NAVPERS 91066-A

FOR OFFICIAL USE ONLY

# THE EVOLUTION OF NAVAL WEAPONS



BUREAU OF NAVAL PERSONNEL

MARCH 1949

NAVPERS 91066-A





# THE EVOLUTION OF NAVAL WEAPONS

U.S. BUREAU OF NAVAL PERSONNEL

MARCH 1949

# CHAPTER 1

# STICKS AND STONES

## Introduction

We are to study the history of naval weapons, first, in order to make the study of the weapons themselves more interesting, and second, to obtain an idea of how the whole process of the evolution of weapons takes place so that we can learn what sort of changes to expect in weapons in the future. Both as members of the armed forces and as citizens, it is our business to be able to weigh the sweeping predictions we hear from time to time about the nature of future warfare and to come out with some sensible result.

## Primitive Warfare

About 500,000 years ago our ancestors learned to hunt and fight with pointed sticks and flat pieces of flint sharpened on one edge and held in the fist. By 10,000 years ago these simple implements had developed into an extensive kit of stone-headed spears, axes, bone harpoons, and the like. Then men learned to finish their stone tools and weapons by grinding and polishing, and to tame the dog to help them hunt. They had then reached the Neolithic or polished stone stage of culture, like that of the most primitive peoples of today.

As far as we can judge, these hunters and food gatherers did not practice formal warfare, not because they were more virtuous than we are, but because the world's human population was so small and thinly spread that no occasions arose for large-scale fighting, though no doubt there was a lot of individual assault and murder. Furthermore, at that stage of culture nobody ever had enough wealth to be worth stealing. Hence two of the main causes for war, economic competition and the prospect of robbery, were absent.

Real warfare became practical when, between 7,000 and 10,000 years ago, men learned to tame food-animals and raise crops. By these inventions they so increased their food supply that great groups of people became possible, and they could save enough to tempt the plunderers. Moreover, these inventions allowed men more spare time, which in turn encouraged them to make still more inventions. This process still goes on in the dizzy pace of technological change that confuses so many people today.

## Ancient Weapons

Although man, compared to most animals, is a fairly large and powerful creature, he is weakly armed in proportion to his size. He lacks not only horns and claws, but even the big canine tusks owned by his cousins the apes. A million years ago, when he began his climb towards civilization, he probably knew how to throw stones and to hit with a stick. All his many weapons developed since have had the same purpose; to kill, wound, or otherwise subdue his enemies in order to compel them to do what the man wanted them to, whether to let themselves be eaten, or to give up their property to the victor, or to lower their taxes. These weapons both enable the warrior to attack his opponent at a greater distance than if he had to depend on hands and teeth alone, and, by storing energy which is released all at once when the weapon strikes, to damage the victim more severely than is possible by biting and kicking.

The bow, invented at the beginning of the Neolithic Age, fulfilled both these functions. Before that time men used a device called a spear-thrower, a stick with a hook or spur at the end. They held the spear-thrower in the same hand that held the javelin or throwing-spear, with the hook of the thrower engaging a hollow in the butt of the javelin. Then they threw with an overhand motion, letting go the javelin so that the thrower acted as an extension of the arm. The bow, having much greater range and accuracy, spread over most of the world and drove out the spear-thrower except among a few isolated tribes. A few peoples developed more specialized missile weapons, such as the boomerang, the sling, the pellet-bow, and the blow-gun. The natives of Borneo not only make a blow-gun for shooting poisoned darts, but also equip it with a sight and a bayonet.

The discovery of metals about 6,000 years ago brought about a revolution in weapons, since they could be made of copper or bronze more quickly than of stone, and since the material allowed a greater variety of forms. For instance, swords became practical for the first time, though some peoples had previously tried to make them by edging a flattened wooden club with sharpened stones or sharks' teeth.

A typical bronze-age battle comprised a few well-armed nobles on each side, each protected by a helmet and a big leather shield, poking at one another with bronze-pointed spears, while behind them howling mobs of the common people hurled stones and insults. The nobles' swords of bronze or (later) of iron were so soft that after a bit of hard fighting, the swordsman had to take time out to straighten the kinks out of his weapon.

As metallurgy improved, not only did the quality of the weapons improve, but also more men could afford armor, beginning that long conflict between armor and armor-piercing weapons that has continued ever since. When King Darius of Persia sent an amphibious expedition agai Greece in 490 B.C., the Greeks beat the Persia at Marathon, not because they were braver, b because they had good bronze armor. The u armored Persian archers had always been ab to mow down their enemies from a distanc now, however, their arrows merely bounced the helmets and breastplates of the Greek so diers, and when the latter got in among the with spears there was nothing for the Persia to do but run.

Although nowadays science and invention a closely connected, such was not the case former times; science was a matter of the vagu speculations of priests and philosophers, whi

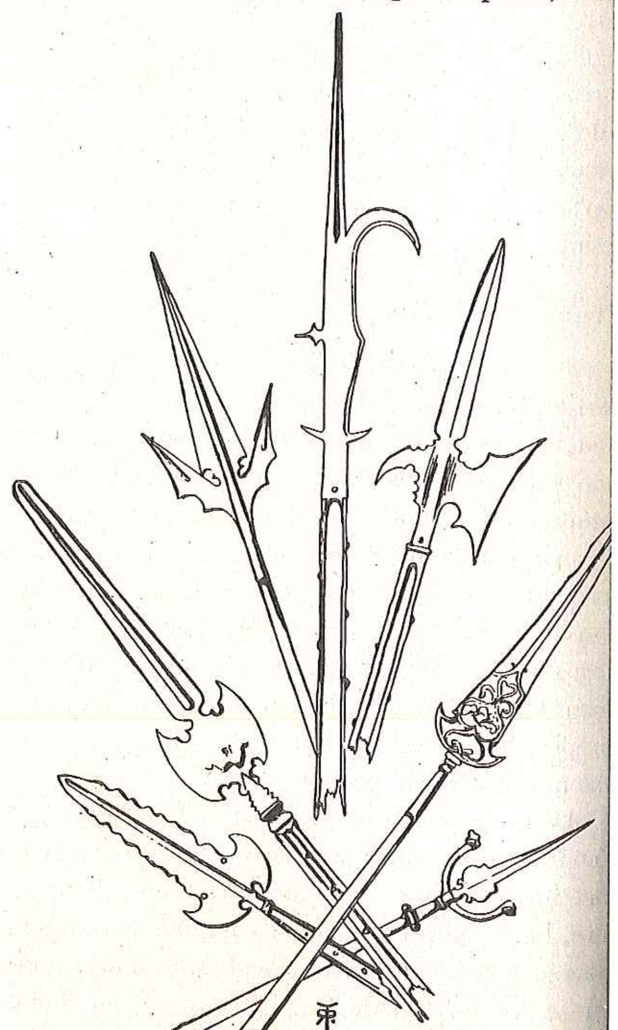

Figure 1.—**Can-opener warfare.** Infantry weapons of the Middle Ages for attacking armored horsemen: halberd, bills, and partisans.

practical inventions were created slowly and under great handicaps by unknown common men. Moreover most societies were very conservative about new ideas, so that brilliant inventions were often not adopted because of inertia, ignorance, or distrust, or because they might impair somebody's vested interest.

For instance, the ordnance department, a group charged with improving weapons and devising new ones, was invented as early as 400 B.C., but failed to become an established institution until modern times. At that time Dionysios, the dictator of Syracuse, was planning to attack the Carthaginian colonies in Sicily. He therefore hired philosophers and skilled artisans at high wages, entertained them with wine, women, and song, and told them to devise something to beat the Carthaginians, or else. The experts accordingly invented the first catapult—a kind of overgrown crossbow on a pedestal, shooting six-foot arrows. After the war one of these arrows was taken to Sparta as a curio, where a certain Archidamos, seeing it, cried: "O Herakles, the valor of man is at an end!" That is the first recorded protest against the mechanization of warfare.

Although such outcries have been heard with increasing frequency ever since Archidamos' time, they have done little to retard the evolution of weapons. When the crossbow came into general use in medieval Europe it was considered such a fiendish weapon that in 1139 the Catholic Church issued an edict against it, but with little effect. Similar objections have been raised more recently against submarine warfare, gas, and the atomic bomb.

In general these protests are based upon an irrational fear of the new rather than upon a reasoned humanitarianism, since after all a man is just as dead when he has been beaten to death with a club as when he has been blown up by an atomic bomb. The great losses of the two recent World Wars were due more to the vast scale of the wars and the size of the armies than to the destructiveness of modern weapons. Moreover, the deliberate massacre of eight or ten million prisoners and civilians by the Germans in World War II was not a matter of machine-age warfare at all, but of the Germans' political and racial theories. As long as trial by battle persists in international affairs, the precise method by which people are killed is a minor consideration.

### The Transition to Modern Weapons

In the Classical or Graeco-Roman Age warfare reached an extraordinarily high degree of organization, with phalanxes of 20,000 spearmen, archers and slingers, war-elephants, armored siege-towers, catapults, incendiary bombs, and warships with crews of a thousand men or more. After the fall the Roman Empire in the 5th and 6th centuries, however, the art of war declined in Europe almost to the howling mob stage out of which classical warfare had grown. For several centuries really skilled warfare was found only in the Byzantine Empire, that revived eastern half of the Roman Empire in Asia Minor and the Balkans. The superior military skill enabled the Byzantines century after century to roll back waves of Huns, Arabs, Russians, and other invaders before they finally went down before the combined attacks of Turks, Slavs, and Western European Crusaders.

The four or five centuries from the fall of the West Roman Empire to the rise of Western European civilization, though known as the Dark Ages because of its political disorganization and general illiteracy, witnessed a number of important inventions such as the wheeled clock, the iron horse-shoe, and the rudder. In the 13th and 14th centuries appeared two of the most important inventions in the history of warfare: the iron-casting furnace and the gun. Until the 13th century all iron was wrought iron, with a low carbon content and hence too high a melting-point to be cast with the types of furnace available. Since the primitive wrought-iron furnace produces metal in small lumps only, large solid pieces of metal, like the cuirass (breastplate and backplate armor) of a classical Greek Soldier, had to be of bronze or brass.

Iron armor first took the form of the Roman legionary's cuirass of narrow iron strips fastened together; later of the mail-shirt of iron scales or rings sewn to a leather jacket; and later yet, during the Dark Ages, of chain-mail of interlocked steel rings. Plate armor, which when properly fitted is easier to move around in and more protective than chain mail of the same weight, did not come in until the beginning of the 14th century, just about the time of the invention of the gun that was eventually to drive all body-armor off the battlefield. For a time armor outdistanced the gun in development, just as it did at sea for a time in the 1860's and 70's. The mounted man's plate armor afforded such fine protection that in one late-medieval battle in Italy only one man was killed, and he fell off his horse into a bog and was drowned by the weight of his armor. A complete suit of plate, though it might weigh 50 to 100 pounds, was so cleverly made that a strong man could get about in it with fair agility—though he had to be hoistered aboard his horse by a kind of derrick. The common infantry weapons (bills, poleaxes, glaives, halberds) were essentially big can-openers mounted on the ends of shafts.

The perfection of the gun as a practical weapon in the 16th and 17th centuries revolutionized warfare by substituting the chemical energies of natural substances for the muscle-energy that had theretofore been used by soldiers in swinging swords, drawing bows, and cranking catapults. So much more power could be imparted to missiles in this way that in time the gun swept all competition from other weapons before it. The few other weapons that remained in use, like the torpedo and the bayonet, were mere occasional auxiliaries. Only in modern times have the airplane bomb and the rocket begun to make serious inroads on the positio of the gun as the weapon.

## The Warship

Although we are concerned here with weapon as distinct from weapon CARRIERS like ships tanks, and airplanes, the development of th warship is worth looking into briefly. In ancien times a warship was essentially an overgrowr rowboat with a beak at the bow. It fought othe rowboats by ramming and boarding. In earlie times, as at the celebrated Battle of Salamis in 480 B.C., a warship was about 75 feet long and 15 feet wide, with about 90 oars arranged in three banks on each side, one rower to an oar. Later, as ships grew larger, oars were arranged

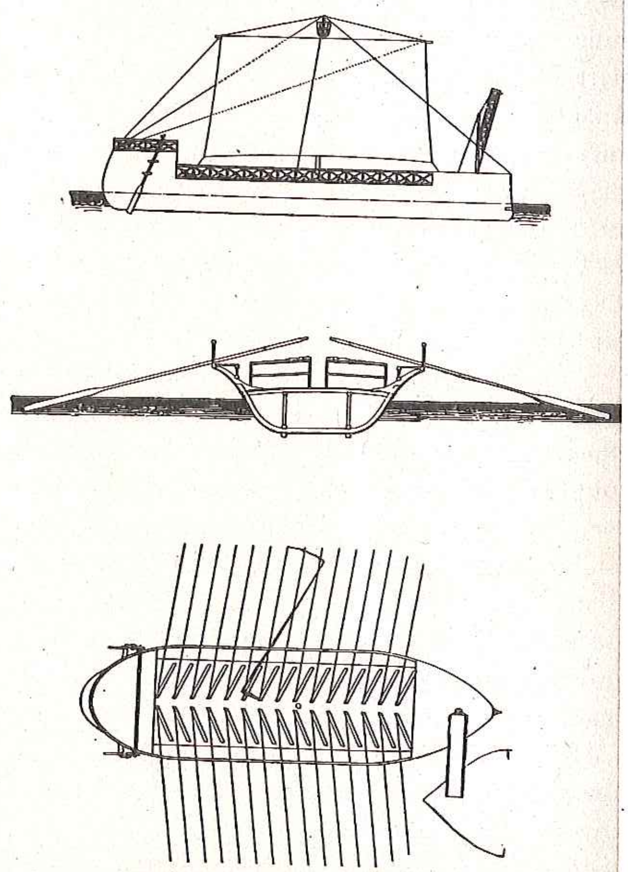

Figure 2.—**Roman quinquireme.** Punic War period; one bank of five-man oars. The derrick-like structure forward is the corvus, a drawbridge for boarding enemy ships. (From Wm. L. Rogers, *Greek and Roman Naval Warfare*, reproduced courtesy of U. S. Naval Institute.)

in one or two banks, but the number of men per oar was increased to as many as ten. After the time of Alexander the Great ships reached a length of 200 feet and a weight of several hundred tons, and some mounted catapults. Still, these galleys were by modern standards impossibly flimsy and unseaworthy affairs. A ship squarely rammed might disintegrate into a tangle of floating boards, and, since the oars required a low freeboard, a good gale sometimes sent a great nation's whole fleet to the bottom. The Romans thus lost four fleets in the First Punic War.

After the Roman Empire became supreme in the Mediterranean in the 1st century B.C., warships declined in size because there was nobody for the Romans to use large ships against, and small ships were adequate for pirate control. For nearly 2,000 years the design of warships changed but little in Europe and the Mediterranean; Byzantine dromons, Viking longships, and medieval Venetian galleys were all essentially classical warships with a few improvements.

The gun brought about a revolution in warship design, partly because the galley was so vulnerable to gunfire, partly because the combination of guns and rowers baffled the designers. First the Venetians tried putting a few fixed cannon in a forward deckhouse. However, the guns wrought such havoc among hostile rowers that the admirals clamored for more guns.

For the Battle of Lepanto in 1571, therefore, the Venetians had prepared eight galleasses, oversized galleys with an upper deck mounting many guns. In this battle the Christian Mediterranean powers broke the Turkish rule of the sea—no small feat, since at that time the Turks were the world's leading military power, being ahead of Europe in such departments as musketry. The guns made the galleasses so heavy that their rowers were barely able to move them. Hence they were towed into position ahead of the Christian line, and when the Turkish galleys advanced, the gunfire of the galleasses did great execution among them.

Still, the galleass was not the answer because of its immobility. Some years previously, however, Venice had built a large heavily-armed sailing-ship, the *Great Galleon of Venice,* an enlarged version of the sailing gunboat called a "nef" that had lately come into use. This ship had gone with a Venetian squadron to demonstrate off the Turkish-held harbor of Preveza in Greece, and the Turks had come out and chased the Christians away—all but the *Galleon,* immobilized by a sudden failure of the wind. The Turks rushed upon the *Galleon,* but their gunfire failed to penetrate the high, thick sides of the ship. Those that rammed her stove in their own bows and sank, while the rest were slaughtered by the *Galleon's* cannon. When the surviving Turks drew off, the Christians returned and towed the *Galleon* home.

Such invulnerability made such a ship worth while, even if it stood the risk of being occasionally becalmed. Therefore in the years following Lepanto ships of the new type were built in large numbers, while galleys were retired. One reason for the English victory over the Spanish Armada in 1588 was that the Spaniards, not having assimilated the revolution in naval warfare, persisted in trying to fight by ramming-and-boarding tactics. As an early example of governmental red tape, during this battle Lord Howard sent a messenger galloping from Dover all the way to the Tower of London to beg the officials there for God's sake to send powder and shot—which they refused to do because the request was not made out in proper form.

The new type of naval warfare with gunnery sailing ships prevailed until the middle of the 19th century, when the introduction of steam power, rifled cannon firing explosive shell, armor, and iron construction brought about an even more drastic revolution. Robert Fulton began it with his steam-powered catamaran

*Demologos,* a gunboat armored with thick wooden bulkheads and driven by a paddlewheel in a well between the two hulls. Although this ship was not finished in time for the War of 1812, steam power was gradually applied to ships of all kinds, though sails were not finally ousted from warships until towards the end of the century.

