Fig. 1-12. This soldier was killed during a firefight in which the enemy was armed with AK47 assault rifles. There are eight wounds of entry in the right posterior trunk.
Source: Wound Data and Munitions Effectiveness Team

Fig. 1-13. The soldier's anterior **wounds** of exit are than his wounds of entry.
Source: Wound Data and Munitions Effectiveness Team

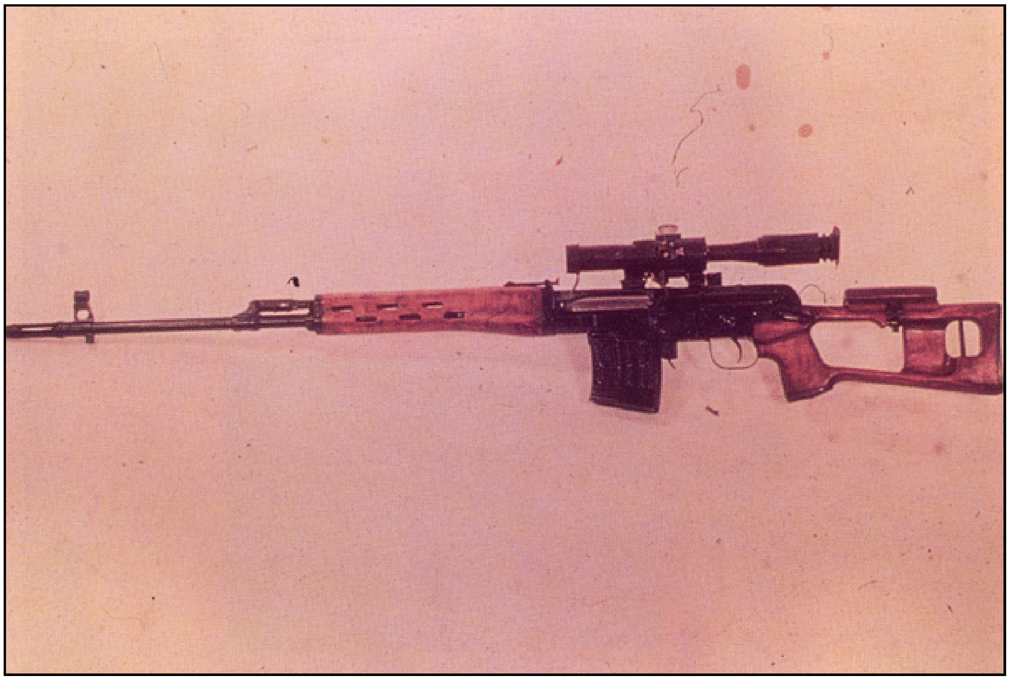


Fig. 1-14. The 7.62-mm Snayperskaya Vintovka Dragunova (SVD) is a semiautomatic gas-operated rifle that fires the 7.62 x **54R** round shown in Figure 1-3. Its telescopic sights make it an excellent sniper's weapon.
Source: Letterman Army Institute of Research

stir up arguments about the comparative effectiveness of slow, heavy bullets versus fast, light bullets. Proponents of the Colt .45 might say that its larger bullet has more knock-down power. Proponents of the Beretta might say that its faster bullet causes more tissue damage. In any event, this controversy is probably more relevant to civilian law-enforcement authorities than to the military.

Mechanisms and Operations of Small Arms

Small arms are complicated pieces of machinery. They have many small parts that need to work in precise sequences and interactions in order to fire a round safely and effectively.

***The Parts of a Small* Arm.** In very simplified terms, a modern small arm consists of the following parts:

- The *barrel* is a metal tube, open at one end, through which the bullet travels after it is fired. On the inside surface of the barrel are spiral grooves (or *rifling)* that make the **bullet** spin on its longitudinal axis as it passes through the barrel, giving it a point-forward stability in air. The diameter of the inside of the barrel (called the *bore)* and the diameter of the bullet that passes through it

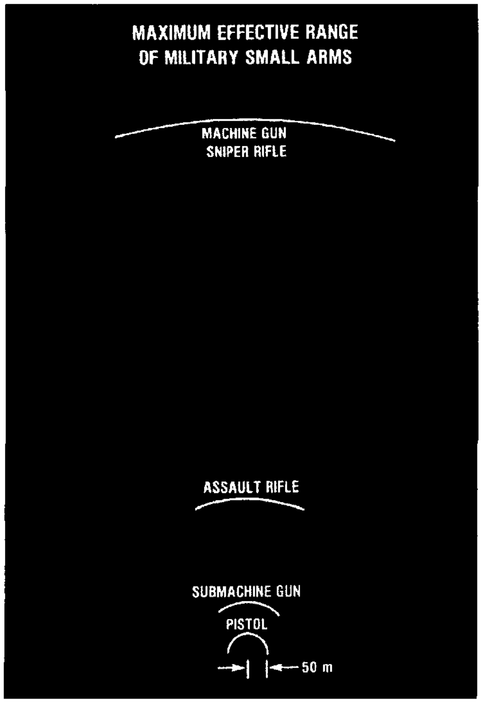


Fig. **1-15.** The maximum effective ranges of various classes of military small arms
Source: Reference 7

are equivalent; thus, the diameter of a small arm's barrel is usually expressed as its *bore caliber.* The *muzzle* is the open end at the front of the barrel, and the *breech* is the opening at the rear of the barrel into which the round is inserted (or *chambered).*

- The *bolt* is a piece of metal that mechanically closes the breech. This complex movement is brought about in different ways, depending on the design of the weapon. After the round is fired, the bolt is moved away from the breech. This movement not only opens the breech, but also mechanically extracts the spent cartridge.
- The *trigger* is a mechanical device that, in a complicated sequence of events, strikes a *firing pin,* which in turn hits the primer on the base of the chambered cartridge, which then ignites the propellant charge.
- In some weapons, the small arm's operating mechanisms (that is, the bolt and the breech) are covered by a protective metal covering known as the *housing.* In some—but by no means all—weapons, the barrel, too, is fixed to the housing.

