lbs.	2 lbs.	30 lbs.	30 lbs.
Range of weight	200-4000	100-4000	17-2000	1000-5000	2-60	17-500	30-600
Sectional pressure	9.7	3.1	2.0	-	0.3	1.5	1.5
Percent of explosive	10-15	40-60	15	90	-	-	-
Terminal velocity	1400 ft/sec	1100 ft/sec	725 ft/sec	-	350 ft/sec	-	-
Penetration	Excellent	Good	Poor	Poor	Poor	Fair	Poor
Blast	Reduced	Heavy	Light	Extr. heavy	None	None	None
Used against	Warships and special targets	Buildings bridges and military concentrations	Personnel and transport	Wholesale demolition of weak structures over wide area	To cause fires for direct damage and to illuminate the target		Personnel contamination

—Courtesy of *The Military Engineer.*

Figure 1. Types of Bombs

maximum velocity attained when the air resistance is equivalent to the weight of the bomb, thus preventing further gravitative acceleration. The actual impact velocity of a demolition bomb is about 760 feet per second when dropped from an altitude of 10,000 feet, and 930 feet per second from 20,000 feet. For purposes of comparison, sound has a velocity of approximately 1000 feet per second.

High Explosive (H.E.) Bombs

Fragmentation Bombs. These bombs are relatively light in weight (30 lbs.), have heavy corrugated cases and a small amount of high explosive (15 per cent of the weight of the

bomb). They are for use against personnel. The principal parts are:

Heavy, more or less streamlined shell. The bursting charge in some is contained in a thin steel shell surrounded by heavy steel bands grooved so as to produce many fragments.

A bursting charge of TNT.

Booster charge to detonate the H.E. charge of TNT.

Fuse to fire the booster charge. This contains mercury fulminate and is usually on the nose of the bomb and provided with an automatic release. Some of these releases are like pi.. wheels which revolve and release the firing mechanism as the bomb falls. On impact, a plunger drives a firing pin into a detonating cap which fires the booster charge. Recently there have been press accounts of a Japanese fragmentation bomb equipped with a delayed fuse which explodes when it receives the vibrations of a passing car or truck.

Fins on tail for flight stabilization.

Demolition Bombs. These are large bombs for destroying buildings, bridges and military objectives. Average weight is 500 pounds, some 1,000 to 2,000 pounds. High explosive (TNT) makes up about 50 per cent of the weight. Their principal parts are:

Relatively thin shell—but of sufficient strength to afford good penetration and prevent shattering upon impact before detonation.

Charge of TNT.

Booster charges.

Fuses on nose and tail or within body of shell.

Fins on tail.

Fuses of demolition bombs usually have a delay action of five to ten seconds to allow for penetration. The so-called time bomb has a special fuse with a delay of several hours or days. This may consist of an acid container which, on breaking, allows the acid to eat through a metal shield, or the release mechanism of the fuse, before the detonating explosive can be fired.

General Purpose Bombs. These are similar to demolition bombs, but smaller in size, ranging from 100 to 300 pounds in weight. Some of the smaller bombs have whistles on their fins to make a terrifying shriek simulating a very large bomb.

Aerial Mines. Very heavy charges of TNT in barrel- or drum-like containers with parachutes to retard the speed of descent, thus permitting the use of lighter cases and far heavier charges of high explosive.

Incendiary Bombs

See discussion of Incendiary Bombs, pp. 13-19.

Gas Bombs

See discussion of War Gases, pp. 20-31.

Methods of Bombing

Low Altitude Level-flying Bombing. In World War I, bombs were simply thrown out of the open cockpit of a plane as the pilot flew low over his target. The plane speed was about 80 miles per hour, and the altitude seldom over 600 feet above the target. With practice the bombardier learned just when to drop his bomb.

High Altitude Level-flying Bombing. In contrast to the above method, modern planes fly at speeds of well over 200 miles per hour, and may bomb from altitudes of over 20,000 feet. If a plane at this altitude is flying at the rate of 210 miles per hour, the bombardier must release his bomb about 2 miles short of the target, and by the time the bomb strikes the target, the plane itself will be almost directly over the target. The path taken by a falling bomb approaches a parabola, but is influenced by many factors. These factors are coordinated by the bombsight, which is a highly efficient mechanical calculator enabling the bombardier to determine accurately the precise instant to release his bomb.