Armor was the next improvement. In the Crimean War (1853) some armored floating batteries were tried out, and in 1859 the British and French navies laid down armored frigates. A few years later the battle of the *Monitor* and *Virginia* (ex-*Merrimac*) showed how important the new development would be; neither of these strange new ships could seriously hurt the other, though either could easily destroy any other ships in the hostile navy.

The development of new weapons is an interacting process, since each new weapon incites people to try to develop some means of neutralizing it; hence the explosive shell begat iron ship-construction and armor, armor begat armor-piercing shells; torpedoes begat underwater compartmentation of large ships; and so on. That is why we hear so much about the conflict between the offense and defense. Each offensive arm stimulates the development of a defense against it, and vice versa.

However, the terms "offense" and "defense" are elastic. Strictly speaking "defense" refers to tactics that involve waiting for the enemy to attack, or to material things like armor and fortifications that cannot themselves invade or vanquish the enemy. But since unprovoked aggression has long been considered immoral among civilized peoples, nations tend to apply the term "defense" to their own military policies, tactics, and weapons for its propaganda value. For instance, during the several disarmament conferences between the two World Wars, each nation referred to the military means wherein it excelled as "defensive," and to those it feared in the hands of others as "offensive." The submarine was considered defensive by Fran (which had a large submarine fleet) and offe sive by Great Britian (which had a large me chant-marine vulnerable to submarine attack).

During the great 19th century revolution warship construction, the world's naval constru tors had a hard time incorporating all the changes at once. As a result they built mar weird craft, like the USS *Union* of the 1840' with horizontal paddlewheels revolving in wel in the ship's sides and a speed of three kno in smooth water. When the U. S. Navy Depa ment wanted shallow-draft armored monitors f the western rivers during the Civil War, an Ericsson, who had built the original *Monito* said it could not be done, Stimers, a Navy D partment engineer, guaranteed to do it if give an independent office. He was told to buil twenty. Unfortunately one of his people erre in calculating weights, with the result that whe the first ship, the *Chimo*, was launched, sh immediately sank with a gurgle to the botto of the East River.

If the introduction of rifled cannon and e plosive shell increased the power of guns again ships, the advent of armor likewise made mo powerful guns necessary. Dahlgren's exper ments to find the distribution of gas-pressure inside a gun made possible greater charge which meant longer guns, and this in turn le to a switch to breech-loading, since muzzle loaders had to be hauled inboard to be loaded and that is not practical with a gun 25 or 3 feet long. The adoption of cylindrical projectile meant heavier projectiles in proportion to th bore of the gun. Even after the cylindrical she had been adopted, the solid roundshot was re tained for a while for armor-piercing, since could be given a higher muzzle-velocity wit the maximum safe charge and hence greate energy despite its lesser weight.

Another curious result of this revolution wa the reintroduction of ramming as in the day of galleys. The *Virginia* wrought havoc with he ram on her first sortie, and that method was used to advantage several other times during the Civil War. Likewise in the Battle of Lissa in 1866, an Austrian battleship sank an Italian battleship in this manner. As a result, for several decades nearly all large warships were built with ram bows projecting forward below the waterline. The 7,000-ton ironclad *Dunderberg*, begun for the U. S. Navy during the Civil War, embodied an extreme form of the ram bow. After this war, when Congress let the Navy go practically out of existence, the *Dunderberg* was sold to France and renamed the *Rochambeau*. As she proved very successful, the French long copied her tremendous snout. However, by World War I guns had so improved that ships would sink one another by gunfire long before they got close enough to ram, except on rare occasions as when the British flotilla-leader *Broke* sank a German destroyer at night in the Channel in this way. Ramming is still a good method of attacking submarines. As late as 1943 the U. S. Navy strengthened the bows of its destroyer escorts so that they could ram submarines without crippling themselves in the act.

The change to iron (and then steel) construction after the Civil War made possible much larger warships of finer lines, since a wooden ship of over 6,000 tons was apt to break up in rough weather. In general, the efficiency of ships increases with size. By increasing the tonnage of a ship 25% one can, roughly speaking, increase its armament about 50%, keeping speed, thickness of armor, and other qualities the same. Hence there was every inducement to build larger ships—a process that has culminated in the 60,000-ton Japanese battleships of World War II and the projected U. S. aircraft carrier of an even larger size.

## The Mechanization of Warfare

Ever since the rise of civilization, men have tried to devise an effective fighting vehicle that would combine mobility, protection and fire-power. The war-chariots of the ancient Assyrians and Egyptians were not a very successful effort in this direction because the horses were vulnerable and the vehicles were confined to smooth ground. Elephants, though tried out for many centuries, made poor tanks because of their sense of self-preservation. Although like chariots they could sometimes frighten the enemy into running away, experienced soldiers could usually stampede them back through their own army by noise and missiles. Indian elephants beat African elephants at Raphia (217 B.C.) mainly because there were more of them.

Some of the early siege-engines on wheels, pushed by manpower, suggest modern armored vehicles, though their mobility was much less—one siege-tower moved a quarter of a mile in two months. The Assyrians had invented the movable siege-tower or helepolis, with a battering-ram on the lower storey and a place for archers above. The art reached its apex with

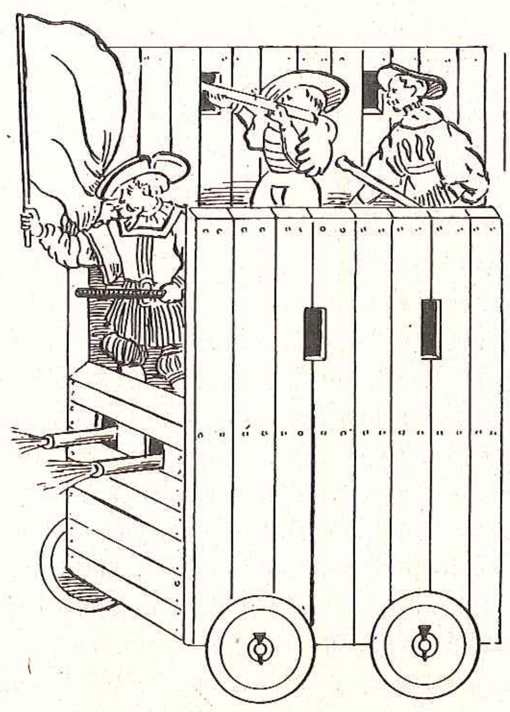

Figure 3.—**Predecessor of the tank.** Battle-car designed by Valturius in 1530.

Demetrios Poliorketes, one of the successors of Alexander the Great. In besieging Rhodes in 305 B.C., Demetrios built a nine-storey helepolis 50 feet square at the base and 100 feet high, armored with iron plates. It had catapults shooting stones and javelins through ports provided with shutters on each storey. There were companionways inside for up and down traffic, water-tanks on each storey for putting out fires, and eight castor-mounted wheels for maneuvering. The contraption was pushed by 3,400 of Demetrios's strongest soldiers.

When it approached the wall of Rhodes, the Rhodians knocked off some of the armor-plate with stones from catapults and threw incendiary bombs into the gaps, whereupon the besiegers pulled the tower back and put out the fires. When they had made repairs they started forward again—but this time the crafty Rhodians had turned the sewers of their town into a field in front of the helepolis, making a bog in which the tower got hopelessly stuck.

Demetrios also built some other remarkable devices during this siege, including battering-rams in wheeled sheds, and monitors made by fastening two to six ships together and erecting a large catapult or a siege-tower on the resulting unit. When he finally reached an agreement with the Rhodians and sailed away, the Rhodians sold his abandoned engines and used the money to build the famous Colossus of Rhodes.

During the later Middle Ages the inventive Scots tried to solve the fighting-vehicle problem. Among other devices, they experimented with battle-cars, two-storey sheds on wheels with a couple of horses for motive-power inside the first storey and a squad of musketeers shooting through loopholes above. None of these devices proved practical because they depended upon muscle-power, and men or animals are too bulky in proportion to their strength to combine the necessary protection and mobility.

With the application of the steam-engine to transportation in the early 19th century the idea of armored fighting vehicles was revived. An armored train was suggested as early as 1826 and used in a siege of Vienna in 1848. Armored trains are still used occasionally, though they are confined to a vulnerable track. The first man to mount a gun on a motor-vehicle was Major Davidson of the Illinois National Guard, who in 1900 combined a machine-gun with a light Duryea horseless carriage.

By the outbreak of World War I several European nations had armored cars, which skirmished gallantly in the opening weeks of the war. After the front became too cut up by trenches for cars to be of use there, the British armored cars were sent to the deserts of North Africa and the Middle East, where they proved useful. Still, like the armored train, the armored car did not solve the problem, being confined to roads or to flat treeless terrain. The problem was finally solved by combining guns and armor with the newly invented caterpillar tractor to make the tank—conceived by Colonel Swinton of the Royal Engineers, mothered by Winston Churchill, and finally designed by Lieutenant Wilson of the Royal Air Service and the engineer William Tritton, to name only a few of those who had a hand in its development. The tank filled the vacant place in the catalog of military tools formerly occupied by the war-elephant and the armored knight.

In a sense, the mechanization of land armies represents a sort of belated catching-up with the methods that have always been used at sea. Many of the features of modern military vehicles and airplanes were worked out long before on ships; for instance, mounting guns in revolving turrets on the centerline. One might say that sea warfare has always been mechanized, in the sense of being carried on in self-propelled, self-sufficient fighting vehicles. That fact does not mean that naval men are more intelligent than others, but that land and air vehicles presented harder problems. Hence one effect of the expansion of air warfare and the mechanization of land warfare has been to make warfare in the three elements more and more alike.

### Weapons and Society

Ever since it arose in the Dark Ages, our Western culture has differed from others in its tendency towards rapid technical development, so that non-Western societies like the Russian and the Japanese have had to copy Western methods in order to hold their own against Western pressure. Since invention is a self-regenerative process, it is likely to go on, faster and faster, until limited by the exhaustion of natural resources or some other factor that cannot now be foreseen.

The development of weapons and the state of society affect one another. Some years ago Silas McKinley, a history professor, claimed to have found a regular correlation—democratic government is stable and successful when the fundamental military unit is a citizen soldier armed with a cheap, easily-used weapon. He cited the democratization of Greece when improvements in metallurgy made arms and armor available to the common people, and the French and American revolutions when the cheap flintlock musket was the universal arm. McKinley thought that democracy would be in danger whenever the fundamental military unit was a highly trained professional soldier, or one using a complicated and expensive weapon. If he is correct, his principle directly affects the people of the United States, because soldiers today use the most complicated and expensive weapons ever seen.

### The Development of Weapons

The evolution of weapons, like that of other devices, is a self-accelerating process. Hence it is safe to say that weapons will become more and more devastating, at least in the absence of any effective world government or other international control to stop the process. And no such super-state seems likely as long as the world is organized into a multitude of sovereign nations grouped into hostile blocs.

However, it is easier to admit that weapons will change than to foresee the nature of the changes. For more than half a century, ever since the pace of modern technical change was appreciated, predictions of future weapons and methods of warfare have been favorite themes of imaginative writers. Some years before submarines became practical, Jules Verne sent one of his heroes voyaging the Seven Seas in one, and Colonel Swinton and H. G. Wells both wrote stories predicting the tank. But for every correct prediction there have been many absurdly wrong ones. About half a century ago Kipling predicted transatlantic air-mail service in his story *With the Night Mail;* while his general prediction has been realized, he made the mistake of going into technical details, nearly all of which have proved wrong. Before World War I many speculated as to the form it would take; almost nobody foresaw the trench-warfare stalemate except a Polish banker, I. S. Bloch.

Two sources of error in making predictions seem to be what we may call the Galahad fallacy and the David-and-Goliath fallacy. The Galahad fallacy is the idea that "my strength is as the strength of ten because my heart is pure." Unfortunately history does not support any such idea. Some of the most bloodthirsty tyrants have also been the ablest and most successful military leaders. The David-and-Goliath fallacy is the belief that weakness has some mystic advantage over strength, and smallness over bigness. This sentiment leads people to praise small military units like the airplane and the torpedo-boat beyond their actual merits, and to disparage large units like big ships and heavy artillery as "clumsy" or "useless." Sometimes, true, a small device will put a big one out of use; but that is not always true.

The development of weapons is by no means free of limitations. For one thing, the first steps in the development of a new weapon are likely to be slow and fumbling. The evolution of weapons is also retarded, not only by the conservatism of military men (or, to put it more fairly, of men in general) but also by the fact that for every good suggestion there are many impractical or absurd ones, and not even the wisest can always tell which is which at first sight. And even when an idea is sound, years may be needed to reduce it to working order.

Moreover, the development of a new weapon does not at once put all the old ones out of use. One of the most striking features of military history is the persistence of old weapons alongside the new ones. In fact it is hard to think of any weapon that has ever gone COMPLETELY out of use, once it was well established. Thus World War II, with its guided missiles and atom bombs, also saw the use of the "obsolete" sword, spear, longbow, crossbow, horse-cavalry, sailing ship, and war-elephant!

# CHAPTER 2

# EXPLOSIVES

## The Origin of Explosives

The Chinese discovered gunpowder about the year 1200 or earlier. Aside from a few experiments with bombs and rockets, they used it mainly for firecrackers. Knowledge of gunpowder spread to Europe in the 13th century, and in the early 14th century the gun, along with rockets, mines, and other military applications, came into use. To be a gunner at that time was, if anything, more dangerous than to be shot at by a gunner, since the gunner had to mix his powder himself, without knowing quite what he was doing.

For over six centuries after the Chinese discovery that a mixture of carbon, saltpetre, and sulphur would explode, gunpowder was the only known explosive. As an explosive, however, it left much to be desired: it was smoky, variable in performance, left a residue in gun barrels, and delivered a push rather than a shock.

Then in 1845 the German chemist Christian Friedrich Schönbein was experimenting on the solubility of various substances in a mixture of nitric and sulphuric acids. Among the materials were some strands of cotton. After a prolonged soaking the cotton looked just the same, so the disappointed Schönbein put the strands on the stove to dry and went to dinner. While he was gone his laboratory blew up: he had accidentally discovered nitrocellulose or guncotton.

Chemists immediately began exploring the new field of nitrate exlposives. They found that by treating various substances with nitric acid and other powerful reagents they could nitrate these substances, that is, add to each molecule of the substance one or more nitro ($NO_2$) or nitrate ($NO_3$) radicals which would come adrift with great violence under certain circumstances. Next year, for instance, Sobrero discovered nitroglycerine, made by nitrating glycerine, an oily liquid that gave, weight for weight, an explosion about eight times as powerful as that of gunpowder.

Nitroglycerine proved too unstable for a practical explosive; that is, it went off when it was not supposed to. Alfred Nobel, the Swedish chemist who founded the Nobel Prizes, in 1863 discovered how to use nitroglycerine by soaking it up in fuller's earth. This treatment, while it impaired the explosive power of the nitroglycerine very little, made it so stable that it had to be set off with a mercury fulminate cap. Thence Nobel went on to invent the even more powerful blasting gelatine by asborbing nitroglycerine in nitrocellulose.

Dynamite proved of little military use, since it detonated too rapidly for a propellant. Whereas a gunpowder explosion is merely a rapid burning, the detonation of the new nitrate explosives was the almost instantaneous breakdown of the explosive into gaseous compounds, transmitted from molecule to molecule by shock. Hence such an explosive, used as a propellant, burst the breech of the gun because the projectile could not move fast enough to relieve the pressure in the powder chamber. Neither did dynamite make a good shell-filling, since a drop of nitroglycerine sometimes accumulated at some point in the charge and exploded from the shock of firing.

The U. S. Navy once tried a compressed-air cannon that would give a dynamite-shell the easy acceleration required. To that end it built the *Vesuvius*, a handsome little 252-foot gunboat that looked more like a yacht. She carried three fixed pneumatic guns sticking up out of the deck forward, throwing projectiles resembling modern airplane bombs. During the Spanish-American War the *Vesuvius* invaded Santiago Harbor nightly during the blockade of that port and fired her weapons. The guns shrieked and the projectiles went off with terrific bangs, shattering the already uncertain nerves of the Spaniards but doing little material harm.

Since then dynamite has been restricted to the peaceful uses of blasting and mining, while other nitrate explosives have ousted gunpowder from nearly all military uses. For a propellant, "smokeless powder" (invented by Schultze in 1865) is used both in small arms and cannon. It consists mainly of nitrocellulose mixed with other substances to retard deterioration and slow down its rate of explosion, and its various forms are known by such names as "cordite" and "ballistite". Its big advantage is that it makes much less smoke than gunpowder, so that the gunner does not have to wait after each shot for the wind to carry the smoke away before he can see to fire again. One of the few advantages held by the hapless Spaniards in the Spanish-American War was that they had switched to smokeless powder while the United States was still using "black powder" or gunpowder proper, with the result that American positions were given away at the start of a battle by smoke. Military engineers are still striving to reduce both the smoke and the flash of nitrocellulose propellants, especially since so many naval actions are now fought at night, and bright flashes not only give away one's own position but temporarily blind one's own people.