The Firing Sequence of a Small Arm. In all small arms—whether they are single-shot, semiautomatic, or fully automatic—several steps occur in sequence each time the weapon is fired: *(a)* the round is chambered in the breech; *(b)* the breech is closed by the bolt; *(c)* the trigger is pulled, which fires the round; *(d)* the bolt is moved away from the breech, which extracts the cartridge in the same movement; and *(e)* a new round is chambered.

With a manually operated single-shot rifle, such as the Gewehr 98, the energy for each step is provided by the soldier, who manually both closes the bolt after the round is chambered and opens the bolt to extract the spent cartridge.

In a semiautomatic weapon, such as the Colt .45 pistol, the energy for extracting one round and chambering the next is supplied by the combustion of the powder in the cartridge. This method of operation is called semiautomatic, but because each firing requires the soldier to pull the trigger to chamber the next round, the term *self-loading* is more accurate.

In a fully automatic weapon, the firing cycle is repeated automatically until the trigger is released or until the *magazine* is empty.

The *cyclic rate of fire* is the maximum rate at which the firing sequence can be carried out. In manually operated weapons, the cyclic rate of fire is usually much too slow to be relevant.
however, the cyclic rate of fire is an important measure of the weapon's performance. Although the M16 is said to be capable of a cyclic rate of fire of 700–800 rounds/minute, a much slower but more sustained rate of fire (about 12–15 rounds/minute) is more correct; at higher sustained rates, the barrel gets too hot to operate properly, and a soldier cannot load ammunition fast enough to keep up with the rate of fire.

There are three different ways in which fully and semiautomatic weapons use the energy released by the combustion of the powder in the cartridges to replace manual energy in perfor or all of the steps in the firing sequence. These mechanisms are *recoil, blow-back,* and *gas operation* (Figure 1-16).

Recoil Operation **All small** arms **recoil** Many small-arm weapons designs (including the Colt .45 and some machine guns) use this property as the basis of their firing mechanism. In recoil operation, the small arm's barrel and bolt are locked together as the round is chambered. When the round is fired, the bullet is propelled out of the barrel while an equal but opposite force moves the barrel and bolt backwards in a recoil motion. This motion simultaneously compresses two powerful springs: *(a)* the *barrel spring,* which encircles the barrel and is attached in front of the fixed housing, and *(b)* the *return spring,* which is located

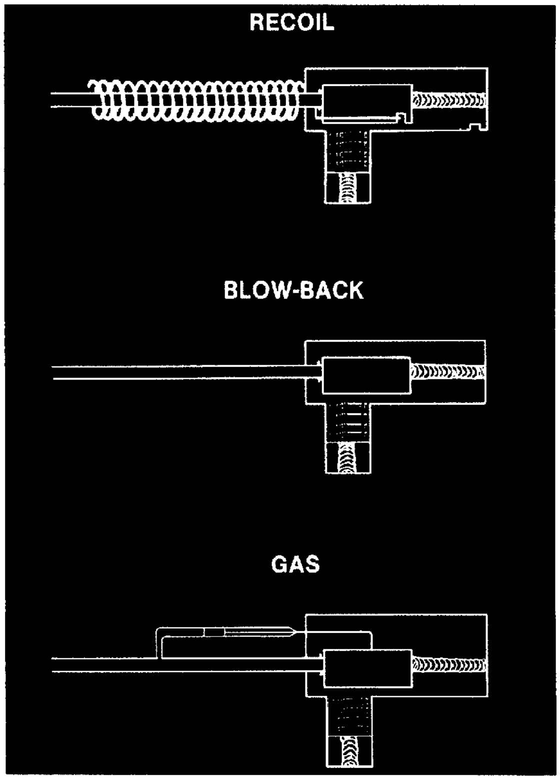


Fig. 1-16. The three basic mechanisms that are used to operate semiautomatic and fully automatic small arms

between the bolt and the back of the housing.

After recoiling several inches backward, the bolt unlocks from the barrel. The barrel rapidly reverses direction and is propelled forward by the energy stored in the barrel spring. At the same time, the bolt and the spent cartridge continue moving backward, and the spent cartridge is ejected. A new round is inserted automatically into the gap between the breech end of the barrel and the bolt. The bolt is then forced forward by the energy stored in the return spring, and this motion both chambers the new round and closes the breech. The new round is now ready to be fired.

Although this mechanism reliably fires without jamming, it is complicated and heavy. Like all weapons, it is also inherently less accurate when fired rapidly.

Blow-back Operation. This is the simplest firing mechanism, and is used in many submachine guns, including the Schmeisser and the Israeli-made Uzi.

With the blow-back mechanism, the barrel is fixed to the housing. The bolt closes the breech, but is not locked to the barrel as it would be in a recoil operation. As the round is fired, the energy from the exploding cartridge propels the bullet out the barrel and simultaneously starts to move the bolt backward. However, in this design, the bolt must be heavy enough to stay in position for a split second longer than it takes for the bullet to be ejected from the barrel. The bolt's backward movement compresses a powerful return spring that connects the rear of the bolt to the housing. (Unlike recoil-operated weapons, the barrel does not move relative to the weapon during this sequence; instead, the bolt and return spring absorb the energy of the recoil.) A new cartridge is inserted into the breech and is chambered when the bolt is driven forward by the energy stored in the return spring.

The blow-back mechanism needs few moving parts, but, because the barrel and bolt are not locked together, this firing mechanism is not commonly used with high-power cartridges. If such cartridges were used, the pressure of the gas that was created when the powder detonated would force open the breech and escape before it exerted its maximum force to propel the bullet out of the barrel. The French, however, have solved this problem and have fielded their FA MAS 5.56-mm high-power automatic assault rifle, which uses the blow-back mechanism.