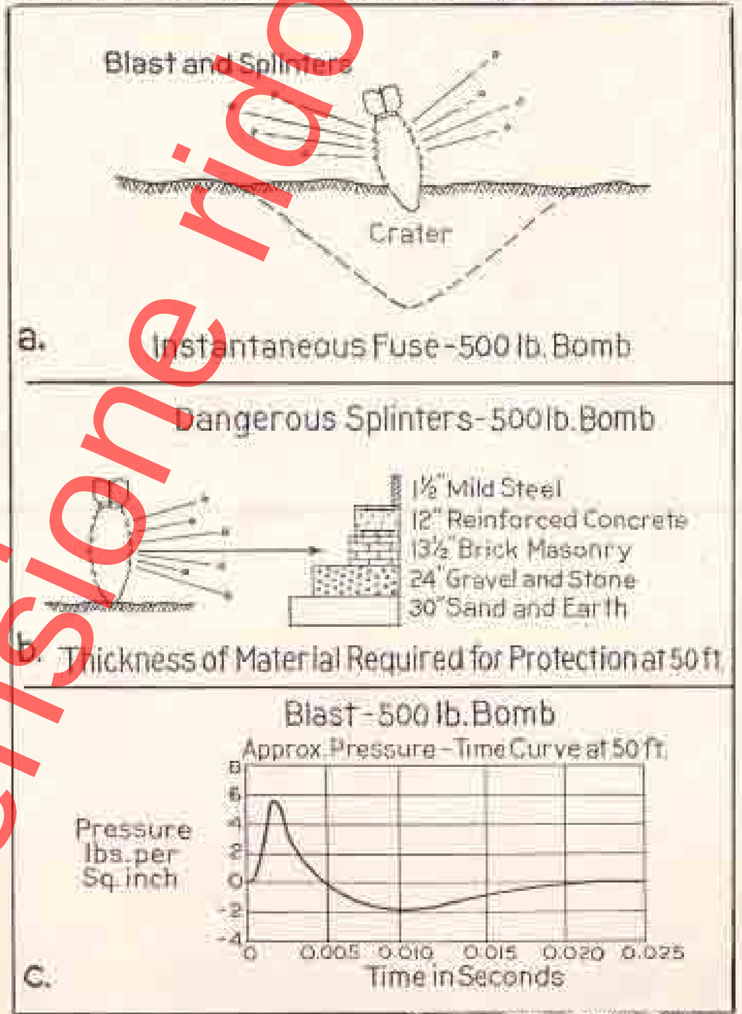
When released from a plane, the longer axis of a bomb is parallel to the plane but in falling it gradually becomes nearly vertical. After falling 5,000 feet it makes an angle of 26° from the vertical, at 10,000 feet of drop, this angle is 18° and at 20,000 feet 12° from the vertical. The greater the deviation from the vertical, the greater is the possibility of side hits on tall buildings. Bombs are commonly dropped in "sticks," i.e., four or five, one after the other at intervals of ¼ second, 1¼, or 2½ seconds, so that hits may be spaced 100, 500, or 1,000 feet apart.

Dive Bombing. From an altitude of about 10,000 feet the pilot puts his plane into a steep power dive at an angle of 50 to 75 degrees directly at his target. A heavy bomb (1,000 lbs.) is released at the relatively low altitude of about 2,500 feet, and then the pilot pulls out of the dive. Dive bombing, first developed by our Navy several years ago and

now used extensively by Germany, is dangerous, not only because the plane may make a good target for anti-aircraft guns, and because of the difficulty of pulling out of a steep power dive at a speed of more than 300 or 400 miles per hour, but also because of the physiological effects on the aviator himself.