## Modern Explosives

The nitrate explosives include many compounds more powerful than nitrocellulose or nitroglycerine, but not necessarily suitable for general military use. A military explosive should be not too expensive, should not deteriorate rapidly, and should not be too sensitive for the purpose for which it is intended. Tetryl (tetranitromethylaniline) is extremely powerful, but too sensitive for anything but percussion caps and boosters. TNT or trinitrotoluene (made by nitrating the coal tar product toluol) is the most widely used all-around military explosive, since it is both powerful and so stable that it is almost impossible to set it off except by a tetryl or a mercury-fulminate detonator. For armor-piercing shells, however, TNT is not quite stable enough; it may go off from concussion before the shell has passed through the armor. Therefore the even more stable ammonium picrate is used in such shells.

During World War II another explosive, RDX (made by nitrating hexamine) came into use; too sensitive to be used pure, it was mixed with TNT, aluminum powder, and wax to make the powerful explosive "torpex" now used in mines and torpedoes. A mixture of charcoal powder and liquid oxygen has been used for blasting in Europe since before World War I, and was tried out in airplane bombs in the Spanish Civil War. It is a fairly successful explosive, having the advantage that in case of a misfire the oxygen will evaporate in half an hour or so, leaving a harmless mass of carbon. On the other hand it has to be mixed shortly before use, and undue delay will spoil the mixture, so that it seems unlikely to replace nitrate explosives in regular military operations.

## Fissionable Materials

Before the perfection of the atomic bomb, men had known for several decades that enormous energies were imprisoned in the atom, and had speculated about releasing these energies. H. G. Wells, in fact, used atomic bombs in a novel published before World War I, though these bombs were practically harmless compared to the real thing. Early in this century physicists figured out that matter and energy were to some extent interchangeable, and Einstein calculated the amount of energy that would be released by the destruction of a given quantity of matter.

In 1938, just before World War II, the German physicists Hahn and Stassmann announced that in bombarding uranium with neutrons they had produced barium. In Denmark Dr. Lise Meitner and her nephew Otto Frisch inferred from this fact that the neutron bombardment had caused some uranium atoms to split into two more or less equal parts. When the celebrated Danish physicist Niels Bohr reported this fission to a scientific meeting in America, physicists amid much excitement confirmed the experiment and added further information.

It transpired that the split occurred, not in the common form of uranium, with an atomic weight of 238, but in the isotope U-235, which occurs mixed with the common form in the proportion of one part in 140. However, when an atom of U-235 splits under neutron bombardment, it gives off not only two or more atoms of lighter elements, together with penetrating radiations of the X-ray type, but also between one and three neutrons. Hence, if enough U-235 could be concentrated together, each explosion would cause (on the average) more than one more atomic fission in the neighborhood, so that the process would proceed through more and more generations until the material was used up or the release of energy blew the mass apart—in other words, a chain reaction.

Since uranium is naturally radioactive, it would not be necessary to bombard the mass with neutrons from the outside; the natural radioactivity of the element would start the reaction once a "critical mass" had been brought together. Moreover, some of the mass of the original U-235 would be converted into energy in the process, so that the reaction would release something like 10,000 to 20,000 times the energy released by the explosion of a similar weight of TNT. Bringing the mass together slowly would cause a low-order explosion that would scatter the material before the chain reaction got more than started. Therefore, a mechanism was needed to assemble the critical mass at explosion speeds.

The U. S. armed forces showed immediate interest in the possibilities of the new discovery, so that in the summer of 1939 President Roosevelt appointed an Advisory Committee on Uranium to oversee further investigations. By the end of 1941 these and other groups of scientists had determined that, theoretically at any rate, an atomic bomb would work. With the entry of the United States into the war, the U. S. Government at once undertook a large program of atomic bomb development. A similar program had been begun in Great Britain, but in view of the greater resources available in the United States, the British merged their effort with that of this country.

Research disclosed that the operation of a uranium pile produced a new element, neptunium, which by radioactive disintegration changed into another, plutonium, having chain-reactive properties similar to those of U-235. Since the separation of U-235 from ordinary uranium by gaseous diffusion, separation by electromagnetic means, and production of plutonium all showed promise, all three methods of obtaining fissionable materials were pursued vigorously to the end of the war. The bombs were finally manufactured between 1942 and 1945 by a special section of the U. S. Army Corps of Engineers, provided with the deliberately misleading name of "Manhattan Engineer District" and calling its program "Development of Substitute Materials." Finally, the dropping of two bombs on Japan in August, 1945, broke the deadlock in the Japanese cabinet over peace terms and paved the way to the surrender of Japan.

During this great project, Americans in the know had worried lest Germany complete an atomic bomb first. After the war it transpired, however, that the Germans had lagged far behind in atomic work. The advent of the Hitler government had caused some of Germany's leading physicists (including Dr. Meitner) to flee the country, and those remaining were handicapped and discouraged by the conviction of the Nazi leaders, in accordance with their pseudo-scientific theories, that physics was a "Jewish science" unworthy of Nordic Aryans.

When an atomic bomb is detonated by bringing the component parts of the mass of fissionable material together suddenly, the release of energy makes this mass hotter than the surface of the sun. The resulting explosion wastes about 98% of the fissionable material; therefore, improvements in atomic bombs since the war have been directed to causing more of the fissionable material to react. The bomb and its contents are instantly vaporized, forming a white-hot cloud so bright that to look directly at it within a distance of several miles may permanently impair the eyesight. The cloud expands rapidly, first in the form of a sphere, then becoming an irregular column, cooling and dimming as it does so, and finally giving rise to a characteristic mushroom-like top several miles above the actual explosion.

The shock-wave of the explosion, while not as sharp as that of a detonant like TNT, is strong enough to knock down nearly all light structures within a mile or more of the site. Inflammable materials close to the explosion may be set afire by heat-radiation from the cloud. Persons quite close to the explosion are not killed by the shock wave, though they may be knocked down; on the other hand enormous numbers may be killed by the fall of houses in the resulting conflagration. Those who escape these fates are injured both by the ultraviolet radiations from the cloud, which cause a violent sunburn, and by the higher-frequency radiations of the X-ray and gamma-ray type. The latter cause the victims, if they do not die within a few hours, to linger on with strange scars, growths, and maladies. Material objects near the explosion are made so radioactive as to be unapproachable for days or even years.

News of the atomic explosions created a world-wide sensation. Thinking persons everywhere recognized that the new weapon had enormously increased the destructiveness of warfare and the advantage of surprise attacks. The success of the atomic project also brought into the realm of possibility the use of fissionable materials to generate electric power in competition with coal and other existing power-sources. Some speculated about the possibility of dusting areas of hostile countries with radioactive dust, composed of the by-products of uranium-pile operation, though that method presents difficulties in the way of shielding the airplane crew from the radiations of their cargo.

Efforts to control the use of fissionable materials and atomic weapons since World War II by international agreement have been blocked by profound differences between the Union of Socialist Soviet Republics and its satellite nations on the one hand, and by the other states represented in the United Nations on the other. Meanwhile the United States has continued to manufacture atomic bombs. We believe that the U.S.S.R. is trying to make such bombs, and that they are undoubtedly behind the United States in this development. At any rate, it seems quite certain that, in the event of another war, the atomic bomb will not only be used, but also will be the most important single weapon.

# CHAPTER 3

# FUZES

## Evolution of Fuzes

Fuzes go back to the earliest use of explosives, since to set off a mine, firecracker, or similar static charge the engineer must have some means of getting out of the way before the charge explodes, or else of setting it off from a distance. The early fuzes consisted of a tube of soft metal or fabric filled with gunpowder that would burn down gradually until the flame reached the main charge.

When bombs with fuzes were first perfected, they were first thrown into besieged places by catapults, and later shot from mortars. About 1600 it was the practice to put a spherical bomb with a tubular sheet-iron fuze into a mortar with a propelling charge, light the bomb-fuze with one hand, and then touch off the mortar with the other, throwing the bomb into the enemy position just in time for it to go off as it hit.

However, wind, weather, and the general unreliability of early gunpowder made this a very ticklish operation. The concussion of the gun might detonate the bomb before it left the mortar; or the bomb fuze might go out or come adrift in flight; or the propelling charge might misfire, leaving the bomb-fuze sputtering away and the gunner leaping madly for cover. Still, the system changed little for over two centuries; the "bombs bursting in air" of the "Star Spangled Banner" refers to mortar-bombs of this kind used at the siege of Fort McHenry in the War of 1812.

Explosive projectiles for regular guns did not become practical until well into the 19th century, when Captain (later General) Henri Joseph Paixans developed a practical explosive shell. In a couple of minor European wars around the middle of the century, these shells were used with devastating effect on wooden ships, blowing them to splinters and setting the remains on fire. Hence this development hastened the switch to iron ship construction.

The 19th century artillery revolution included the use of the mercury-fulminate percussion cap to start the fuze burning, along with rifling, and the use of a cylindrical projectile with a nose tapered to a rounded point, called a "cylindro-conoidal" projectile. All these changes were in progress during the American Civil War and the decade following, so that during this period these improvements were used in all combinations with the older methods: spherical explosive shell, cylindro-conoidal solid shot, and so on.

Fuzes were soon developed in two types: time fuzes and contact fuzes. In a time fuze the discharge of the gun started the fuze burning, either because the flame of the propellant had direct access to the fuze, or because the concussion set off a fulminate cap which in turn ignited the fuze. In a contact (percussion or concussion) fuze, on the other hand, the cap was detonated by the shell's striking the target and set off the bursting charge immediately. The term "shot and shell" encountered in the literature of the 18th and 19th centuries refers to the fact that both solid projectiles ("shot") and exploding projectiles (called "shell" because of their hollowness) were then in use.

In using time fuzes, the gunner adjusted the time of burning to the distance of the target by cutting the fuze with an instrument to the proper length, screwing the fuze into the shell, and firing; or else the shells and fuzes were furnished already assembled, the fuzes being cut for several times of burning (e.g., 3 and 5 seconds) which were marked on the shell. Such pre-assembled fuzes could be re-set for shorter periods by taking them out of the shell and tinkering with them, but this was not practical in a battle. As a result, 19th century artillerymen were often rendered helpless by having no shells whose fuzes had been cut to the distances at which the enemy happened to be.

By the Franco-Prussian War (1870-1871) solid shot had practically disappeared from land warfare, though it lingered on at sea for some years for armor-piercing purposes. In the latter part of the century solid armor-piercing shot was replaced by armor-piercing explosive shell with a delayed action percussion fuze—that is, a fuze set off by the impact of arrival, lighting an extremely short, fast-burning powder train that would explode the shell a fraction of a second after it had passed through the armor-plate into the ship's interior.

At the same time the time fuzes were made adjustable on the spot as they still are. In these fuzes the powder train, instead of following a straight path down the axis of the shell from the percussion cap to the main charge (or to a booster-charge that sets off the main charge) pursued a roundabout course about the nose of the shell, running for some distance around it circumferentially. The fuze was equipped with a rotatable section, or fuze ring, marked off with numbers like the knob of a combination safe, so that by rotating this ring the gunner could set the fuze to be ignited at any desired point, and therefore to burn, within limits, for any desired time.

Thereafter fuzes changed but little down to World War I. They were made increasingly complicated by the addition of safety devices to prevent the fuze from going off if the shell were accidentally dropped or jarred, and from bursting in the gun-barrel or just after leaving it a result of malfunctioning of the fuze.

Between the two World Wars the stringent r quirements of anti-aircraft fire led to the d velopment of mechanical fuzes to replace th less exact powder train type. This involved ver difficult problems, since, if it is hard to desig a combustion fuze that will work after being sh from a gun, it is that much harder to make piece of clockwork do so. Modern mechanica fuzes use the several forces that act upo shells to arm the fuze (that is, get it ready t set off the shell), operate the mechanism, an finally detonate the shell. These forces includ the setback (the acceleration in the gun barrel) the centrifugal force of the shell's spin, an the creep (deceleration due to air resistance).

Modern shells usually combine time fuze with contact fuzes, in case the shell hits th target before the time fuze has operated. Fur thermore, anti-aircraft shells are made self-de structive; that is, they are equipped with a fuz to detonate the shell a certain time after firing regardless of whether any other fuze has operated, to avoid dropping the shell among one's own people. Shells for small-caliber anti-aircraft guns (37 millimeter and the like) have extra sensitive contact fuzes to detonate them when they strike the thin fabric or sheet metal of an airplane, which ordinary shells would pass through without noticing.

During World War II the Germans specialized in delayed action bombs, which prohibited the use of the area where the bomb fell until it had been disarmed by a bomb-disposal squad, sometimes called an ensign disposal squad or the equivalent by those assigned to that nerve-wracking work. The Germans also provided their bombs with trick fuzes to make them explode while being disarmed. An example of this was a bomb with a photoelectric-cell trigger to set it off when the bomb was opened and light penetrated its interior. The secret of the German magnetic mine was discovered by a British bomb-disposal squad which disassembled one found awash at low tide along the shore. At each step in the process of bringing the mine to shore with non-magnetic tools and its disassembly, specific information was relayed to watchers on the shore as to what was found, what was being done, and what it was intended to do next. Thus, if they were blown up there would at least be a clue as to what they had done wrong and another crew would profit by the knowledge. However, they survived the operation and were decorated for their work.

### The Proximity Fuze

The most important development in recent fuzes was the proximity or VT fuze—a development as significant in that field as the introduction of the repulsion principle in aeronautics or of uranium products in explosives. Prior to World War II, although mechanical fuzes and optical range-finding instruments were developed to a high degree of perfection, the ever-increasing speed and ruggedness of airplanes kept them one lap ahead of anti-aircraft fire, so that in 1940 it was estimated that 2,500 rounds of anti-aircraft fire was needed to bring down one airplane. Clockwork fuzes might explode anywhere within 500 feet of the point where they were supposed to, and, since a burst within 50 or 100 feet was needed for a kill, the shells were not very effective.

To improve accuracy of fire, the fuze-setter was added to the other instruments of an anti-aircraft fire control set. This was a device with an orifice into which the gunner thrust the nose of the shell before feeding it to the gun. In the fuze-setter, steel fingers turned the fuze ring to the setting that would explode the shell at the point where, the instruments predicted, the airplane would be when the shell arrived. Again, however, this method involved a delay of several seconds between the setting of the fuze and the bursting of the shell, during which time a fast airplane would have traveled a quarter of a mile or more and might not be where the instruments had predicted. To be sure of making a hit, therefore, anti-aircraft gunners early in World War II had to fill the sky with a rain of shell-fragments from great masses of guns, some of which pieces of iron would probably hit by sheer chance.

Inventors had tinkered with the problem for years without solving it. Some proposed a fuze with a photoelectric eye to "see" the target; others an acoustic device to "hear" it. None worked, however. For instance, the shell itself made enough noise in flight to drown out the sound of airplane motors in the vicinity. Of the several countries working on proximity fuzes during World War II, the United States was the only one both to solve the problem and to put the fuzes into actual use before the war ended.

The American proximity fuze, developed by the Office of Scientific Research and Development, the National Defense Research Council, the Bureau of Ordnance, Army Ordnance Department, and other cooperating organizations, is a small radio broadcasting set that sends out a single high-frequency radio signal and is detonated when an echo of this signal from nearby objects strikes an oscillator-detector unit in the fuze. In other words, it functions much like a small, very simplified, nondirectional radar apparatus.

If it was hard to develop a clockwork fuze that would stand the shock of firing, it was ever so much more so to build a piece of radio apparatus that would survive the same treatment. The engineers had to resort to many ingenious dodges. For instance, the set was to be battery powered, and to keep the battery from deteriorating the electrolyte had to be kept separate from the plates until the set actually came into use after firing. Therefore, the fuze held the electrolyte in a glass ampule along the axis, while the battery plates consisted of radial ring-shaped shelves surrounding the ampule. When the shell was fired the ampule was broken by setback and the electrolyte spread itself out radially amongst the battery plates by centrifugal force.

After several years of large scale effort proximity fuzes were finally put into action in January, 1943, when the second salvo from the cruiser *Helena's* after 5-inch guns brought down a Japanese dive-bomber whose pilot had thought he was flying out of effective AA range. During the remaining year and a half of the war the VT fuze destroyed hundreds of Japanese airplanes attacking American ships, and stopped the V-1 attacks on London.

The VT fuze was also employed on land for exploding shells a few feet over the heads of enemy soldiers, much as shrapnel had been used in World War I but much more effectively. At the end of the war the fuze was also being applied to bombs, rockets, and mortar-projectiles, and if the war had continued longer it would have proved effective in these applications also.

The biggest single accomplishment of the VT fuze, however, was making the Okinawa campaign of the U. S. Navy possible in the closing months of the war. Because of the fuze, a large American fleet was able to do what had been called impossible—stand close off a hostile shore in support of landing operations, for weeks at a stretch, within easy range of land-based hostile aircraft. At that time the Japanese not only had quite a large number of airplanes left, but were using the unexpectedly effective *kamikaze* ("divine wind") attack, suicidally diving their bomb-laden aircraft into American ships. By this means they sank many destroyers and destroyer escorts, and seriously crippled several large aircraft carriers by fires, despite the attacks of hundreds of fighter 'planes from carriers and the fire of hundreds of anti-aircraft guns. Had it not been for the proximity fuze, which enabled the guns to shoot down a large number of the kamikazes before they reached their targets, the rate of American losses might well have been so high as to make the Okinawa campaign impossible.



## Early Cannon

During the Dark Ages Europe forgot m
the highly developed siegecraft of cl
times and had to learn it all over agai
early-medieval "castle" was merely a s
built house of stone and timber erected
mound and surrounded by a wooden sto
However, when military men reached
stantinople during the First Crusade in th
century and saw the magnificent fortific
there, on their return to the West they im
the walls and towers of old Byzantium in
own manor houses.