Gas Operation. Designers of military small arms are focusing on a third mechanism, known as gas operation, which is used by the greatest number of automatic weapons fielded today.

As the round is fired, some of the gas from the exploding powder passes out of the barrel through a small port proximal to the muzzle. The port leads to a tube that extends along the length of the barrel, and, depending on the design, affects the bolt in one of two ways. In some gas-operated weapons, such as the AK47, the pressure of the gas compresses a small piston located at the front end of the tube. A backward-moving piston rod then mechanically moves the bolt away from the breech. In other gas-operated weapons, such as the M16, the pressure of the gas traveling through the unobstructed tube moves the bolt away from the breech.

The latter mechanism has the virtue of simplicity, but—as was shown in Vietnam—may be subject to fouling and consequent jamming unless the weapon is kept clean. The advantages of a gas-operated weapon are its *(a)* low weight, *(b)* ability to function with a high-power cartridge, and *(c)* high cyclic rate of fire.

Trends in Small-Arms Development

The trend in military small-arms development is to design and field weapons that are capable of generating more casualties. If a victim receives multiple random wounds from a weapon, the likelihood that a critical organ will be injured is greater than if the victim were hit with only one projectile. In addition, weapons that make multiple wounds require the opponent to use more resources and personnel to evacuate and treat their casualties.

Weapons designers are experimenting with ways to increase the number of wounds that a small arm can produce. This research is taking three directions:

One approach is to update the shotgun. Firing many projectiles from a single cartridge increases the likelihood that a person within a given range will receive multiple wounds. However, shotgun pellets and similar projectiles have relatively poor aerodynamic properties and do not travel very far. Combat shotguns that use tiny, aerodynamically superior *fléchettes* (literally, tiny arrows) within such rounds are a possible solution.

A second approach is to dispense entirely with inert bulletlike projectiles and instead to fire explosive munitions from small arms. For example, weapons designers are working on lighter and more easily deployed grenade launchers.

A third approach is to develop small arms that have much higher cyclic rates of fire than currently fielded weapons have. But there is a trade-off inherent in automatic weapons: The higher the rate of fire, the less accurate the weapon will be because of its recoil. For example, modern assault rifles have cyclic rates of fire of 600–700 rounds/minute, but the soldier cannot hold even a well-designed weapon steadily enough to completely overcome its recoil. As a result, beyond a range of 200–300 m, the bullets may be so widely dispersed that the probability of the shooter's scoring a hit will be even less than it would have been had a well-aimed single-shot rifle been used. Firing a salvo of lightweight projectiles (like fléchettes) would be one way to overcome the recoil problem, but fléchettes tend not to cause as much physical damage as other projectiles can. Another solution might be to fire a burst of conventional bullets so rapidly that they will have left the barrel before the recoil action becomes apparent to the shooter. There are two ways to do this: *(a)* a tandem round can be used, in which two or three bullets fit one behind the other within the cartridge in such a way that, when the round is fired, the equivalent of three rounds are propelled out of the barrel; or *(b)* caseless ammunition can be used, in which the propellant is molded around the bullet and the cartridge is completely eliminated. This shortens the operating cycle of the weapon by making the cartridge-extraction step of the firing process unnecessary. The German-made Heckler & Koch G11 automatic rifle is an example of a weapon that uses caseless ammunition; it fires a three-round burst of 4.8-mm bullets in 60 msec, too short a time for the weapon's recoil to spoil the shooter's aim.

EXPLOSIVE MUNITIONS

The generic prototype of the exploding munition is the *shell,* which originally was a hollow casing made of metal. Explosive powder was packed into the shell, along with a fuse to ignite the powder, and—depending on the design—various kinds of fragments, projectiles, chemicals, or other agents that were designed to spew out when the shell exploded (Figure 1-17).[8] In the older designs, the fragments of the shell casing did most of the damage.

From this basic concept came the more specialized modern exploding munitions, such as grenades, rockets, bombs, and mines.

Like small-arms munitions, explosive munitions that are fired from weapons are often called rounds. An exploding-munition round is larger and more complicated than a small-arm round, although the design principles are similar. The *warhead* corresponds to the bullet, but—unlike that inert projectile—is usually designed to explode. In smaller exploding munitions, the propellant-filled cartridge case will be attached to the warhead, just as the cartridge case is attached to the bullet in small-arms munitions. In very large exploding munitions, however, the warhead and the bags of propellant are loaded into the weapon separately.

The fuses in these weapons have also become much more reliable and sophisticated over time, and now commonly allow detonation to be preset for *(a)* impact, *(b)* a designated time delay, or *(c)* an altitude of several feet to several yards above the ground. Impact fuses rely on a metal rod that is driven into a primer of high-explosive material, which in turn detonates the main charge. Some impact fuses are designed to have a delay of 0.15–0.35 seconds, which allows the exploding munition to penetrate the target before the firing pin is activated. A designated time-delay fuse uses an electronic timer that has been preset to detonate the primer at a designated moment. The altitude (or proximity) fuse relies on a small radar that measures the distance either from the ground or from the target; when a preset distance is reached, the primer is detonated. Other modern munitions use fuses that are