Effects of High Explosive Bombs

The effects of bombs are twofold: First, that of penetration due to their energy in falling from a height, and second, the destructive effects resulting from their explosion. Much de-

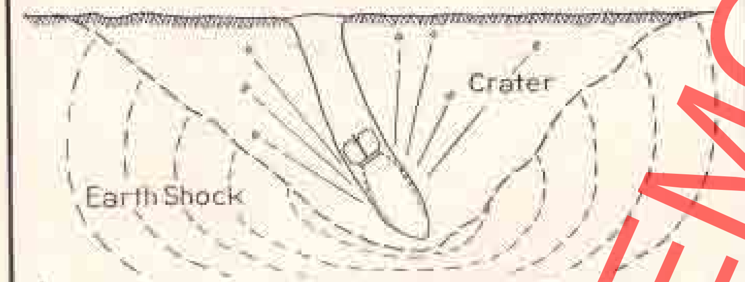


—Courtesy of *The Military Engineer.*

Figure 2a. Effects of Bombs on Striking Earth

pends upon the structural nature of the target. Many of the following data were obtained from the excellent article by Sherwood B. Smith, Principal Engineer, Fortification Section, Office of Chief Engineers, entitled "Air Raids and Protective Construction," and published in July-August, 1941, issue of *The Military Engineer*.

A bomb with an instantaneous fuse exploding on contact will be able to penetrate only about one-third of its length into the ground before exploding. Any object at a distance of 50 feet from the place of explosion of a 500-pound bomb



d. Delayed Action Fuse-500 lb. Bomb

Crater Dimensions-Sandy Loam

Bomb With Delay Action Fuse	Penetration Feet	Diameter of Crater Feet	Earth Displaced Cu. Yds.
100 Pound	6	20	25
300 "	11	27	75
600 "	17	37	225
1100 "	26	45	500
2000 "	39	50	950

e.

Crater Dimensions-Sandy Loam

Bomb With Instantaneous Fuse	Depth of Crater Feet	Diameter of Crater Feet	Earth Displaced Cu. Yds.
100 Pound	2	9	4
300 "	3	13	10
600 "	5	17	17
1100 "	6	20	28
2000 "	7	22	47

f.

—Courtesy of *The Military Engineer*.

Figure 2b. Effects of Bombs on Striking Earth

is first subjected to a blast of positive pressure of about six pounds per square inch for a fraction of a second. There follows immediately a negative pressure or suction of about 2 pounds per square inch for a duration of 0.015 second. (Fig. 2a and 2b.) There is also a terrific outward movement of the gaseous products of the explosion in addition to the above effects. The blast effect of aerial mines is particularly devastating, especially on light frame buildings. Opening doors and windows tends to equalize the pressure and may avoid shattering.

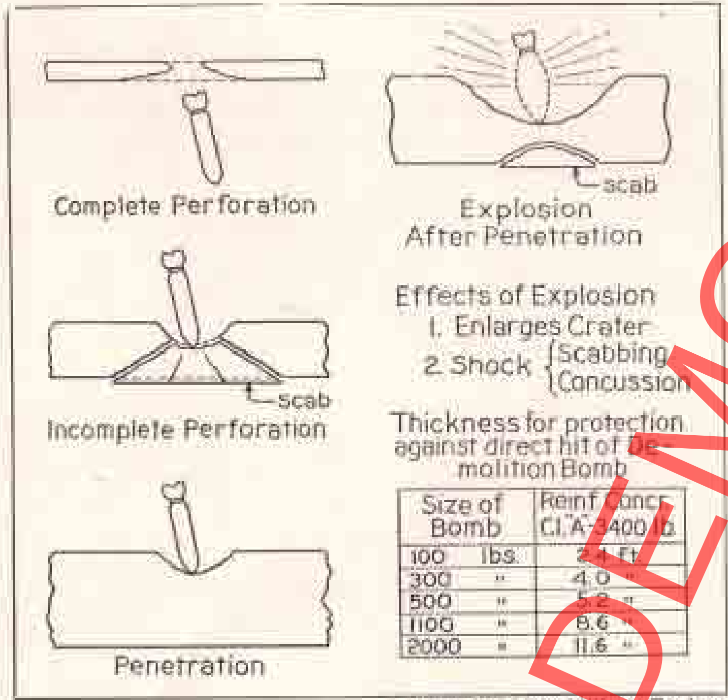
Splinters or fragments from a demolition bomb have initial velocities of about 6,500 feet per second, or more than twice as much as that of a bullet from an army rifle. These splinters, however, on account of their ragged shape, lose their velocity rapidly. They may travel for a distance of half a mile. Flying fragments of rubble and glass would have less velocity than the bomb splinters, but might be very dangerous.