For about three centuries the new art of
building gave the defensive such an adv
that most medieval battles were not clas
armored knights, but sieges. The besiegers
to climb over the wall with ladders, to b
under it, or to knock it down with catapult
and battering-rams, while the besieged reta
in kind. The siege usually ended whe
besiegers ran out of food, or the enlistme
their peasant militia expired and the boys
home. Castles were rarely taken except b
prise or treachery.

This deadlock (comparable with the t
warfare deadlock of World War I) was f
broken by the development of cannon. A
ing to tradition, the gun was invented b

# CHAPTER 4

# ARTILLERY

## Early Cannon

During the Dark Ages Europe forgot most of the highly developed siegecraft of classical times and had to learn it all over again. The early-medieval "castle" was merely a solidly built house of stone and timber erected on a mound and surrounded by a wooden stockade. However, when military men reached Constantinople during the First Crusade in the 12th century and saw the magnificent fortifications there, on their return to the West they imitated the walls and towers of old Byzantium in their own manor houses.

For about three centuries the new art of castle building gave the defensive such an advantage that most medieval battles were not clashes of armored knights, but sieges. The besiegers tried to climb over the wall with ladders, to burrow under it, or to knock it down with catapult stones and battering-rams, while the besieged retaliated in kind. The siege usually ended when the besiegers ran out of food, or the enlistments of their peasant militia expired and the boys went home. Castles were rarely taken except by surprise or treachery.

This deadlock (comparable with the trench-warfare deadlock of World War I) was finally broken by the development of cannon. According to tradition, the gun was invented by the German monk Berthold the Black in 1314. Some of the early guns were strange contraptions indeed—bottle-shaped vessels to shoot feathered darts. Since nothing was known about the distribution of pressures inside gun barrels, some guns were made much thicker at the muzzle than at the breech with disastrous results. The term "barrel," by the way, commemorates the fact that some early guns were built up of staves and hoops like a real barrel. The early gunsmiths even experimented with breech-loaders, but they did not persevere when they found that breech-loaders blew up even more often than muzzle-loaders.

After a few decades of experiment, heavy guns took two main forms: a long gun for direct fire, and a very short gun, called a mortar from its shape, for indirect fire with exploding bombs. Early mortar bombs consisted of a pair of hollow hemispheres fastened together with straps to enclose the bursting charge.

Muhammad II, the half-mad young genius who was Sultan of the Osmanli Turks, demonstrated the effectiveness of cannon against medieval fortifications when he undertook to clean up the Byzantine Empire, then reduced to Constantinople and a few outlying scraps of territory. In 1453 he appeared before Constantinople with 68 guns including a monster of 30-inch bore called "Basilica," pulled by 60 oxen. At that time a cannon was hauled to the scene of operations on a cart, dumped off the cart, rolled on its side into position on the ground, and given the right elevation by wedging boards and stones under the muzzle end. The gunners mixed their powder on the spot, and collected boulders in the neighborhood which they chipped down to the right size for cannon balls.

Muhammad's artillery gradually battered down the great Byzantine walls, and after seven weeks the city fell despite a desperate defense. Within the next century the same fate befell many of Europe's castles. Thus cannon helped to bury the feudal system even before the hand gun put the armored horseman out of business. An entirely new system of fortification grew up, based upon a complex of ditches and low ramparts, and culminating in the great star-shaped fortresses of Louis XIV's engineer Vauban, which in plan look like one of those magnified pictures of a snowflake. Vauban used the science of projective geometry, which Descartes had just discovered and which the French government tried for a while to keep a military secret, to calculate angles and slopes so that no dead spaces were left around the approaches in which attackers could huddle out of harm's way.

Guns were early applied to field and naval use. In the former capacity they were mere noisemakers until Gustavus Adolphus of Sweden put them seriously to work in the Wars of Religion of the 17th century by standardizing their sizes and improving their carriages. The carriage had two large wheels and a trail by which horses pulled the guns. This form of vehicle was to last with little change for three centuries. The gun itself had a pair of projecting lugs or trunnions which, fitting into a pair of bearings in the carriage, allowed the gun's elevation to be varied. Elevation was controlled first by wedges under the butt, later by a screw. Train was managed by hauling the trail right or left with ropes. Since there was no recoil mechanism, the gun bounded to the rear when discharged, sometimes squashing an unwary gunner. Then it had to be laboriously hauled back into position for the next round.

At sea guns were originally fixed, requiring the whole ship to be aimed. Then they were mounted on carriages with four small wheels for hauling inboard to reload. A tackle of ropes and pulleys was developed for running the gun in and out and hauling it sideways through the few degrees of train the port allowed.

The usual shot was a solid iron ball, which, since it fitted the gun loosely, pursued a wobbling course down the barrel, bouncing from side to side and often leaving the muzzle at an angle quite other than that intended. For close-range work, guns were sometimes "double-shotted"; that is, two balls were fired at once. Pre-cast iron shot early replaced stone cannon balls, since a battle is no time to go looking for round stones of the right size for cannon balls. Besides the exploding mortar bombs, gunners used other projectiles such as grape shot and case shot, essentially the application of the shotgun principles to cannon, and chain shot, a pair of cannon balls linked by a chain for carrying away the foe's rigging. Or a hard-pressed gunner might stuff his piece with scrap iron, crowbars, or anything else handy.

On land, the standard muzzle loading smooth bore cannon on its two-wheeled carriage became more and more effective until in the Napoleonic campaigns, in which it was used in great masses, it became almost the dominant arm. Then for several decades it declined in importance as a result of the improvement of small arms, which forced artillery to move back so far from the firing line, to avoid having the gunners picked off by rifle fire, that the guns ceased to be very effective. Then towards the end of the century the many improvements in cannon that had taken place made artillery essential again. At sea the effective range of guns, and hence the distances at which naval combats occurred, increased until boarding and ramming actions almost ceased.

### Modern Artillery

The first half of the 19th century saw the reduction to practice of most of the ideas that go into making the modern artillery piece—a practical explosive cannon shell; a rifled cannon; a practical breech loader; and a shock-absorbing recoil mechanism. However, these ideas were not effectively combined into the rifled breech loader, firing cylindro-conoidal shells with either contact or time fuzes, until the time of the

American Civil and Franco-Prussian Wars. At the same time the built-up gun, composed of liner, jacket, and hoops, replaced the former type cast in one piece, thus allowing higher gas-pressures, while the pivot mounting gave guns wider arcs of fire. In the closing years of the century the howitzer, a short-barreled gun suitable for either direct or indirect fire, which originated in the 18th century, became increasingly important. At the same time a number of special types of ammunition were developed: high-explosive shells with thin walls and large charges, armor-piercing shells with thick walls and small charges, smoke shells for ranging, and shrapnel for use against infantry.

Shrapnel, originally invented at the end of the 18th century by a British officer of that name, was a shell packed with lead balls around a small charge exploded by a time fuze. Its function was the same as that of the old grape shot and case shot, except that the container, instead of disintegrating as it left the gun, remained intact until it almost reached the target, giving far greater range. Shrapnel was used extensively in the Boer War and World War I. At Gallipoli, a campaign with great possibilities ruined by bungling, the British battleship *Queen Elizabeth* fired enormous 15-inch shrapnel shells, unfortunately hitting men of her own side and breaking up an important attack. Although shrapnel was important enough in World War I to bring the steel helmet back into use after an absence from the battlefield of two and a half centuries, it played little part in World War II, high-explosive shell having become more effective.

The use of fixed ammunition (propellant and projectile incorporated in a single cartridge) was extended from small arms to cannon, first, in the smallest calibers, thus allowing the French 75-millimeter field gun, the best all around cannon of World War I, to be fired almost as fast as a bolt action rifle. Since then this practice has been extended to larger and larger calibers, especially as a result of the need for high rates of fire against airplanes, and there is no telling where it will end.

### Naval Guns

If by "gun" is meant merely the tube, breech block, and firing mechanism, there is little difference between land guns and naval guns. In fact the same guns with different mountings are sometimes adapted to both uses. The differences lie in the mounting, and the methods of loading and aiming. Since in a mobile land gun weight is all-important, an artillery unit consists of little more than the gun proper, a carriage, and a base or standard on which the gun can be quickly set up. Ammunition is carried in separate vehicles and loaded into the gun largely by man-power. Special fire control devices such as radar and range keepers are also separate. The shields with which field guns were once equipped to protect the crew from infantry fire have now largely been abandoned, partly to save weight, partly because modern cannon usually fire from out of sight of infantry, and partly because a modern field gun must be able to shoot in almost any direction at tanks and airplanes on a few seconds' notice. On the other hand a gun mounted permanently either on land or on a ship can afford a much greater mass of accessories to speed up its fire, make its aim more accurate, and protect its crew.

Ericsson embodied the main features of the modern naval gun mounting, the revolving armored gun turret and the power-driven ammunition hoist, in his original *Monitor*. Although a few ships after the *Monitor* were built with the old broadside gun arrangement, like the USS *New Ironsides*, an ironclad frigate that saw more action than any other Civil War ship, the new turret system was soon generally adopted for the main guns of large ships. For a time the British experimented with a "barbette" mounting, in which the guns peeped over the top of a fixed circular armor-plate wall. A light horizontal gun shield revolved with the guns.

Soon however they returned to the turret, wherein the whole structure, guns and all, revolves together. Modern gun mountings, in which a turret sits atop an armored handling room and ammunition hoist, may be considered as combinations of the old turret and barbette mountings.

Down to the end of World War I the world's navies continued to mount the small guns of large ships, and all the guns of small ships like cruisers and destroyers, either in casemates or on pedestal mounts on deck. A casemate is a lightly armored gun position in the ship's side, something like the old broadside mounting. A gun on a deck mounting might be either bare or protected by a splinter-proof gunshield. In the last two decades the increasing effectiveness of shell fragments and airplane machine guns has led navies to enclose more and more of their smaller guns in turrets. The need for such mountings was shown in the Battle of the Plate. The *Graf Spee* had a formidable secondary armament of eight 5.9-inch guns, four on each side in single mountings, but got little use out of it because the crews, inadequately protected by open gunshields, were soon slaughtered by shell fragments.

Turrets have been built for every number of guns from one to four. Down to the 1930's the British and Japanese navies used twin turrets (turrets with two guns) almost exclusively. Before World War I the Italians brought out the triple turret, soon copied by the Russians and the United States and now the commonest type in the main batteries of cruisers and battleships. The French, usually favoring the twin, have adopted the triple in recent cruisers, and also a quadruple turret, used both in some unfinished pre-World-War-I battleships and in their recent battleships of the *Dunquerque* and *Richelieu* classes. The use of a larger number of guns per turret saves weight for a given number of guns and thickness of armor; on the other hand it introduces mechanical complications and slows the rate of fire per gun. Therefore, the United States, in its latest 6-inch gun cruisers has gone from triple back to twin turrets to allow faster fire at airplanes.

Around the turn of the century a battleship or heavy cruiser carried guns of many sizes. The USS *Oregon* of the 1890's, for instance, mounted four 13-inchers, eight 8-inchers, and four 6-inchers, not counting smaller guns. Such an arrangement made organized fire-control difficult, as it was hard to tell which guns were making which splashes. Furthermore, the fire of one battery interfered with that of the others.

These problems were solved in the HMS *Dreadnought*, begun in 1904 and finished two years later. The *Dreadnought* was not only larger and faster than any existing battleships, being driven by the newly invented steam turbines, but also carried a main armament of ten 12-inch guns, a secondary armament of 24 3-inchers to deal with torpedo boats, and nothing intermediate. This revolutionary ship, though out of date by World War I, had the pleasure of sinking a German submarine by ramming. The slightly smaller USS *Michigan* and USS *South Carolina* built at the same time, employed the same idea, so revolutionary in warship construction that for years battleships with main batteries all the same size were called "dreadnoughts."

The *Dreadnought's* 12-inchers were disposed in five twin turrets, one forward on the cen-

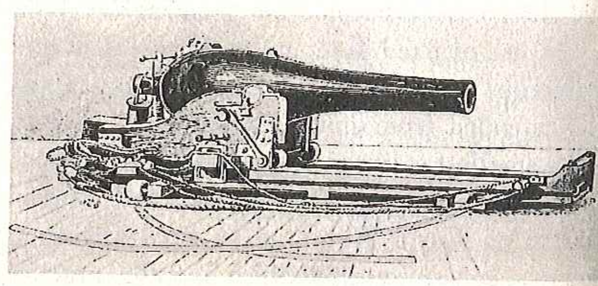

Figure 4.—**Early naval gun.** Note the systems employed for handling recoil, counterrecoil, elevation, and train.

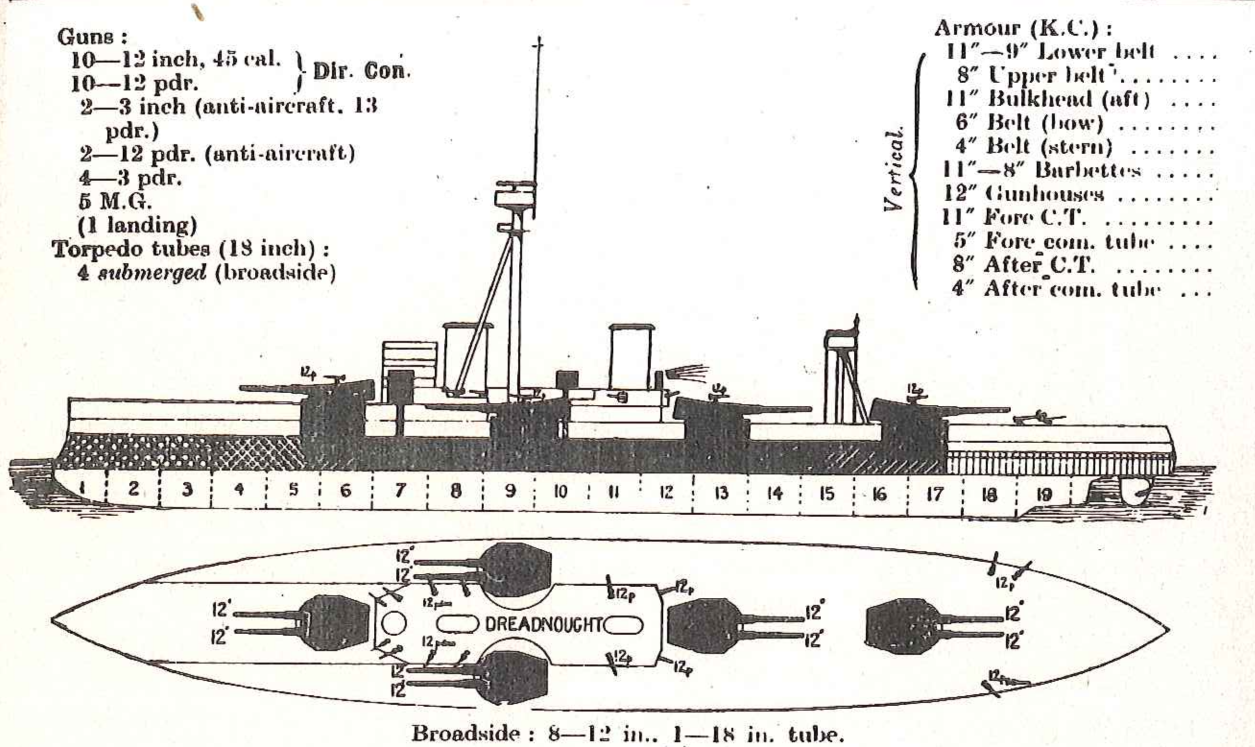


Figure 5.—**H.M.S. *Dreadnought.*** The revolutionary first all-big-gun battleship.

terline, one on each beam, and two aft on the centerline. For some years most navies built ships with main battery turrets on the beam, despite the reduction in their arc of train, though some such turrets could shoot across the deck towards the opposite side of the ship, over a limited traverse. When beam turrets were abandoned, some ships were built with all turrets on the centerline, some forward, some aft, and some in the waist. The most extreme design was perhaps that of the British battleship *Agincourt* with seven twin 12-inch turrets, all on the centerline. Gradually all navies adopted the system that the *Michigan* pioneered: all main turrets on the centerline and at the ends of the ship, to give maximum arcs of fire. The *Michigan* arrangement—eight guns in four twin turrets, two at each end, with the second and third turrets a deck higher than the first and fourth—because for a time, between the two World Wars, the commonest single arrangement of heavy warship guns.

## Giant Guns

How big can a gun be? Guns can certainly be built in larger sizes than it is desirable to build them. On the other hand technological changes may make it practical to build a larger gun at one period than at another. For instance, Muhammad II's "Basilica" has seldom been surpassed in bore. During the Crimean War, Robert Mallet sold the British Army a pair of 36-inch mortars, firing ton-and-a-half bombs, successful enough on trials though never put to use in war. While some Civil War monitors fired 15-inch guns, the development of rifled cannon using smokeless powder with high muzzle velocities caused cannon to become longer but smaller in bore. About the time of the *Dreadnought* revolution the standard heavy battleship guns were nearly all of 11 or 12 inches, while land guns, being harder to haul around, were smaller.