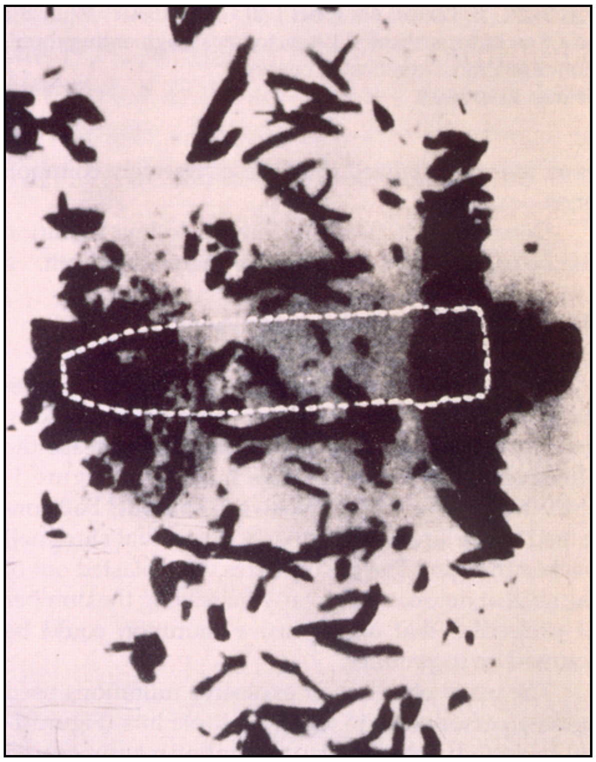


Fig. 1-17. A 20-mm cannon shell at the moment of its detonation
Source: Reference 8

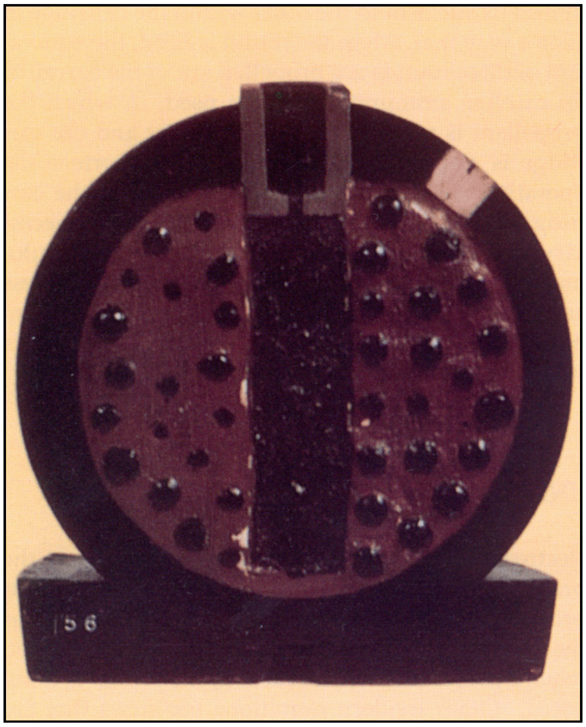


Fig. 1-18. Spherical shrapnel ball (circa 1830). With the addition of sophisticated fuses, today's fragmenting munitions are almost identical in concept.
Source: Reference 9

even more specialized than these relatively common ones.

Depending on its design, an exploding munition can be used against personnel or materiel or both.

Antipersonnel Exploding Munitions

In the nineteenth century, when facing increasingly powerful infantries armed with rifled muskets, artillery forces began to use *shrapnel* to increase the effectiveness of their explosive munitions (Figure 1-18).[9] In addition to its explosive, a shrapnel ball contained many small lead [illegible] actual shrapnel) packed in resin. The lead spheres were blasted out of the shell at detonation, greatly increasing the number of projectiles that an explosive munition could be counted on to produce.

The usual objective of explosive munitions used against personnel is to make multiple hits (Figure 1-19), taking advantage of the penetrating injuries caused by the *ballistic effects* of the fragments flying out from the exploding shell. The two other components of such a detonation are the *blast effects* from the force of the explosion and the *thermal effects* from the explosion's heat.

These three effects generate wounds according to the victim's distance from the epicenter of the explosion (Figure 1-20). Casualties who are close to the detonation are likely to show evidence of all three effects, while casualties who are farther away will sustain only penetrating injury. Even casualties who are some distance from the epicenter are likely to be blown over by the blast; the closer they are to an exploding munition, however, the less likely they are to survive or even to enter the medical-treatment system. Casualties who have received combined ballistic, blast, and thermal injuries usually suffer mutilating blast injury (Figure 1-21) and are unlikely to survive.

Because the radius for ballistic injury retracts more slowly than do the corresponding radii for blast and thermal effects, munitions designers capitalize on the ballistic effects by ensuring that weapons have a ready supply of potential fragments. The simplest way to do this is to build the munition with a thicker wall. This

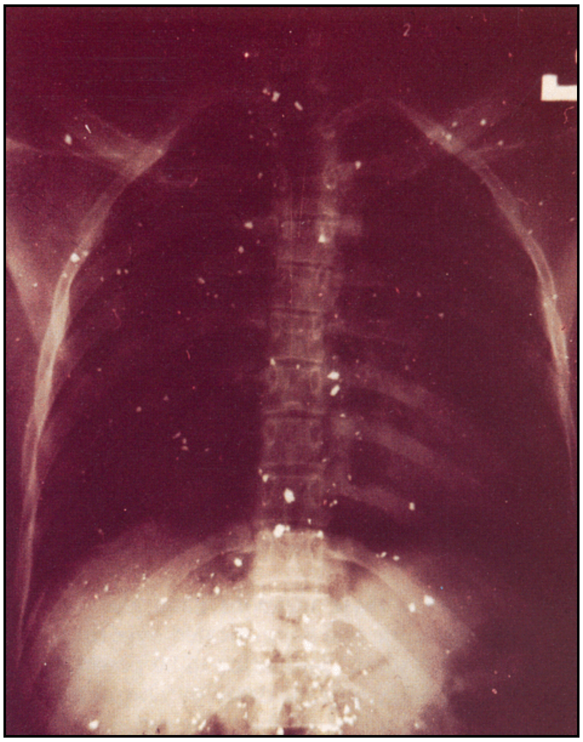


Fig 1-19 This roentgenogram shows the chest of a casualty who was [illegible] an 82-mm mortar bomb. Unlike small arms, which usually make few hits, modern explosive munitions usually cause multiple fragmentation wounds.
Source: Wound Data and Munitions Effectiveness Team