When a bomb penetrates several feet into the ground before exploding, blast and splinter effects are reduced, but a heavy earth wave or pulse results. Serious damage near the bomb may result from the earth shock or actual movement of the earth at a very high rate of acceleration. A shock wave of high frequency but small amplitude will travel for a long distance from the explosion. Damage to structures by this wave is relatively unimportant. Earth shock from bombs is analogous to a small concentrated earthquake. The energy released by even a moderate earthquake is thousands of times greater than that of any bomb.

Crater dimensions in sandy loam for bombs with delay fuses range from a depth of 6 feet and a diameter of 20 feet for a 100-pound bomb to a depth of 39 feet and a diameter of 50 feet for a 2,000-pound bomb. (Fig. 2.) From this it can easily be seen that water and gas mains and even sewers may be seriously damaged by direct or nearly direct hits. It should be noted, however, that penetration and craters in hard pan or tightly cemented glacial till would be less than in sandy loam.

Penetration of Concrete

Thick sections of reinforced concrete resist the penetration and the explosive effects of demolition bombs; but thin sections, such as flooring, are more easily penetrated on account of the scabbing effect on the under side of the member. Therefore, several thin concrete floors do not afford as much protection as their aggregate thickness in a single member. (See Fig. 3.)



Size of Bomb		Reinf. Concr. Cl. A-3400 lb.
100	lbs.	2.4 Ft.
300	"	4.0 "
500	"	5.2 "
1100	"	8.6 "
2000	"	11.6 "

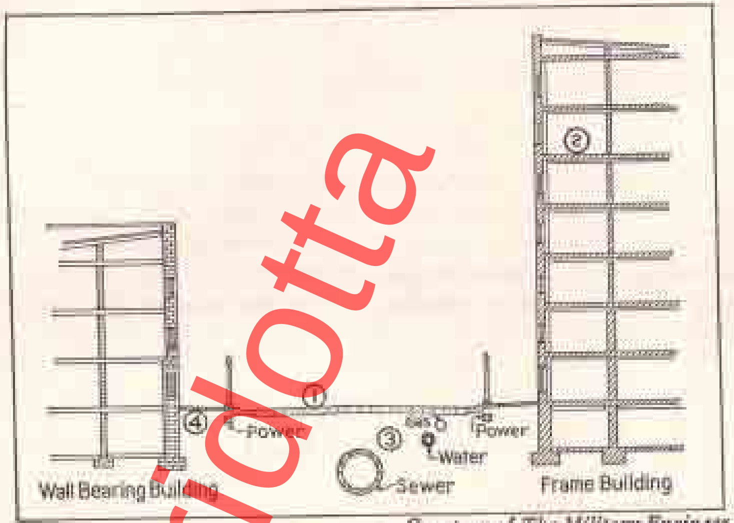
—Courtesy of *The Military Engineer.*

Figure 3. Effects of Bombs on Concrete

In Figure 4, if a bomb explodes at (1), the building on the left where the walls support the floors may collapse and windows within 200 feet will probably be broken. A bomb exploding at (2) in the steel frame building will cause local damage, while one with a delayed fuse at (3) would probably break or seriously damage the gas and water mains and perhaps the sewer. A similar bomb at (4) would probably collapse the outer wall of the adjacent building.

Protection Against Aerial Missiles

An aerial bombardment may be roughly compared to a tremendous electrical storm. In a thundershower any prominent object such as a lone tall tree may be struck; in an aerial bombardment *even a small ray of light* may draw the fire of the enemy. Therefore, the **first protection is a complete** blackout. The importance of a blackout cannot be



—Courtesy of *The Military Engineer.*

Figure 4. Typical Section through Street

overemphasized, and every civilian should thoroughly understand the methods of obtaining one.