As soon as the new qualitative developments in artillery had been assimilated, the guns began to grow quantitatively, to 13.4, 13.5, 14, 15, and 16 inches, this growth culminating in the 18-inch gun. During these decades the U. S. Navy tried to lead the procession in gun size, since American naval doctrine long emphasized long-range fire by guns of the largest size, mounted on ships with the most rugged armor protection. British doctrine, on the other hand, emphasized bold tactics and rapid close-range fire; German doctrine, scientific accuracy of fire-control from smaller guns on minutely compartmented ships; Japanese doctrine, night attacks with torpedoes; and Italian doctrine, hit-and-run tactics by fast unarmored ships.

A committee under Admiral Sir John Fisher, later First Sea Lord (the equivalent of CNO) had fathered the *Dreadnought*. Fisher, a man of daring ideas, announced as a principle that "the best protection a ship can have is the well-directed fire of her own guns." On this basis he inspired the building of a new type of ship, the battle-cruiser, to combine battleship armament with cruiser speed, at that time ranging from 24 to 28 knots. Since the ships were about the same size as their battleship contemporaries, something had to be left out to allow for the big engines. These ships were therefore given fewer big guns and much less armor than battleships. Fisher thought that with guns of the largest caliber and superior speed, the battle-cruiser could run away from any ship whose guns outranged its own, while against any ship whose guns it outranged it could stand off out of range of the smaller-gunned ship and shoot it to bits without injury to herself. This theory worked in the Battle of the Falkland Islands, in December of 1914, when the British battle-cruisers *Invincible* and *Inflexible* destroyed the German armored cruisers *Scharnhorst* and *Gneisenau* with little damage to themselves.

Beginning with the *Invincible* class of 1905 and ending with the 41,000-ton *Hood*, finished after World War I, the British Admiralty built a total of 13 of these ships. The navies of Germany, Japan, the United States, Russia, and Italy all imitated the type, though only the Germans and the Japanese ever finished any of the battle-cruisers they started. The only survivor of all these ships is the Turkish *Yavuz Sultan Selim*, ex-German *Goeben*.

The German battle-cruisers, built in accordance with Admiral Tirpitz's maxim that "the first requirement of a warship is that she shall stay afloat under fire," were much better protected than the British. Jutland proved that Tirpitz's maxim was more realistic than Fisher's, for there the German battle-cruiser squadron sank three ships out of the British battle-cruiser squadron, losing only one themselves, though the British had them heavily outgunned. The principle was belatedly underlined in World War II when the *Hood*, which supposedly incorporated the lessons of Jutland, blew up after a few minutes' duel in Denmark Strait with the *Bismarck* of the same main armament (eight 15-inch guns). The battle-cruiser in the old sense no longer exists as a separate type since all modern battleships have cruiser speeds, though the term is sometimes applied to ships like the *Alaska* and *Dunquerque*, vessels intermediate in size between battleships and heavy cruisers.

Fisher went on from his battle-cruisers to reduce his principle to absurdity in the large light cruisers *Glorious*, *Courageous*, and *Furious*, called by those who did not admire them the OUTRAGEOUS CLASS. They were fast ships of about 20,000 tons with mere 3-inch armor belts. The *Glorious* and *Courageous* each mounted four 15-inch guns in two turrets, one forward and one aft. Toward the end of World War I these two ships tangled with German cruisers in Heligoland Bight, with the result that one was put out of action by 4-inch shells from a little German light cruiser that got into her machinery, and had to be towed home.

The *Furious*, Fisher's masterpiece, was designed to mount two 18-inch guns, the biggest naval guns built up to that time, firing 3,000-pound shells. They were mounted in two single turrets, one forward and one aft. During construction the Navy became nervous about the effect of the recoil of these guns on this rather flimsy ship. Hence only the after gun was mounted, while the forward part of the ship was made into a flight-deck. On her trials the firing of the 18-inch gun shook her up so badly that this gun, too, was removed and the ship converted to a complete aircraft carrier, the world's first. Her quasi-sisters were likewise converted to carriers under the Washington Treaty, both being sunk in World War II.

The Admiralty, however, still had five of these guns, and also a number of monitors—wide-beamed, shallow-draft gunboats mounting a single big-gun turret and minutely subdivided against underwater explosions, which they used to bombard the German-held coasts in World War I. They mounted the 18-inch guns on the fantails of five monitors of the *Earl of Peterborough* class (*Lord Clive, Admiral Howe,* etc.) despite the fact that each of these little ships already carried a twin 12-inch turret forward. The 18-inch guns were set up on plain pedestal mountings with a traverse of only 20 degrees, the gun pointing to starboard so that the ship had to sail east in order to bombard the Belgian coast. They erected a light steel gun-house over the gun, and racks for ready 18-inch ammunition on the deck.

The guns proved very effective and accurate. When the Germans hid one of their main coastal batteries behind smoke-screens, the British located it on the map, and constructed a range-table by which they could shoot at the invisible battery by shooting at a visible point on shore simultaneously with their 12-inchers and correcting the latter. The Germans never learned how the British succeeded in dropping 18-inch shells so accurately on their concealed battery.

After that war the British scrapped most of their monitors, and sent the 18-inch guns to Singapore as part of the fixed defenses there. Unfortunately they pointed to sea and were useless against the Japanese who, in 1942, attacked from the land side.

The British also, in a mood of pacifism and economy, scrapped the *Hood's* three unfinished sisters, but soon began construction again as a result of the large American and Japanese programs of 16-inch-gunned ships. The British planned a quartet of SUPER-HOODS, 47,500-ton ships each to mount nine 16-inch guns. After their engineers had struggled with weights, D'Eyncourt, the Director of Naval Construction, suggested putting all the big guns forward and everything else aft to shorten the armor-belt. "It won't look pretty," he said, "but perhaps that doesn't matter."

When these ships and their 18-inch-gunned battleship companions were dropped as a result of the Washington Treaty, the Admiralty reduced the super-Hood design to the 35,000 tons allowed by the treaty and produced the *Rodney* and *Nelson.* The D'Eyncourt ships certainly did not look pretty—long foredeck with three triple turrets, great bridge tower slightly aft of center, and everything else aft—but the ships worked well enough. The French imitated that gun arrangement in their battleships of the *Dunquerque* and *Richelieu* classes, which mounted eight guns in two quadruple turrets forward.

The Washington Treaty of 1922 limited the United States, Great Britain, Japan, France, and Italy to ratios, in capital ships and aircraft carriers, of 5:5:3:1.75:1.75. It left the United States, Britain, and Japan with three, two, and two 16-inch-gunned battleships respectively, stopped all capital ship construction for a decade, and forbade ships with larger guns. This treaty (a fairer arrangement than any of the signatories was willing to admit at the time) also defined capital ships as ships of more than 10,000 tons or mounting guns of over 8 inches. Since non-capital ships were not limited, all the leading naval powers built 10,000-ton cruisers with eight to ten 8-inch guns, a much larger type than most previous cruisers. The earlier ships of this type, badly under-armored for their size, were often called "tinclads."

In 1930, Great Britain and the United States agreed to limit their cruisers and destroyers, and enshrined in this new treaty an artificial distinction between "heavy cruisers" with 8-inch guns and "light cruisers" with 6-inch guns, though some "lights" were heavier than some "heavies." Japan refused to enter this treaty on the ground that her prestige demanded equality with any other power, so that the world was treated to the remarkable spectacle of the world's two leading naval powers, on excellent terms with each other, agreeing to disarm while aggressive governments in other parts of the world increased their armaments as fast as they could. With the expiration of all these treaties in 1935, however, all the powers began building furiously in all categories.

The U. S. Navy had never really been sold on guns over 16 inches, since in that gun-size the problems of breech pressure, recoil, rate of fire, and wear on the gun barrel begin to take one into the region of diminishing returns. Therefore, the post-treaty American battleships were all designed with 16-inch guns; nine each in the twelve ships of the *Washington*, *South Dakota*, and *Iowa* classes, and twelve in the five unbuilt 60,000-ton *Montanas*. The British preferred smaller guns, though their construction of five 14-inch-gunned battleships at this time may have been inspired partly by a political desire to revive arms-limitation. France, Germany, and Italy all built 15-inch-gun battleships, and subsequently Great Britain, Germany, and Russia all either planned or began 16-inch-gunned ships, though none of these was completed.

The Japanese, meanwhile, began construction of the world's largest battleships: the *Yamato*, *Musashi*, and a third, completed as the aircraft carrier *Shinonu* and ignominiously sunk by an American submarine on her trials. The 65,000-ton *Yamatos* each mounted nine 18.1-inch guns. These mighty ships, completed early in the Japanese-American phase of World War II, were used so cautiously that they never fought when they might have had a serious effect. When they were finally put into the Battle of Leyte Gulf the Japanese position was desperate anyway. Airplane torpedoes sank the *Musashi;* Admiral Kurita withdrew *Yamato* with the rest of his central striking force after she had rather ineffectively shelled some American escort carriers, and later she was sunk by airplanes off the home islands.

Within the last half-century, remarkable as the achievements of naval gunnery have been, they have been surpassed by those of the most extreme forms of land ordnance. At the outbreak of World War I the Germans threw the Allies into a panic by demolishing the Belgian forts with siege howitzers of unheard-of size: first an 11-inch Skoda gun and then a 16.5-inch Krupp gun. (The actual bore of the latter was 42 centimeters. Frenchmen measure gun bores in millimeters, Germans in centimeters, Americans in millimeters and inches, and the British, to make things even more confusing, in millimeters, inches, and weight of shell in pounds.) Somebody, looking at the thick barrel of the 42-centimeter monster, was reminded of the shape of the wife of the head of the Krupp works, and nicknamed the gun *die dicke Bertha*, whence BIG BERTHA. This name is sometimes carelessly applied to the 75-mile Paris gun, an entirely different piece.

Later the British used a 15-inch gun on wheels, and a number of 12-inch and 13.5-inch railroad guns. The most successful railroad guns of the war were probably the five 14-inchers originally ordered for the American battlecruisers of the *Saratoga* class. The original design of these six ships, as composed before the American entrance into World War I, called for strange craft with seven stacks and half the boilers above the waterline. When the United

States entered the war, work on capital ships was stopped, and after the war these battle-cruisers were redesigned as 16-inch-gun ships of more conventional type. Under the Washington Treaty, the *Saratoga* and *Lexington* were completed as aircraft carriers, while the rest, not far beyond the keel stage, were scrapped.

These five guns, however, were installed on railroad mounts and sent to France, where their 1,400-pound shells and 25-mile range made them very useful. When one of them began to shoot up Metz in the closing months of the war, the French not unreasonably asked the Americans to stop, as Metz would be French after the war and they would therefore rather not have it blown off the map.

The record for range is still held by the German 75-mile gun, or rather guns. Three were built, and several extra barrels. In 1918, during the great German spring offensive, these guns fired 367 shells into Paris from the Forest of Crepy, 70 to 80 miles away. These extraordinary weapons had barrels over 100 feet long, built up of parts of several coast-defense guns. They fired from permanent emplacements at an angle of 54 degrees to take advantage of the lower air-resistance in the upper atmosphere, into which the shell rose to a height of nearly 30 miles. The long barrels had a bridge-like truss built up on them to stiffen them, were smoothbore for the last quarter of their length, and, when fired, quivered like a sapling in the breeze for some seconds.

The calculations required to shoot such a gun were so minute that the shells were made different sizes to allow for wear on the barrel with each shot. Thus the first shell of a series had a diameter of 8.2 inches, while No. 60, the last one that the gun could shoot before the barrel had to be replaced, had a diameter of 8.7 inches. One of the guns blew up because the gunners loaded shell No. 5 (or some higher number) into the gun in place of No. 4. The guns produced a mild panic in Paris, as was intended; but although they killed a few people their damage was negligible compared to that of a modern air-raid. Before the end of the war they were hauled back to the Krupp works and melted up.

During World War II German ordnance engineers outdid even their feats of the previous war. Besides their excellent 88-millimeter field-gun, they produced such weapons as the K5-E 28-centimeter (11-inch) gun which could shoot either an ordinary shell 38 miles or a rocket-assisted shell 50 miles, and the "Thor" mortar which threw 3,750-pound projectiles. Thor was used in the first siege of Sevastopol, when the Germans took it from the Russians.

At Sevastopol, also, the Germans put into action the greatest gun ever built: "Dora," an 80-centimeter (31.5-inch) railroad howitzer that threw an eight-ton shell. Such a vast gun had to run, not on one railroad track, but on two parallel tracks, four rails altogether, which meant that the Germans had to build a special railway halfway across Russia to bring their gun into position. Later in the war, the Russians retook Sevastopol without any Dora, and, in view of the damage that can be done by an airplane with one atomic bomb, or even a large bomb of conventional type, the experiment is unlikely to be repeated.

### Special Guns

Men have made guns for special purposes ever since that Tudor gunsmith who built a multi-barrelled arquebus to shoot square bullets at Turks and round bullets at Christians. The outstanding special types of guns that have come into use during the two World Wars are aircraft and anti-aircraft guns, antitank guns, trench-mortars, and recoilless guns. Of these the most important from a naval point of view are the first two.

The airplane saw its first military use in the Italian conquest of Tripoli, 1911-1913. A few Italian airplanes, stick-and-wire contraptions resembling hastily assembled chicken coops, putputted over the Turkish lines while the aviators hung from the structure with one hand and dropped home-made bombs with the other. Meanwhile the Turks canted up field-guns in a futile effort to hit back. In World War I ordinary heavy machine-guns and field guns were first adapted to anti-aircraft use by special mounts allowing vertical fire; then special guns of high muzzle velocity were built.

The biggest anti-aircraft actions took place in England, which the Germans raided throughout the war. At first the Germans used rigid airships, called "Zeppelins" after their inventor, a German count who had served as an officer on the Federal side in the U. S. Civil War. Against these huge slow targets, filled with inflammable hydrogen, the British 3-inch batteries proved effective, so that during the last year of the war the Germans sent Zeppelins on only a few raids, and these at such altitudes that the airships mostly failed to find their targets.

In the latter part of the war, however, the Germans put more and more reliance on twin-engined Gotha bombers, against which anti-aircraft batteries proved comparatively ineffective. The difficulty lies in the fact that the speed of an airplane amounts to an appreciable fraction of the speed of the projectile, so that the gunner must lead his target by such a wide angle that he cannot count on hits by observation and judgment alone, but requires mechanical means to help his calculations.

Throughout the history of anti-aircraft artillery the guns' effectiveness has continually been increased by more advanced range-finders and fuze-setters, though the speed of airplanes has also increased and thus kept the airplanes one lap ahead of the guns. The guns have also been vastly increased in numbers. Thus, whereas at the end of World War I a battleship's anti-aircraft armament might consist of one or two 3-inchers, a modern capital ship bristles with over 100 anti-aircraft guns of all sizes, and large guns are increasingly adapted to high-angle fire. Finally the proximity fuze and radar in the latter part of World War II enabled the guns for a time at least to catch up with the airplanes—but then the atomic bomb and jet propulsion again increased the effectiveness of airplanes with respect to the guns. Altogether it is unlikely either that anti-aircraft guns will ever become so effective as to neutralize airplanes, or that conversely airplanes will become so effective as to make the guns useless. Probably they will continue to see-saw, as is usually the case with these contests between attack and defense.

As for aircraft guns, at the start of World War I airplanes were unarmed; aviators popped at each other with pistols and shotguns. The Fokker interrupter gear for firing a machine gun through a propeller without shooting off the blades, and the Scarff mounting for flexible machine guns, made these guns practical for airplanes, so that by the end of the war most airplanes mounted one to three machine guns. After this war the .30 caliber machine guns used in airplanes were augmented by guns of .50 caliber or larger. The number of guns was also increased. The World War I fighter with one or two fixed forward-firing guns became the World War II fighter with four to twelve such guns, while bomber armament was likewise increased from two or three guns to ten or fourteen.

Aircraft guns of .50 caliber or larger made necessary extra-heavy plating on the upper works of ships, ever since five American fighter planes sank a Japanese destroyer by .50 caliber machine gun fire alone, and American carrier planes made a shambles of three French destroyers in the Casablanca battle by the same means. The United States was successful in mounting fixed 75 millimeter guns in light bombers, one of which sank a Japanese destroyer with five rounds from its cannon. However, in view of the increasing effectiveness of aircraft rockets and guided bombs, this development may not continue.

Altogether, despite the rise of rockets, atomic bombs, and guided missiles, it seems likely that the cannon will continue to be one of the most important weapons for a long time to come.

# CHAPTER 5

# SMALL ARMS

## The Hand Gun

About 1400, a century after the invention of the cannon, somebody had the idea of a small gun that could be carried by an individual soldier. The early hand gun consisted simply of a tube of brass or iron mounted on a pole which the gunner supported with one hand under his armpit while he applied a piece of punk to the touch-hole with the other hand. At the range at which such a gun was accurate it was almost as practical to hit the foe over the head with the gun as to try to shoot him with it. Still, they made a fine noise and smell, so that European princes hired German hand gunners as auxiliaries. At the start of a battle the hand gunners marched out in front of the army, let off one volley, and then filed to the rear while the rest of the force got down to serious fighting with swords and spears.

Towards the end of the 15th century, however, the ingenious Germans made their hand gun into a practical weapon by moving the touch hole to one side, providing it with a firing pan into which a little fine powder could be dropped to set off the main charge, securing the "match" (a punk-like length of tarred rope) with a hinged clamp projecting underneath the gun in the form of a trigger, and modifying the pole into a shoulder-stock. Then all the gunner had to do was to measure out his charge, drop it down the barrel, pack it down with his ramrod, drop in a bullet, pack that down too, push down a wad of cotton or paper to keep bullet and powder from falling out, raise the firing pan cover, sprinkle priming powder into the firing pan, smooth it down with his thumb, replace the cover, adjust his match, blow on it to get the lighted end hot, aim (without sights) and pull the trigger. One can see why the quick-firing bow long held its own against the hand gun.