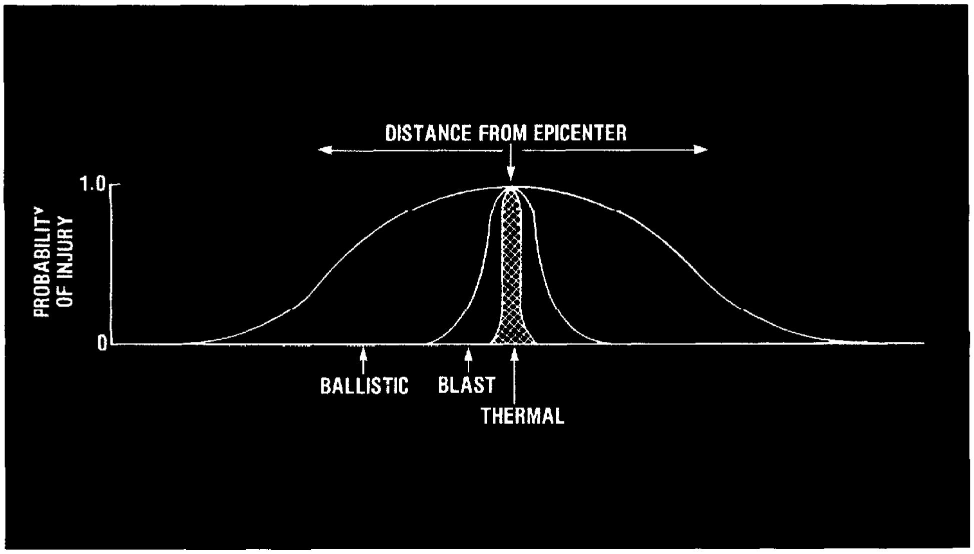
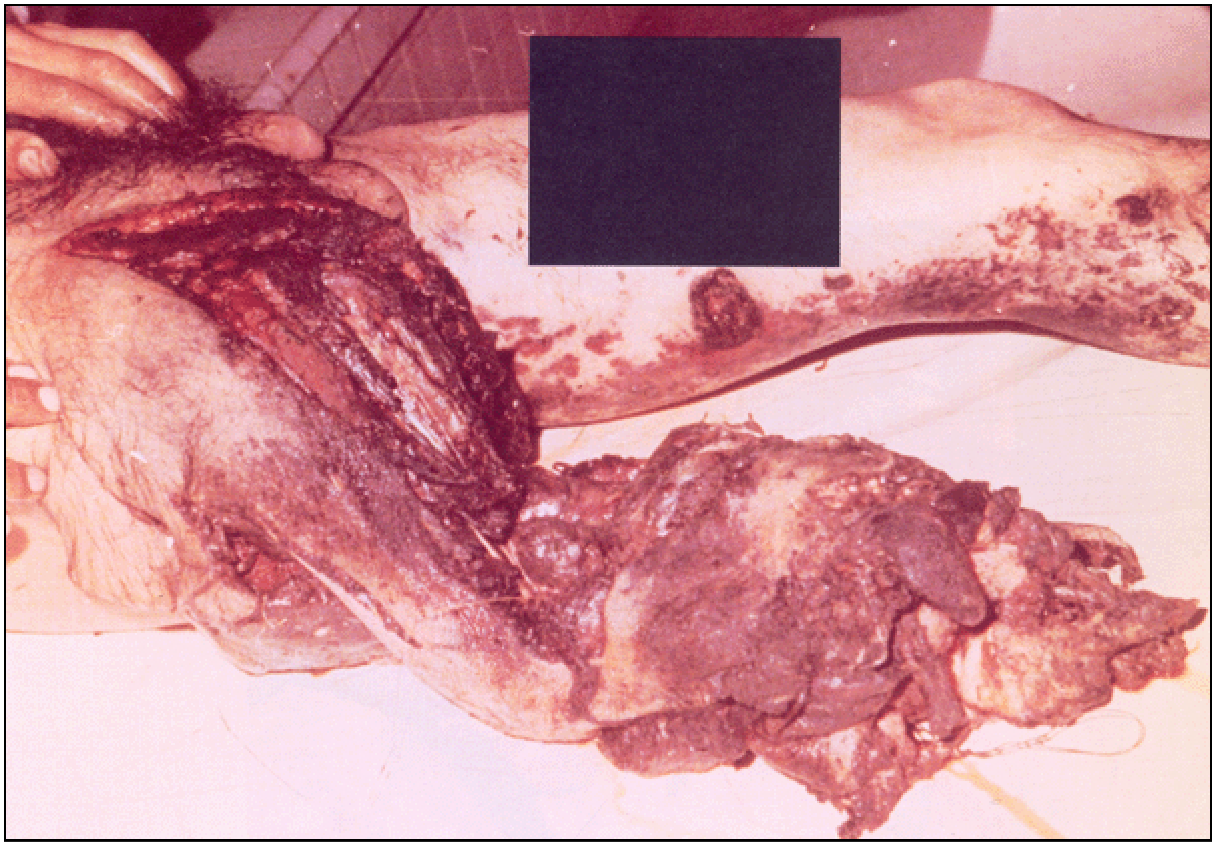


Fig. 1-20. The probability of sustaining a given trauma is related to the casualty's distance from the epicenter of the detonation.



[redacted]

Fig. 1-21. This soldier was killed by a 105-mm shell that detonated several feet from his body. Penetrating ballistic injuries have obviously occurred, and there is evidence of burns. The blast wave also caused some of the tissue mutilation.