Protection Against High Explosive Bombs. Fragments from fragmentation bombs move upward and outward, therefore, a zone close to the ground is the safest. British soldiers escaped many injuries by lying flat on the ground when being bombed. A 30-pound bomb containing about 5 pounds of TNT will produce, on exploding, about 1,400 small fragments which have an effective range of more than 25 yards. The demolition effect of these bombs is not great on account of the small bursting charge. The effective range of fragments from a demolition bomb depends upon the size of the bomb and the place of explosion. For a rough comparison a zone 200 feet away from a 100-pound bomb, and one 1,200 feet away from a 2,000-pound bomb would be dangerous because of splinters. The blast effect of a 100-pound bomb would be severe within a distance of 70 feet, while the blast of a 2,000-pound bomb would have a destructive zone 400 feet from the bomb.

In an ordinary house, a basement below the ground level is the safest from H.E. bombs, provided the structure is strong enough to resist earth shock. Reinforced concrete buildings or ordinary frame buildings afford more protection in this respect than a brick supported building. However, a basement unless made gas tight might be a dangerous place should war gases be used. There are many designs of air raid shelters from small ones, accommodating six people, to those having a capacity of 200 people.

Unexploded H.E. Bombs

All unexploded bombs are dangerous because there is no way of determining whether they have faulty firing mechanisms or delay action fuses. They may be disposed of by detonating with suitable explosives where they have fallen, provided no important structure is in the vicinity. If this is done, protective materials such as chain mats or logs may lessen the effects of the explosion. If they are to be removed to some safe place, this work must be done by a bomb-removal squad of especially trained, skilled men. At the chemical warfare school recently held in Olympia, Spokane, and Seattle, Major W. A. Johnston stated that the ordnance department of the Army, or special details of the Police department would furnish such services.

An unexploded bomb makes a relatively small hole where it hits, and may be buried deep in the ground. This should be recognized by air raid wardens who should take all necessary precautions, such as roping off a considerable area or having adjacent buildings evacuated. They should also make sure that the bomb-removal squad is immediately notified.

Falling Buildings and Rubble

Blast or earth shock from heavy demolition bombs may weaken structures so that collapse sooner or later is inevitable. Such falling material may be a serious menace. Great care should be taken in approaching or passing weakened structures.

Fragments from Anti-Aircraft Shells

Since these shells burst at high altitudes, falling fragments will have a very considerable impact velocity; enough perhaps to penetrate a shingle roof and certainly enough to necessitate steel helmets for all who have to be out of doors during an air raid.

Machine-gun Strafing

Low flying planes may subject portions of a city to a hail of machine-gun bullets. Basements below ground would afford adequate protection from such strafing, but wood frame buildings would be easily penetrated.

INCENDIARY BOMBS

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Types of Incendiary Bombs

Many substances are known to be highly combustible. Only a few have been successfully used for incendiary purposes in World Wars I and II. The heating value should be relatively high and the burning rate not too rapid: conditions which are common to magnesium metal. Common incendiaries are tabulated below in the order of heat generated during combustion.

MATERIAL	*Heat of Burning Calories per Gram*	*Probable Flame Temperature Deg. Fahr.*
Petroleum (gasoline, fuel oil)	11,000	2,000
Pitch (tar, rosin)	8,400	1,500
Magnesium	6,000	3,300
Phosphorus	5,900	250
Sodium	2,200	....
Thermite	800	4,500

The above heating values are not excessive when one recalls that that of a good grade of coal averages 6,500 to 8,000 calories per gram. Trinitrotoluene, the well known explosive, has a heat of combustion of 3600 calories per gram. The rate of burning is indicated roughly by the "*probable flame temperature.*" Thermite, which is relatively low in calories, burns so rapidly that temperatures of 4500 degrees Fahrenheit are created. In order that phosphorus be used successfully as an incendiary, adjacent material of a highly combustible nature must be present.

Chemical and Physical Properties

This discussion is limited to precautions suitable for *residential districts.* For such areas numerous small incendiaries are used, with a correspondingly light weight of charge. Petroleum and pitch are seldom used, for their incendiary value in small quantities is slight in the presence of fire-fighters. Except for large buildings such as apartment houses these bombs need scarcely be expected.

The magnesium bomb, on the other hand, needs special emphasis. This "*elektron*" bomb, used by the British and