The Germans who invented the improved hand gun called it a *Hackenbüchse,* corrupted by Englishmen and Frenchmen to "hackbutt" and "arquebus" respectively. A larger version of this gun, a matchlock musket and fired from a forked rest, came into use in the early 16th century, especially in the Spanish army, then the best in Europe. Matchlocks continued to be made down to recent years in the remoter parts of Asia. Vitelli of Pistoia, Italy, devised a miniature gun to be held in one hand and called a "pistol" after its town of origin. The Germans invented a mechanical firing mechanism, the wheel lock, which worked like a modern cigarette lighter by whirling a toothed wheel against a piece of flint or pyrites, throwing a shower of sparks into the firing pan. Although this mechanism was easier to handle (especially for pistols) than the matchlock, it was also delicate and expensive, and if left wound up too long the spring might weaken and fail to spin the wheel.

The new weapons were not warmly welcomed, since many oldtime military men felt

> ". . . that it was a great pity, so it was,
> This villainous saltpeter should be digg'd
> Out of the bowels of the harmless earth,
> Which many a good tall fellow had destroy'd
> So cowardly . . ."

When Queen Elizabeth appointed a commission to test the musket against the bow, they reported

Figure 6.—**Early small-arms.** Musketeer with matchlock, early 17th century.

that the latter had the advantage in nearly all respects. It was about as accurate, lighter, faster-shooting, and easier to protect from rain. The musket, however, proved to have one advantage that outweighed all its shortcomings: almost any able-bodied man could be taught to handle a musket in a few weeks, whereas it took a lifetime of practice to make a good archer.

## From Matchlock Smoothbore to Repeating Rifle

Although as early as the 16th century gunsmiths learned to rifle the barrel with helical grooves to make the bullet spin, increasing its range and accuracy, rifling did not soon become common. For rifling to be effective, the bullet had to fit tightly so that the lands of the rifle would bite into it. Therefore the bullet could not simply be dropped down the barrel, but had to be driven down by pounding the top end of the ramrod with a mallet, which meant slow fire. Hence the use of rifles was long confined to hunting, where one shot was enough. The rifled musket first made its mark in the American Revolution. While most of the rebel troops were armed with smoothbores like their British antagonists, some, like Morgan's riflemen, used the long hunting "squirrel rifle". They made life unhappy for the British by standing up out of smoothbore range, picking off a Redcoat, and running away when the British took after them.

The 17th century saw the invention of the repeating gun and the flintlock musket. The former had little immediate effect: the King of Denmark's bodyguard was equipped with an enormously expensive three-shot lever-action musket full of delicate little sliding parts to measure out the right amount of powder from the powder chamber, and insert a bullet from the bullet compartment: not very practical. On the other hand the flintlock musket proved much more practical than either the matchlock or the wheellock and for over a century was the universal infantry arm. It had a spring mechanism to snap the hammer, whose clamp held a bit of flint, against a vertical piece of steel attached to the firing pan cover.

The bayonet (named for Bayonne, France) had been invented in mid-17th century, first in the form of a dagger with a wooden handle that fitted like a plug into the muzzle of the musket. While this invention meant that musketeers no longer had to be accompanied by pikemen to protect them, the gun could not be fired when the bayonet was in place. At the Battle of Killiecrankie in 1689, the English got off one good volley, but while they were struggling to fix bayonets in their muzzles the Scots swarmed down on them with pikes and swords and routed them. Mackay, the English commander, profited from his defeat by inventing the ring bayonet, allowing fire with the bayonet in place. The bayonet is now strictly a last-ditch weapon, since the modern infantryman's fire power is so great that he seldom gets close enough to his enemy to use cold steel.

In matchlock days musketeers had lined up four to six ranks deep. The front rank would fire, then file to the rear while the next rank fired and in its turn walked back, and so on. Cavalry used a similar system of delivering volleys from horse-pistols. However, if a soldier is given an excuse to start towards the rear he is likely to keep right on out of danger. The flintlock speeded up loading so that in the 18th century two ranks were enough, and they usually fired all at once, when the officers signalled with their swords; the front rank kneeling and the rear rank shooting over their heads.

The complicated close-order drill that prevailed prior to World War II came down from the time of Frederick the Great, when men actually fought that way. Eighteenth century infantry marched onto the battlefield in a column of squads, wheeled into company fronts facing the foe, fired, reloaded, marched forward through their own smoke until the enemy were again in sight, and repeated the process until one side fled and the other ran after them waving their bayonets and cheering.

The 19th century saw rapid evolution in small arms as in cannon. The rifled musket with sights replaced the old smoothbore. Then the fulminate percussion cap speeded up loading and made it possible to shoot in the rain. Then around the middle of the century the breech loading musket replaced the muzzle loader—a change much desired because muzzle loaders had to be loaded standing up, and the fire power of small arms was making standing up on a battlefield a rash thing to do.

The most promising of the early breech loaders, the bolt action Dreyse needle gun, was adopted by the invincible Prussian Army for the German Civil and Franco-Prussian Wars. However, breech loaders suffered from the escape of gases through the cracks in the breech, which wore out both gun and gunner until Jacob Snider's metal cartridge sealed the breech against the escape of gas.

Meanwhile the repeating musket also came into use. The first really practical repeating gun was Samuel Colt's revolver, patented in 1835, but attempts to apply the revolver principle to muskets were not very successful because the escape of gas between the cylinder and the barrel reduced the muzzle velocity. Beginning about the time of the American Civil War the modern lever action, bolt action, and pump action repeating rifles were developed, though they did not become altogether practical until the invention of smokeless powder by Maxim in the 1880's, because the residue from black powder gummed their mechanism. One of the first repeating rifles, the Sharp's, was issued to Federal troops in the last year of the U. S. Civil War, causing the Confederates to complain bitterly about the unfairness of a gun that permitted a Yankee to "load up in the morning and shoot all day."

### Automatic Guns

The quest for faster and faster fire led to the development of the machine gun in the closing decades of the 19th century. Back in the days when guns were still competing with lances and crossbows, several military engineers built great multi-barrelled contraptions called ribauldquins, mounted on carts and designed to be fired off all at once or in quick succession. Three monster Italian ribauldquins built in 1387 had 144 barrels each. Such devices could be fired only once per battle, since loading them was an all-day job.

By mid-19th century the rate of fire even of single shot breech loading rifles had become such as to make massed maneuvers obsolete; when the Russians tried bayonet charges with squares of massed infantry in the Crimean War, the "thin red line" of British infantry massacred

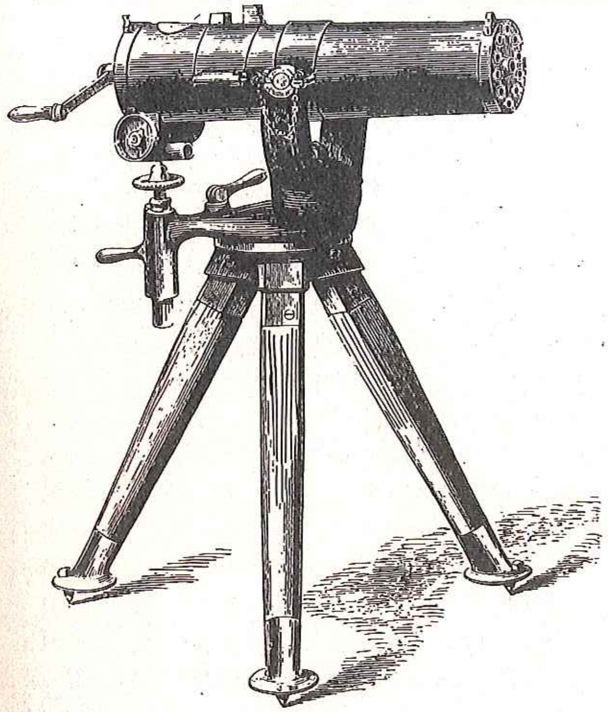

Figure 7.—**Gatling gun.** One of the first successful machine-guns, with ten revolving barrels turned by a crank.

them with their Minie rifles. Then infantry fire power was multipled still further by the machine gun, which filled the gap that had long existed between the cannon and the musket. The first machine gun was that of Richard Gatling of Chicago in 1862—the original "gat." It had ten barrels, a hopper above the breech containing more cartridges, and a crank which revolved the barrels and fired them one by one. As the barrels revolved, the spent cartridges were automatically ejected and fresh ones fed in from the hopper. The gun was tried out inconclusively in the Civil War, and used to some extent in all the later wars of the 19th century such as the Spanish-American. About the same time the French Army developed a larger revolving gun of this kind, the mitrailleuse, with 25 to 37 barrels mounted on a field artillery carriage, with which they vainly tried to stop the Prussians in the Franco-Prussian War.

Since all the early machine-guns, operated by cranks or levers, proved inaccurate, Maxim in 1889 developed the first modern machine gun, in which the recoil of one shot ejected the empty cartridge case, loaded the next cartridge into the chamber, cocked the gun, and (if the gunner kept his finger on the trigger) fired the gun. The cartridges were fed through the breech on a belt. The Maxim, first tried out in the Russo-Japanese War, was soon followed by similar guns like the Vickers and Browning. Early machine guns had a habit of jamming every few shots, the American Browning being the first that was more or less jam-proof.

Since the machine gun increased the fire power of its crew at least twenty-fold over the same number of riflemen, it gave the defensive a temporary advantage over the offensive, like that of the Middle Ages. The machine gun also put horse cavalry out of action, since even the most willing horse cannot be trained to crawl on his belly from bush to bush as any unarmored creature must do to advance against a machine gun. Therefore infantry attacks in World War I took the form of trying to smother machine guns with living targets. The immense slaughter that ensued had a profound social effect. After the war it caused a great popular revulsion against things military, even in the victorious countries, where strong pacifistic movements inhibited the governments from taking any strong action to stop the rise of aggressive and militaristic governments in Germany, Japan, and elsewhere.

The increase of infantry fire-power has continued ever since, despite the fact that automatic weapons consume ammunition by the ton and each new one means that more men have to be assigned the job of rushing ammunition to the gunners. Ideally each soldier nowadays should have a truck loaded with cartridges to follow him around the battlefield. The fire power of one infantryman with a submachine gun or similar weapon is greater than that of a whole battalion of Napoleon's grenadiers.

To combine the fire power of a heavy machine gun with the portability of a rifle, armies have developed a number of automatic weapons in the last twenty years: light machine guns, submachine guns, and automatic rifles. The Browning automatic rifle, really a light machine gun, was introduced into the American Army in World War I, and in the more recent world war infantry were equipped with the Garand (M-1) semi-automatic rifle and a semi-automatic carbine. Other countries have similar weapons, such as the Bren gun of the British and Czechoslovakian armies. (In a semi-automatic gun the trigger has to be pulled separately for each shot.)

The Thompson submachine gun, a light full automatic gun firing .45 automatic pistol ammunition in drums and clips of 40 to 100 rounds, just missed service in World War I. A shipment of these guns was sent to France in 1918, arriving too late to be used. On the way back to the United States a number of these guns were stolen, and later turned up in the hands of criminals during the era of Prohibition. Armsmakers the world over have since imitated the "tommy-gun," and for some types of fighting, e.g., in the jungle, it has proved even more effective than the rifle.

Finally, the idea of automatic fire has been applied to aircraft and anti-aircraft guns, which have been built in sizes of .50 inches, .60 inch 20 millimeters, 25 millimeters, 1.1 inches, millimeters, 40 millimeters, and 45 millimete The most effective light anti-aircraft weapo prior to World War II were the Swiss Oerlik 20-millimeter and Swedish Bofors 40-millimet machine guns, both taken over with little chan by the British and American armed forces. O shipboard these large machine guns are mount either singly or in multiple mounts of two four guns.

The U. S. Navy also had a 1.1-inch quadrup machine gun of which it expected great thing but these guns proved a disappointment at t start of the war. For instance, the 1.1's fail to do their part in checking the Japanese Pearl Harbor, because there were not enough them, and they jammed frequently, and the were not equipped with adequate fire contro The octuple Vickers 40-millimeter pom-pon failed to save the *Repulse* and *Prince of Wal* in the Gulf of Siam for similar reasons. Whe the guns were subjected to mechanical an electrical fire control, and their numbers eno mously increased, their effectiveness was muc improved. Now the U. S. Navy is developin an automatic 3-inch gun with an unheard-of ra of fire for a gun of that size, and there is no tel ing how big future machine guns may be.

# CHAPTER 6

# TORPEDOES

## Early Submarine Warfare

Like so many "modern" military methods, the idea of fighting under water goes back a long way. In 1622 Cornelis van Drebbel built a submersible rowboat in which he once gave King James I of England a ride. In the American Revolution David Bushnell, who had left Yale to become a lieutenant-captain in the Continental Army, made an egg-shaped submarine with which he intended to attach mines to the bottoms of hostile warships. It was driven under water by two screw propellers; one vertical and one horizontal, operated by cranks from inside. About 20 years later Robert Fulton tried to sell a similar idea, first to Napoleon's France, and when that failed to England.

For the charges that he intended to attach by stealth to enemy ships Fulton adopted the name "torpedo," previously applied to a fish, the electric ray that can give a numbing shock. For some decades the word "torpedo" was applied to any sort of static charge designed to be set off in water under enemy ships. Farragut referred to such charges when he said "Damn the torpedoes!" at Mobile Bay. Later in the century static charges became known as "mines" from the analogy of similar charges used on land, while "torpedo" came to mean the self-propelled steel explosive fish, or small unmanned submarine, invented by Whitehead.

The American Civil War brought out a rash of experiments in submarine and torpedo warfare. On the Confederate side Raines built a sausage-shaped iron craft called *David* (after Goliath's antagonist) armed with a spar torpedo. This was a charge on the end of a long pole projecting from the bow, with a lanyard running back to the boat to set it off. With this torpedo the *David* one night dealt the stout *New Ironsides* a wallop that sent her to the yards for repairs, and the Confederacy set up a secret weapons department that built a crank-operated submarine called *Hundley* after its designer. On trials *Hundley* sank fives times, suffocating her crew each time, whence her designers concluded that she would be more successful as a surface torpedo-boat. As a surface-craft, she sank the Federal corvette *Housatonic,* and also herself, for the sixth and last time. After that it became too hard for the Confederates to find suicide crews to man their submarines.

The Federals also worked on spar torpedoes, their greatest success being Cushing's sinking of the Confederate ram *Albemarle* by a spar torpedo mounted on a little steam-launch. Although the spar-torpedo was used in the Chilean-Peruvian war of 1879-1880, it soon went out of use because the development of quick-firing guns made it impossible for the torpedo-boat to get close enough to its victim. Experiments with torpedoes with fins, designed to be towed at an angle from the bow of a torpedo-boat, like a modern paravane, were not very successful.

## The Automotive Torpedo

A Scottish engineer, Robert Whitehead, developed the first practical automotive, self-propelled torpedo in the 1860's, working alone lines previously suggested by Captain Luppis of the Austrian Navy. This torpedo was so successful, and so far surpassed its competitors, that it was

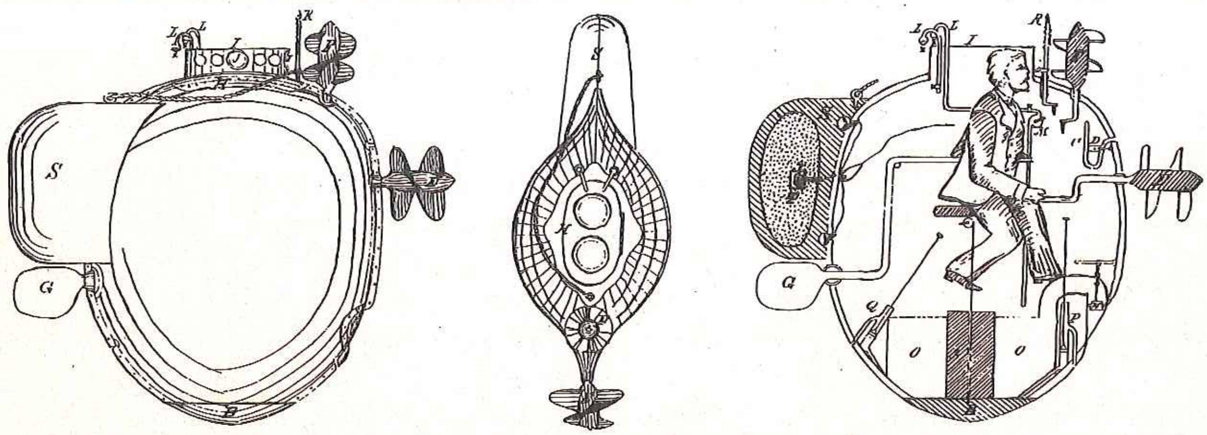

Figure 8.—**Bushnell's submarine.** *The Marine Turtle,* operated by hand-cranks, used unsuccessfully against British men-of-war in the American Revolution.

soon adopted by nearly all the navies of the world. Whitehead had combined two essential elements: a compact compressed-air engine to propel the craft, and a hydrostatic valve mechanism controlling the horizontal rudders, so that the torpedo would run at constant depth. Without this control the torpedo would either dive into the mud of the bottom or go leaping about the surface like a hooked tarpon.