Source: Wound Data and Munitions Effectiveness Team

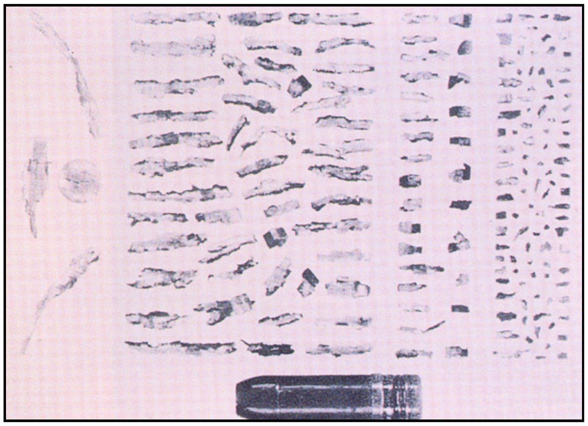
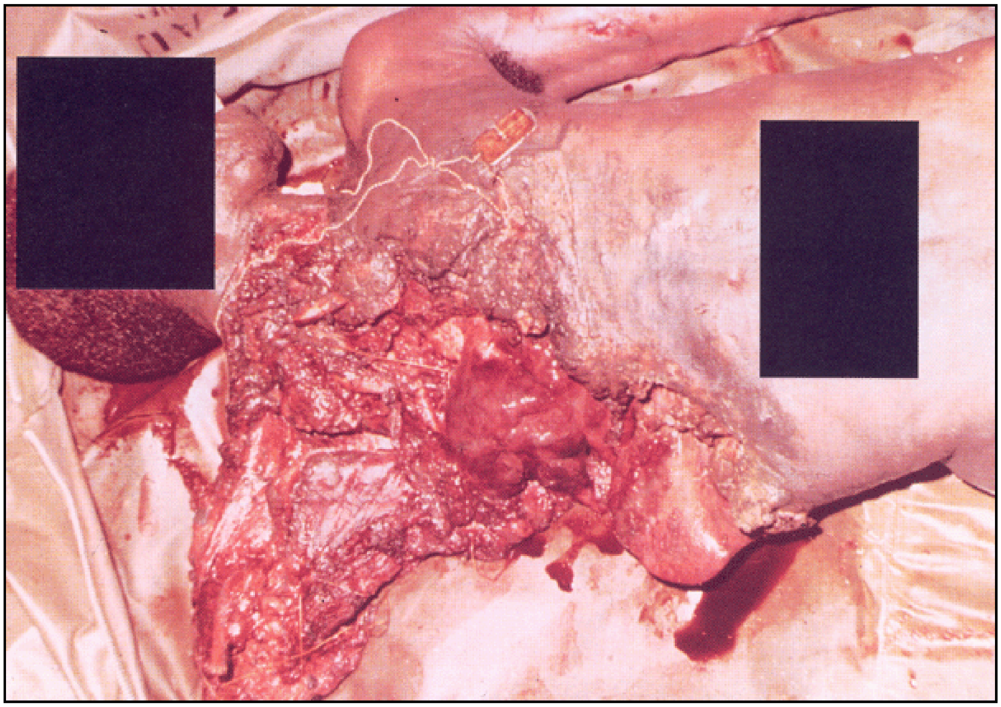


Fig. **1-22.** The explosion of a conventional random-fragmentation high-explosive shell yields fragments of various sizes and shapes.
Source: Reference 8

Fig. 1-24. The roentgenogram shows a large fragment from an 82-mm mortar round that has fractured the casualty's tibia.
Source: Wound Data **and** Munitions Effectiveness Team



[redacted]

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Fig. 1-23. This soldier was hit by an unusually large fragment from a random-fragmentation munition.
Source: Wound Data and Munitions Effectiveness Team

will reduce its blast effects somewhat, but will also increase the likelihood that the exploding wall's fragments will have enough mass to injure the nearby personnel whn are hit by them

Random-Fragmentation Munitions. The shell of a random-fragmentation munition splinters unpredictably, and the resulting fragments vary in size, shape, and velocity (Figure 1-22). **A** large fragment is usually lethal (Figure 1-23), although the casualty may survive if its velocity is low and the body part struck is not a vital one (Figure 1-24).

Even small fragments can seriously wound a soldier. An explosive spray of a greater number of fast-moving, smaller fragments **would be** more **likely** to **hit** more personnel, and thus would be more efficient than a spray of fewer, larger, and slower chunks (Figure 1-25), which would not only hit fewer personnel, but would do so with more destructive force than would be necessary to incapacitate them. Because a random-fragmentation munition breaks apart unevenly, much of its power is wasted.

improved-Fragmentation Munitions. Two modern designs have improved the effectiveness of fragmentation munitions (Figure 1-26). The first is the which can *(a)* be made of a fragmentable material that breaks up in a con-

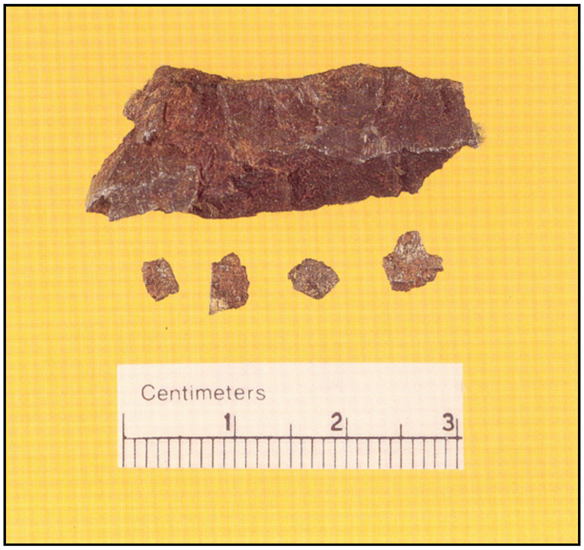

Fig. 1-25. These are random fragments. The larger chunk weighs 15.5g and is typical of the fragmentation munitions used in World War I; the smaller pieces weigh 100–200mg and are typical of those used in Vietnam.