As usually happens with a new weapon, the early torpedoes left much to be desired. There was the case of the British cruiser that fired a torpedo at the Peruvian ironclad *Huascar,* whose crew had mutinied and started out on what they hoped would be a profitable career of piracy. Since the torpedo's speed was only 9 knots, the *Huascar* simply turned away and outran her robot pursuer. Then there was the case of the Peruvian warship that fired a torpedo whose rudder jammed, causing the missile to loop around towards the ship that fired it. A brave officer saved the ship by diving overboard, seizing the torpedo in his arms, and guiding it clear.

Although torpedoes sank a couple of ships in the South American civil wars of the 1890's, they did not show themselves really effective until the Russo-Japanese War of 1904-1905. The Japanese began the war with a surprise attack on Port Arthur, disabling a battleship and two cruisers. At the great Battle of Tsushima the Japanese finished off four of the battered Russian ships with torpedoes.

Torpedoes were thereafter mounted both in large ships and in small fast steam-launches which became known as torpedo-boats. By appealing to the David-and-Goliath prejudice the torpedo-boat acquired an exaggerated importance in the public mind. Although early 20th-century ships, lacking modern underwater compartmentation, usually sank when successfully torpedoed, the torpedo-boat was largely neutralized by mounting quick-firing guns on large ships and accompanying them by a new type of ship, the torpedo-boat destroyer—a small fast unarmored ship with enough gun power to sink torpedo-boats. In a few years the old torpedo-boat became rare; torpedo tubes were mounted on the torpedo-boat destroyer, which took over the functions of the smaller craft. Cruisers were assigned to the battle-line to keep off torpedo-boat destroyers, which were really torpedo-boats, though they kept their old name, shortened in World War I to "destroyer."

To enable torpedo-carrying ships to deliver their punch from greater distances, inventors greatly improved the torpedo from Whitehead's 6-knot machine with a range of a few hundred yards to the modern torpedo with a speed of over 40 knots and a range of several miles. Torpedoes have generally been fired from a torpedo-tube, a steel sleeve from which the torpedo is ejected either by compressed air or by a small powder-charge. Underwater tubes are generally fixed in the ship's structure; above-water tubes may be either fixed or mounted on a turntable in groups of two to five. Destroyers usually have one, two, or three banks of tubes in tandem on the centerline; cruisers, one or two banks on each beam. The later Japanese cruisers carried their torpedoes in fixed tubes. Prior to World War I battleships and battle-cruisers commonly carried two to four fixed underwater tubes. The last ships to be so armed were the *Rodney* and *Nelson*, each of which had two tubes for torpedoes of special large size, 24.5 inches in diameter. (The usual size is 21 inches.)

At the outbreak of World War II the heaviest torpedo armaments were 16 tubes in the British light cruisers *Emerald* and *Enterprise* and in the U. S. destroyers of the *McCall* and *Craven* classes. Most other cruisers and destroyers carried six to twelve. During this war torpedo tubes were removed from many ships to make room for additional anti-aircraft guns. Many destroyers lost half their torpedo armament, and some, converted to radar picket duty, lost all their tubes. The United States, relying upon long-range gunnery, had taken the tubes out of its earlier heavy cruisers and installed no more in ships of that kind. The Japanese, putting their trust in torpedo action, did just the opposite; they installed no less than 24 tubes (three quadruple banks on each beam) for huge 25-inch torpedoes on the decks of old light cruisers of the *Kuma, Natori,* and *Jintsu* classes, which already mounted eight 21-inch tubes. These ships, however, got few chances to use their imposing torpedo armament, for they proved so vulnerable, especially to American submarine torpedoes, that by the end of the war all but one of the fourteen had been sunk.

On the other hand, the Japanese torpedo developments should not be sneered at, for at times during the Pacific war they made better use of them than we did. For one thing they considerably increased the range and speed of their torpedoes by substituting oxygen for part of the air used in the torpedo engines, and by means of their superior torpedoes and effective torpedo tactics they inflicted a crushing defeat on Allied cruisers in the Battle of Savo Island at the start of the Solomons campaign.

The original Whitehead torpedo was expected to run in the direction it was aimed, so that its tube had to be aimed directly at the enemy. The gyroscope made it possible to steer the torpedo in any direction regardless of the way the tube pointed by pre-setting the gyro to hold the torpedo to the desired course. World War II saw additional wrinkles in torpedo design, such as an acoustic control that would make a torpedo chase the sound of a ship's propellor (countered by noise-making devices towed behind ships) and magnetic torpedoes that would explode as they passed under a ships' keel. The Germans made use of an electric torpedo, which, while slow, had the great advantage of leaving no wake of bubbles, as ordinary turbine-driven torpedoes do, and therefore giving no visual warning of its approach. Present U. S. Navy opinion tends towards placing destroyer torpedoes in fixed mountings to save the space and topweight imposed by trainable mountings, on the theory that modern torpedo actions take place at such long ranges that the error introduced by running in an arc while straightening out on the desired course is negligible.

One more torpedo-craft is the high-speed motorboat armed with two or four torpedoes, called variously the PT-boat (patrol torpedo boat), coastal motor boat, motor torpedo boat, or torpedo launch. These craft, pioneered in World War I by the British firm of Thornycroft, saw considerable use in that war, as when an Italian boat sank the Austrian battleship *Szent Istvan*. PT-boats also proved themselves useful in World War II, but performed most effectively in narrow waters and at night, since otherwise the guns of a destroyer or a fighter-plane made short work of their flimsy hulls.

### The Submarine

After the abortive Confederate attempts at submarine building, the French Navy in the 1880's and 90's procured a number of small submarines driven entirely by electric storage-batteries. While not unsuccessful, their ships were, because of their restricted range, thought of as purely coast-defense vessels. The next step in the art was taken by two American constructors, Simon Lake and John Holland; the latter, of Irish birth, motivated by hatred of England. They developed the combination of internal-combustion power for use on the surface and electric power submerged that has prevailed in nearly all subsequent submarines.

Submarines just failed to get into the Russo-Japanese War. Germany was late in acquiring submarine flotillas, and at the outbreak of World War I had fewer submarines than Great Britain, though these were of the most advanced design. From a naval point of view, however, this war soon became more a submarine and anti-submarine war than anything else. Germany stuck to practical designs of moderate size, while Great Britian experimented with radical submarines. The latter, for instance, built the K class, steam-driven on the surface at the high speed of 23.5 knots for fleet action; the M class, or monitor submarines, which carried a short 12-inch gun; and the R class which, with extra-large batteries, were faster submerged than on the surface and meant for stalking hostile submarines.

When World War I began, the new weapon soon proved its worth when the German submarine U-9 sank the British armored cruisers *Aboukir*, *Cressy*, and *Hogue* within minutes of each other. However, during the first year of the war the Germans operated their submarines in irregular fashion and to a considerable extent adhered to the international rules of war: stopping ships and allowing passengers to take in boats before sinking them. Sinking was w gun-fire or demolition charges when possib because a submarine could carry only a f torpedoes.

Allied arming of merchantmen and emplo ment of decoy ships with concealed guns so made these policies impractical. When the G man Navy adopted a policy of sinking all shi around the British Isles without warning rega less of nationality, the United States proteste The German government wavered, twice adopti the policy and twice repealing it, until its fir adoption in 1916 brought the United Sta into the war against Germany without achievi the decisive results that an earlier adopti might have effected.

Even so, German submarine warfare ca closer to winning the war for the Central Powe than any other one thing. At its height, in t spring of 1917, one out of every four shi that left the British Isles was sunk before returned. The campaign was only put down an enormous material and technical effort the part of Great Britain and the United State by the building of great fleets of destroye and submarine-chasers, the mining of vast tra of sea, and the development of the hydropho and the depth-charge.

### Recent Torpedo Warfare

The success of the torpedo in World War led to drastic changes in warship design. Shi were more and more minutely compartment below the waterline, until post-Jutland batt ships were built with the equivalent of five six hulls one inside the other, the space betwe the hulls being divided up by bulkheads li an egg-crate. To give older ships the same pr tection, navies added steel blisters call "bulges" to the sides of pre-Jutland battleshi In World War II the ever-increasing power the torpedo forced navies to reinforce the unde water protection of comparatively modern shi still further, even at the cost of slowing them down by increasing their beam. The United States, for instance, widened the *California*-class battleships and some of the *Brooklyn*-class cruisers in this manner.

For a decade and a half after World War I the United States built no torpedo-craft except for a few large submarines, relying upon its large but old fleets of destroyers and submarines left over from the war. Other powers however built both types of ships. In this construction France was outstanding for her large submarine fleet and her squadrons of fast large destroyers armed with 5.1 and 5.5-inch guns. The destroyer type, in fact, soon grew to twice the 1,000-ton size it had averaged during World War I. To fill the gap in sizes several countries revived the torpedo-boat of 500 to 1,000 tons.

A singular incident of this period was the launching of the Japanese torpedo-boats of the *Chidori* type. Prior to the Washington Treaty Japanese naval design had been conventional, following British models, but thereafter it became increasingly radical. Their new ships had undulating decks, sharply raked trunked funnels, great pagoda-like bridge towers, and a much heavier armament than other nations installed on ships of equivalent size, which caused them to roll alarmingly. The *Chidoris* carried three 5-inch guns and a triple torpedo-tube bank on their slender 527-ton hulls, with the result that on her trials the *Tomodzuru* of this class capsized and was found floating bottom-up with most of her crew drowned. The Japanese hastily reduced the armament of these ships to forestall similar accidents.

During the Long Armistice, also, several nations experimented with submarines of extreme design. Several submarines of over 2,500 tons were built, such as the British *X-1* with four 5.5-inch guns, the French *Surcouf* with two 8-inch guns, and the American *Argonaut, Narwhal,* and *Nautilus* with two 6-inch guns. Japan also built several such giants, and some large submarines were equipped to carry a small airplane. In general, giant submarines did not prove very successful. The *X-1* was scrapped before World War II; the *Surcouf* was lost in action; and the Japanese submarines showed themselves less effective than had been expected.

One reason for this failure is that the difficulty of submerging and surfacing increases with the size of the submarine. While the tanks are being filled, the center of gravity moves downward and at one instant coincides with the center of buoyancy. Then the submarine has no stability against rolling, but will turn right over if nudged. Therefore it is desirable to get past this point quickly. Also, most submarines are between 250 and 350 feet long, and can submerge to a maximum depth of 300 to 400 feet. Therefore, the average submarine can only submerge to a little more than its own length, which means that if it dives too rapidly, at too steep an angle, it may dig its nose below pressure-depth and collapse its hull before it can level off. The longer the submarine, the more imminent the peril.

Several nations also built midget submarines operated by a two-man crew and carrying one or two torpedoes apiece. The Japanese began their attack on Pearl Harbor with an ineffective raid by several of these craft, and were building a large number at the end of the war as part of their planned last-ditch defense. The Japanese midgets developed the unfortunate habit of turning turtle when they fired their torpedoes because of the change in distribution of weights. Great Britian had better success with midget submarines when a group of these little ships crippled the great German battleship *Tirpitz* in a Norwegian fjord.

Perhaps the most remarkable weapon of this kind in recent years was the Italian dirigible torpedo, designed to run just under the surface guided by a pilot who sat astride it half in and half out of the water. Although the Italian fleet in general, and the manned torpedoes in particular, were much derided during World War II, they had one accomplishment to their credit. On December 19, 1941, Italians penetrated Alexandria harbor in diving-suits with two of these torpedoes, attached them to the bottoms of the British battleships *Queen Elizabeth* and *Valiant*, set time-fuzes going, and swam away. In due time the torpedoes exploded and the ships settled to the mud of the bottom. This feat had some strategic effect, for the ships were laid up when they were needed to strengthen the meager British naval forces in the Indian Ocean against the foray by the Japanese in that region in April, 1942.

The most significant torpedo development since World War I, however, has been the airplane torpedo. Experiments with dropping torpedoes from airplanes were performed as early as 1910 by Rear Admiral Fiske, USN, and some use was made of such torpedoes in World War I—ineffectively, however, since the torpedoes of the time were often damaged by the drop and would not run true. After World War I the U. S. Navy led the world in torpedo plane development for many years, developing special torpedoes and special airplanes: first float seaplanes, then carrier planes.

Early in World War II the German and Italian air forces made ineffective attacks on British warships with torpedo planes. With the entry of Japan into the war the true importance of the torpedo plane was shown when the Japanese crippled the American fleet at Pearl Harbor and sank the *Repulse* and *Prince of Wales* in the Gulf of Siam. Later the United States regained its preëminence in the use of this arm. Of the twenty-odd Japanese capital ships (battleships, battle-cruisers, and large aircraft carriers) destroyed in this way, the airplane torpedo accounted for about as many as guns, bombs, submarine and surface-ship torpedoes, and mines put together, though in some cases the ships sunk by airplane torpedoes had been previously crippled by shells or bombs.

The German submarine campaign in this war followed a course remarkably like that of the previous World War. This time the Germans acquired the great advantage of the use of ports in France and Norway, from which they could not be sealed off by mining. They also improved their techniques, as by hunting in packs and being guided to their victims by long-range airplanes. In the last year of the war they developed the snorkel, a tube that enabled a submarine to "breathe" below the surface, and therefore to operate on its Diesels submerged.

Once again German submarines brought Britain within sight of defeat by attrition of her merchant-marine. Once again this campaign was mastered by a vast effort and improved devices. Britain and the United States built vast fleets of anti-submarine craft—destroyers, destroyer-escorts, frigates, corvettes, sloops, patrol motor-boats, blimps, and long-range airplanes. They introduced radar, ultrasonic detectors, and improved depth charges.

An examination of the data of World War II (aside from the atomic bomb, which makes everything uncertain) shows that this war did not definitely settle such controversies as those about airplanes *v.* battleships and land-based *v.* carrier-based airplanes. All these weapons proved useful, more or less depending on circumstances. However, a tally of surface sinkings (merchantmen and auxiliaries as well as warships) shows the torpedo running far ahead of the gun, bomb, mine, and rocket. To this extent the naval part of the war may legitimately be considered a torpedo war. Of the three kinds of torpedo carriers—airplanes, surface-ships, and submarines—all proved effective, with submarines leading.

In several cases, warships' upperworks were reduced to junk by shells and bombs, but the ships stubbornly refused to sink, and either got away or had to be finished off by torpedoes. Such was the fate of the German *Bismarck* and *Scharnhorst*, and of the old Japanese battle-cruiser *Hivei.* Aviators went out to sink the last-named with torpedoes after she had been crippled in the first night action in the Battle of Guadalcanal. They observed hits, but the ship continued to crawl away. Then it occurred to a torpedo-officer that the torpedoes were set to run shallow, so as not to pass clear underneath small ships, and the *Hivei,* because of damage, was low in the water; hence the torpedoes were exploding against the armor-belt with a fine bang but little damage. When the torpedoes were reset, a couple more sent the ship down.

The torpedo, we may be sure, will not soon become obsolete as a weapon. Not only is it the most effective single weapon against ships at present, but also it stands to be improved in the near future. A torpedo with a target-seeking device to control it, a fuze of the proximity type, and possibly a warhead of fissionable material, would, to put it very mildly, present the commander of any hostile group of ships with a serious problem.

CHAPTER 7

# MINES

## Early Mines

One of the first applications of gunpowder to warfare, older even than the gun, was to set off a stationary charge under the enemy before he knew where it was. This could be done either by secretly digging under the foe and planting a charge, or by planting the charge where he was expected to go. The term "mine" was borrowed from metallurgical mining since similar techniques were used. You may recall Hamlet's remark:

"For 'tis the sport to have the engineer
Hoist with his own petard . . ."

A petard was a kind of mine in a bucket-shaped container used to blow in the gates of a besieged city. Naturally the soldiers who planted the thing were sometimes blown up before they could get away, whereupon the rest of the army, disliking this devilish new weapon, gunpowder, cheered.

The principles of mining were applied to marine warfare in 1585, when Ferderigo Gianibelli undertook to help the city of Antwerp, besieged by the Spaniards. The latter had built a fortified bridge across the Schelde to stop the Dutch from running supplies into the city. Gianibelli filled a small ship with gunpowder and sent it drifting down against the bridge, where a clockwork fuze exploded it, blowing up half the bridge and a thousand Spaniards. The explosion so frightened the Dutch themselves that they forgot to attack as planned, with the result that eventually the city fell anyway.

Then in the American Revolution Bushnell, the submarine-inventor, equipped his *Marine Turtle* with a drill by means of which he hoped to attach a 150-pound mine to the bottom of one of the British men-of-war anchored near New York City. Sgt. Ezra Lee of the Continental Army navigated the *Turtle* to the British ship all right, but then the drill failed to penetrate the Britisher's copper sheathing and the attempt failed. Later Bushnell tried out mines consisting of kegs of gunpowder with contact fuzes to be sent drifting down the tide against British ships. Poor Bushnell's floating mines proved no more successful than his submarine; Hopkinson the poet wrote a derisive verse beginning:

" 'Twas early as the poets say
Just as the sun was rising,
A soldier stood on a log of wood
And saw a sight surprising . . ."