Sources: **Author and Wound Data and Munitions Effectiveness** Team

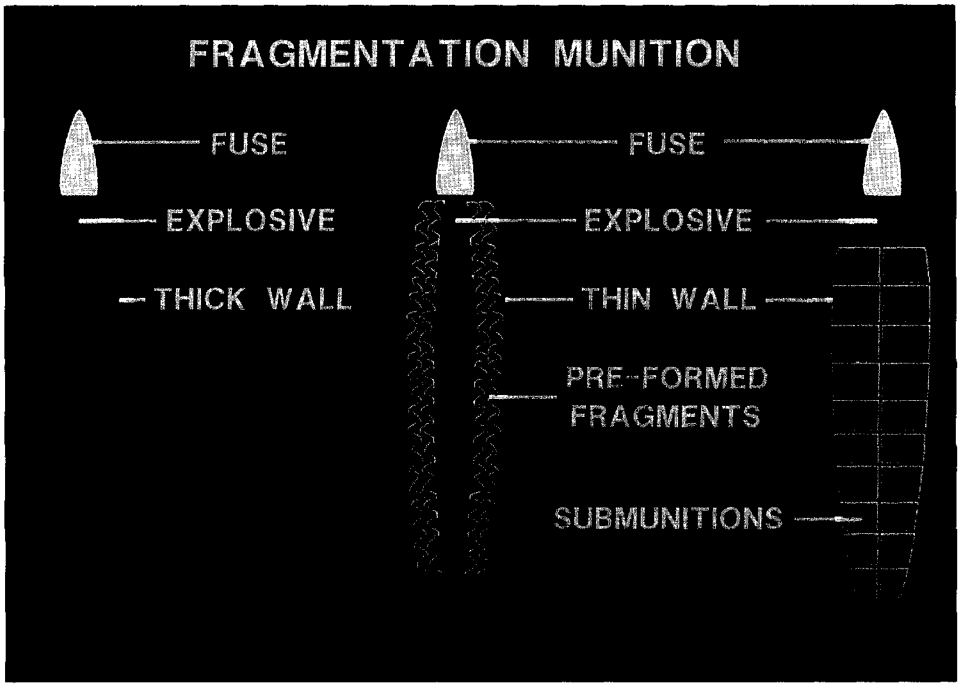

Fig. 1-26. Three varieties of fragmentation weapons are *(a)* the conventional thick-walled, random-fragmentation shell on the left, *(b)* the improved-fragmentation shell in the center, in which preformed fragments are stored between the explosive charge and the outer casing, and *(c)* the cluster munition on the right, in which each submunition is a small explosive bomb.

Fig. 1-27. These are typical preformed fragments. The smaller American-made fléchette, which was extracted from a casualty, is bent and is missing a fin. Fléchettes occasionally deform in tissue; such a deformation vastly increases their wounding potential. The smaller fléchette weighs 550 mg; the larger Soviet-made fléchette weighs 1.3 g. The ball and rod weigh 0.7 and 1.0 g, respectively.

Sources: Authors and Wound Data and Munitions Effectiveness Team

trolled fashion along preformed notches or *(b)* be filled with preformed fragments.

In the first improved-fragmentation model, the shell wall breaks up along preformed notches when the munition is detonated, just as a sheet of postage stamps will tear along its perforations. A typical fragment from a 105-mm improved-fragmentation shell will weigh only about 600 mg, compared to an average fragment from a conventional random-fragmentation shell of the same caliber, which will weigh about 2 g. Because the two whole munitions weigh about the same, three times as many fragments may be created when the improved-fragmentation shell explodes, with a consequent increase in the probability of either hitting many targets or making multiple hits on a given target.

In the second improved-fragmentation model, fragments of optimal size are inserted into the munition when it is manufactured (Figure **1-27**). These fragments will be widely disseminated upon detonation. Common types of preformed fragments are *(a)* flechettes, which have a streamlined shape and stabilizing fins and, thus, superior ballistic properties, *(b)* preformed rods, and *(c)* preformed spheres. The velocity degradations of flkchettes and random fragments are compared in Figure 1-28.[10]

One example of an improved-fragmentation munition that is filled with fléchettes is the 105-mm antipersonnel round, commonly known as a *beehive round* (Figure 1-29). The small cans contain a total of 8,800 flkchettes that are released from the shell at a time determined by the fuse setting. The beehive round is especially effective when fired defensively at opposing forces within 100 m.

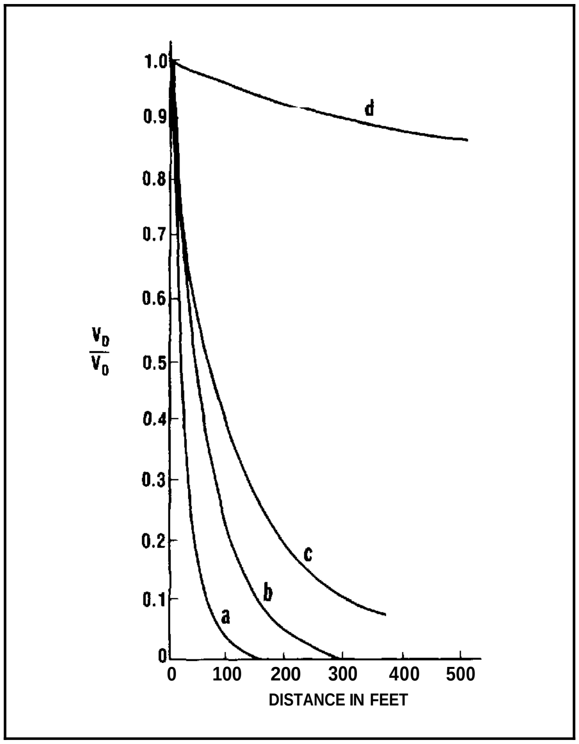

Fig. 1-28. Relative velocity as a function of range for three types of forged-steel missiles and a fléchette found in explosive munitions: (1) a 65-mg forged-steel irregular fragment, (2) a 600-mg forged-steel irregular fragment, **(3)** a 6.5-g forged-steel irregular fragment, and **(4)** a nontumbling fléchette. The abscissa represents the distance from the detonation site. The ordinate represents the ratio of the velocity at this given distance (VD) divided by the initial velocity at the detonation's origin (VO). Initial absolute velocities measured close to the munition can be as high as 6,000 fps for the sphere and irregular fragment, but are much lower for the fléchette.

Source: Reference 10

Because the fléchette is fin-stabilized, it flies straight in air without needing to spin on its long axis (unlike a rifle bullet, which acquires gyroscopic stability from the rifling spin it receives in the spiral grooves of the barrel). This aerodynamic property also allows the fléchette to pass through helmets and armored vests more easily than bullets can. Paradoxically, the streamlined shape may actually work to the casualty's

Fig. 1-29. The marine holds a cutaway demonstration model of a 105-mm improved-fragmentation munition (called a beehive round) that is loaded with flechette-filled containers.
Source: **Explosive** Ordnance Disposal Group, Quantico Marine Corps Base, **VA**

advantage. Unlike a chunky shell fragment or even a rifle bullet, which lose their point-forward stability and tend to become unstable when they enter a denser-than-air medium, the fléchette penetrates deep and straight into tissue, creating an extremely narrow pathway, and thus may cause a less severe injury. The easily overlooked wounds of entrance and exit that the point-forward flechettes create are tiny cruciate slits only a few millimeters long.

In Soviet-made weapons, the fléchettes are packed so that they will all be expelled in a point-forward position. However, some American designs maximize the number of flechettes that can be packed into a carrier by loading half of them point forward and half of them fin forward. Those that are fin-forward when they are expelled will not have good aerodynamic stability in flight. They will straighten out to a point-forward position by the time they have traveled a few hundred feet, but if they hit a target before then, the force of impact—which may be strong enough to break off the fléchettes' stabilizing fins—will cause a much more severe injury and be more likely to embed the flechettes in tissue.

Whereas irregular fragments from random-fragmentation munitions fly out at high velocities but have casualty-generating ranges measured only in hundreds of feet, the casualty-generating range of flechettes is measured in thousands of feet. The superior range of flechettes is of limited value, however, because most wounding by explosive munitions occurs at very short range. In the Vietnam War, for example, the median distance between a casualty and the site of detonation was only 10 m.[11]

Some improved-fragmentation munitions are filled with preformed rods—hardened steel bits that are packed inside the munition and are expelled when the casing explodes. Preformed rods are less aerodynamic but easier to manufacture than the farther-ranging flechettes are. Their range and effectiveness are better than those of random fragments. A *cannister shot* is a shotgun-like container that can hold thousands of preformed rods (called *slugs).*

Mortar bombs and grenades commonly have a spiral coil of thick wire notched at 1-cm intervals inserted between the explosive charge and the thin outer case of the munition. Technically, these bits of wire are not preformed fragments because the wire does not break apart until the moment of detonation. But the effect is the same: Small, lightweight, equally sized fragments will be spewed out, causing similar kinds of injuries (Figure 1-30).

Like their nineteenth-century counterparts, some

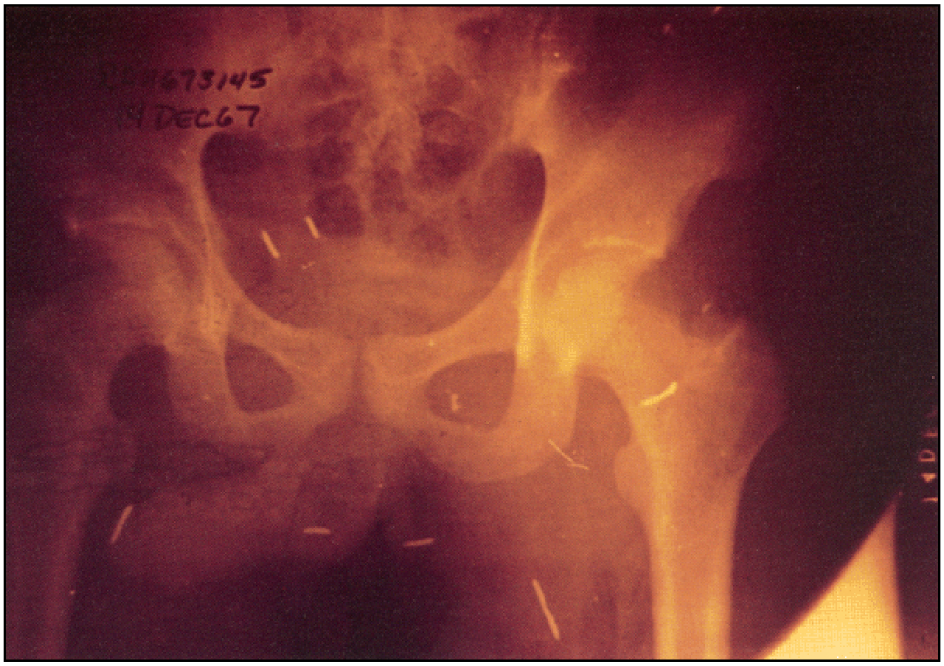

Fig. 1-30. Prenotched wire fragments from an M26 grenade perforated the small bowel and rectum of the casualty shown in this roentgenogram. The average weight of the fragments was 200 mg.
Source: Wound Data and Munitions Effectiveness Team