Overcome by ridicule, the man ahead of his time retired to the wilds of Georgia where he opened a school under an assumed name. However, experiments with submarine mines continued. Russia in the Crimean War and the Confederacy in the American Civil War developed contact mines, ("infernal machines," the British called them), exploded by means of a projecting horn which, when struck, caused an ampule of sulphuric acid to break over a mixture of sugar and potassium chlorate. The heat of the resulting chemical reaction set off the charge. Also, Lt. Davidson, C. S. A., invented an electric mine, exploded by pushing a button on shore. In the Civil War mines became sufficiently perfected to send several ships on both

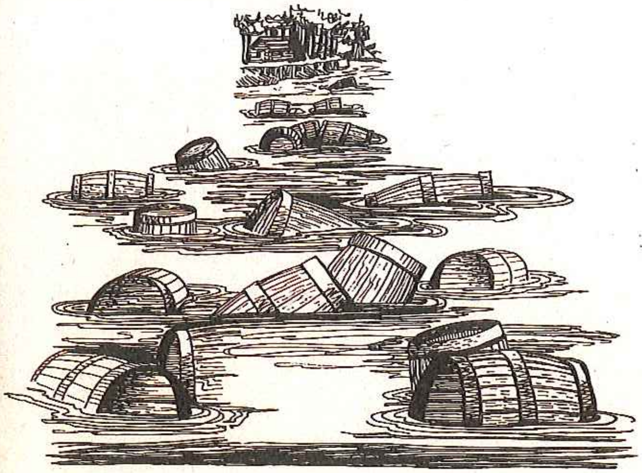

Figure 9.—**Early floating mines.** Kegs of gunpowder with contact fuzes.

sides to the bottom, as when the Federal monitor *Tecumseh* had her bottom blown out by a contact mine at Mobile Bay.

Mines became really important in the Russo-Japanese War, in which both belligerents used them liberally. The Russians lost their one good admiral, Makarov, when during the siege of Port Arthur he went out to reconnoiter on a cruiser and was sunk by a mine of uncertain nationality. The Russians not only pioneered in the development of contact mines, but ever since the Russo-Japanese War, in which they lost most of their fleet in a series of great battles, they have specialized in minelaying as their principal naval technique.

The prototypes of most of the modern types of mines were developed before World War I. Mines may be either lighter-than-water floating mines, or lighter-than-water captive or moored mines, swaying on the ends of cables anchored to the bottom; or heavier-than-water mines lying on the bottom. Stationary mines may be exploded either by contact or by an electric signal from the shore. Floating mines are always contact mines. International law supposedly requires that either floating mines, or captive mines that break their cables and bob to the surface, be so made as to become harmless within a short time, as otherwise the world's shipping lanes would become menaced by these objects.

The commonest type of mine is the moored mine, held to the bottom by a heavy frame called an "anchor", which incorporates a cable on a reel and means for paying out enough cable after the mine and the anchor have been dropped together to let the mine float the desired distance below the surface. Against surface-ships mines must be near the surface, while against submarines they are staggered at various depths. The anchor commonly has small wheels on which it can be pushed along a railroad on the deck of the minelaying ship. Warships of nearly all the smaller types, including submarines, have been modified for minelaying, and many nations have built special minelayers. Britain and France, for instance, have constructed cruiser-minelayers, fast ships of good size, which theoretically could hold off a pursuing fleet by dashing in front of it and dropping floating mines; but this tactic has yet to be tried.

## Mines in World War I

Mines showed their importance in the opening weeks of the first World War, when a mine laid by a submarine sank the British battleship *Audacious*. During the war enormous numbers of mines were laid by all belligerents. To bottle up German submarines in the North Sea, the British and American navies not only blocked the English Channel with mines, but also laid an immense belt of mines, 230 miles long, across the North Sea from the Orkney Islands to the coast of Norway. For this operation they used over 70,000 mines, mostly of a new American type with long wire antennae which detonated the mines electrically when a ship touched them. Allied navies were still laying mines to complete this North Sea Barrage, as it was called, when the war ended.

Mines also affected the Dardanelles campaign. After the preliminary bombardment, the Anglo-French fleet carefully swept all the mines the Turks had laid to block the strait. The Turks, desperate because of the destruction of their forts and exhaustion of ammunition, sent a little steamer converted to minelaying out at night to lay some more. When the Allies attacked again, mysterious explosions sank three of their capital ships and damaged another, so that the naval attack was called off. By the time they had reorganized and mounted an amphibious attack the Turks had so strongly fortified the straits that it, too, failed.

To remove mines, first fishing trawlers were sent out to sweep them up by towing either one cable between a pair of ships with a weight or kite to hold it down, or one ship with two cables streaming out at an angle from it by means of a similar kite at each end. At first, mine-sweepers were blown up at the uneconomical rate of one ship to two mines, but later in the war this rate was reduced to a mere one ship to 80 mines. Devices were also invented to snip the cables of the mines as the sweep fouled them, letting the mine rise to the surface where it was exploded by gunfire. The paravane, a minesweeping kite that looks like a model airplane made of boiler-iron, was also developed at this time, and is still carried aboard warships. After the end of the war, several years were required to sweep up all the mines.

## Modern Mining

Mining proved important, even if less crucial, in World War II. The main developments were the techniques of minelaying from the air (with a parachute to lower the mine gently) and complicated trigger-mechanisms to make the mines hard to dispose of. Some of the special mines developed were the limpet mine (named for a mollusk with great powers of adhesion) which was held to a ship's hull magnetically; the series-switch mine, exploded by the pressure-changes caused by the passage of ships, and capable of being set to go off with the first ship, or the second, and so on. Acoustic mines, set off by the sound of ships' propellors, were used, but did not prove altogether satisfactory because they were often exploded prematurely by the peculiar noises that some species of fish make.

Early in the war the Germans sprinkled heavier-than-water magnetic mines along the British coasts. Dropped in shallow water, they sank to the bottom where they could not be swept by conventional means, and lay there until an iron-hulled vessel passed over them and operated their magnetic triggers by warping the earth's magnetic field. The magnetic mine was counter-acted by equipping ships with degaussing cables, electric conductors running around the ship and neutralizing its magnetic effect by an electric current. The mines themselves were destroyed, among other methods, by equipping a large airplane with an electromagnet in the form of a huge horizontal loop of copper cable, and flying low over the infected areas with the current on. The mines burst beneath and tossed the airplane about by their concussion. Another method was dragging an electrically charged cable along the bottom from a minesweeper.

The mining of the Norwegian coastal waters by the British, to stop the passage of German ships, gave the Germans a pretext for their long planned conquest of Norway. After that there could be no more North Sea Barrage. During the Egyptian campaigns, the German Air Force made the Suez Canal practically unusable for a while by dropping mines into it faster than they could be swept out.

Mines had less effect in the Pacific phas of the war because most naval activity in tha theater took place in water too deep for th purpose. However, the possibility of mines stil had to be taken into account in every one o the American amphibious attacks on islands and provisions made for sweeping them. All th Axis powers, in fortifying their coasts, use small mines attached to obstacles laid in sha low water to keep off landing craft, and on of the more hazardous jobs of some of the a tackers was to swim in with goggles and rubbe fins on their feet ahead of the boats to disarm these mines. In the closing phases of the war the U. S. Navy blocked the Japanese harbors with series-switch mines, so that at the time of the surrender the Japanese were reduced to sending suicide boats weaving back and forth across their harbors until they blew themselves up.

Mines affected the war with Japan in a peculiar way. The Japanese had a pair of 16-inch-gun battleships, the *Nagato* and *Mutsu*, built at the same time as our *Marylands*, but faster, and next to the giant *Yamatos*, their best gunnery ships. One day the *Mutsu* sailed out to test new anti-aircraft guns. While she was gone another department laid a mine-field. Nobody remembered to inform the captain of the *Mutsu*, with the result that on her return she plowed into the field at full speed, hit eight mines, and sank, while those on shore watched helplessly. Therefore she was not available at Leyte Gulf, and thus Japanese mines helped to win the war for the United States.

CHAPTER 8

# DEPTH-CHARGES

## Origin of the Depth-Charge

Can one weapon win a war? This question cannot be answered by a simple yea or no. Weapons certainly have a profound influence on the outcome of a war, and when one side has much more advanced weapons than the other, as when Cortes conquered Mexico or Mussolini Ethiopia, they may render any resistance futile. Yet seldom does a single weapon win a war by itself, because the other side soon copies it and develops antidotes to it. Thus the atomic bomb did not win World War II for us, since Japan was already in a hopeless position. It merely induced them to give up the last-ditch defense they had planned, which included such picturesque items as men called "fearless dragons" who were to wade out from shore in diving helmets carrying mines on the ends of poles, with which they would blow up American landing-craft and themselves as well.

Likewise the tank did not win World War I for the Allies because it was not introduced in decisive quantities until the Central Powers were on the decline anyway. Sometimes a new weapon fails to avert defeat because it is improperly used, or is not sufficiently perfected, or is not available in sufficient quantities as in the case of poison gas and the V-2 rocket, introduced by Germany in World Wars I and II respectively. However, if any of the recent wars can be said to have been won by a single weapon, the depth-charge or depth-bomb won World War I by averting the imminent defeat of Great Britain.

The depth-charge seems hardly glamorous
enough for the role of a decisive weapon, b
a simple heavier-than-water mine with m
for setting it off as it sinks. Most depth-cha
are exploded by a hydrostatic trigger that
be pre-set to detonate the charge at any des
depth up to 600 feet or more. Some recent t
use fuzes of the influence or proximity t
which detonate the charge when it comes w
a certain distance of the submarine.

Fast ships like destroyers can drop d
charges off rails leading to the stern like m
This method, however, is unsuitable for
ships, which would have their own sterns b
off unless the charge is set to explode at a
siderable depth. The other method of unloa
depth-charges is to shoot them from a proj
in the form of a simple mortar fixed to the s
deck. Since the depth-charge is much too
to go into the gun, an accessory called an "a
is fastened to the charge, having a cylind
projection that fits into the gun.

The usual method of using depth-charg
to fire several at once, and drop one or
off the stern at the same time, when the
is thought to be over a submarine. The ch
strike the water in a pattern that makes as
an area as possible dangerous to the q
Since the projector cannot be trained or ele
range is varied by size of the propelling c
The weight of the explosive in depth-c
varies from 200 to 600 pounds. The 600-
charge is damaging at 80 feet and fatal
the 300-pound charge is fatal at 20. If on
pares these figures with the size of the a
submarine—about 300 feet long—one se
considerable accuracy is required. It d

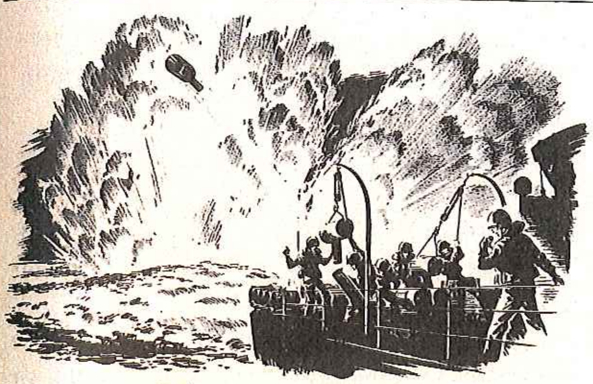

Figure 10.—**Depth charge.** Shot from a projector on deck.

good to sprinkle charges at random about a submarine-infested area.

At the start of World War I there was nothing to do against submarines except to lay mines and nets to keep them out of certain areas, and to shoot or ram them when they appeared on the surface. Sometimes they could be rammed when proceeding at periscope depth, but a periscope is hard to see except in smooth water and bright daylight. Submarine commanders naturally learned to avoid the nets and mines and to avert attacks from surface ships by staying below. Once a submarine had submerged below periscope depth, there was nothing a surface ship could do.

The Navy of Great Britain, which suffered most severely from submarine attacks, therefore developed the depth-charge early in World War I. The charges were not very effective at first because the submarines could not be located accurately in most cases. The pursuing ship had to get a good look at the submarine before it submerged to judge its position. Still, the charges did sink some submarines, and damaged others so that they had to rise to the surface where they could be disposed of by other means.

To enable ships to locate submarines under water the hydrophone, a kind of stethoscope mounted in a ship's hull below the waterline, was developed. By using special controls the operator could determine the direction of the hostile propellers, and several such fixes at the same time or in quick succession would locate the submarine. The hydrophone-and-depth charge combination saw its first success the night of July 6, 1916, when the British motorboat *Salmon* bombed the submarine minelayer UC-7 and set off her mines with a grand explosion.

Still the menace was not mastered, for it took months to install hydrophones in all the anti-submarine ships and to jack up the manufacture of depth-charges to more than a thousand a week. Meanwhile sinkings of merchantmen increased to about half a million tons a month in the spring of 1917, and when Admiral Sims arrived from the United States in Britain to plan Anglo-American naval coöperation, Jellicoe told him that Britain was losing; they were down to three weeks' food-supply and getting lower.

The British Navy had not used convoy; partly because they did not think they had enough destroyers, partly to get the maximum use out of their ships, since convoy means that ships have to wait in ports for convoys to form, and the faster are held down to the speed of the slowest. When American destroyers were added to the anti-submarine fleet, convoy was tried out, then adopted in full force as sinkings declined. The combination of the depth-charge, the hydrophone, and convoy finally broke the back of the submarine campaign, or at least reduced sinkings to where new construction could keep up with them. The North Sea Barrage finished the campaign, when in September, 1918, mutinous German sailors refused to board the doomed submarines any longer. The final box-score for destruction of German submarines in that war was:

| | |
|---|---|
| Mines | 41 |
| Depth-charge | 34 |
| Ramming | 23 |
| Gunfire | 20 |
| Other submarines | 19 |
| Decoy ships | 13 |
| Miscellaneous | 28 |

Depth-charges were relatively more important than this table implies, since some of them forced submarines to the surface where they were destroyed by other weapons, and many of the mine sinkings occurred towards the end of the war when the depth-charge had already saved Great Britain.

### Recent Use of Depth-Charges

The story of the German submarine campaign in World War II paralleled that of the previous great war, with everything more complicated and on a larger scale. Depth-charges were dropped from airplanes and blimps, improved in design, and filled with torpex instead of TNT. The U. S. Navy now has a slightly streamlined depth-charge that looks like an overfed airplane bomb, and sinks more rapidly than the cylindrical "ash-can".

The rocket principle was combined with the depth-charge to produce two formidable new anti-submarine weapons, the "mousetrap" and the "hedgehog." In the mousetrap, so called from its appearance, a set of rocket-launchers is welded to the forward deck of an anti-submarine vessel. The projectiles are rocket depth-charges, 7.2 inches in diameter, with contact or proximity fuzes. Since the effectiveness of a charge varies more or less inversely as the cube of its distance from the target, a small charge in actual contact with a submarine is worth one several times the size a few feet away; hence with modern fuzes it is profitable to shoot a number of small charges in place of one large one.

The "hedgehog" uses a similar (but not identical) rocket depth-charge, fired in all directions from the deck of the ship so that the missiles strike the water in an elliptical pattern. The outstanding accomplishment of this weapon was the engagement in which the U. S. destroyer-escort *England* sank six Japanese submarines in one week.

The greatest advance of World War II in anti-submarine technique, however, was the development of ultrasonic detection apparatus during the 1930's. In the previous war, submarine commanders had learned to neutralize the hydrophone, at least in shallow water, by lying on the bottom and keeping the crew from talking or otherwise making noise. Moreover an anti-submarine ship had to slow down or stop altogether to use its hydrophones, making itself a fine target for a submarine's torpedo.

The new detector, called a "sonar" or (in Great Britain) an "asdic," searches the neighborhood of the ship using it with beams of ultrasonic sound, making it possible to locate a submarine lying still. The principle is similar to that used in radar, or in the sonic depth-sounding apparatus that for some years has been in use on ships. The distance of the object is measured by the time it takes for the echo to return, and the direction is determined by using waves of such short length that they have beam properties, instead of spreading in all directions like sound in the audible range. Operating the apparatus is called "pinging" from the sound it makes. Now it has been combined with a new plotting device called a chemical recorder. Ultrasonic detection apparatus and depth charges accounted for most of the more than nine hundred Axis submarines sunk in World War II.

Like most new devices this detector, too, had its shortcomings, one of which was that it would register whales as if they were submarines, with the result that a number of these rare and inoffensive animals were depth-charged to death by hasty anti-submarine crews.

# CHAPTER 9

# ROCKETS AND GUIDED MISSILES

## Early Rockets

The rocket probably evolved from the fire-arrow, a primitive but effective incendiary weapon used the world over before gunpowder, and even employed by the British in Ethiopia in World War II. As far as is known, the Chinese made the first rockets in the 13th century. In a few years Arab scientists brought the knowledge of rockets to medieval Europe. For instance, Hassan Alrammah in his *The Book of Fighting on Horseback and with War Engines* told how to make "Chinese arrows" or rockets.

Europeans at once applied the invention both to pyrotechnic and military uses. The Island of Chiozza was taken in 1379 as a result of a lucky rocket hit that set a tower of the defense works on fire. Military engineers were long uncertain about what to do with the new device, as they were for that matter about guns. Some of their proposals showed imagination, as when Joanes de Fontana about 1420 designed a rocket car on rollers, intended to ram down the gates of cities, and a rocket boat or torpedo to perform the same office against warships.

Rockets were used in war in desultory fashion until they were revived at the end of the 18th century as a result of British wars in India. In one series of these wars the British cavalry had been badly battered by swarms of rockets launched at them by the troops of Haidar Ali, Sultan of Mysore, and his successor Tipu Sahib. This unwonted military ingenuity on the part of a non-European aroused interest in Europe. Colonel William Congreve of the British Army, having read of the Mysore Wars, built experimental rockets until he achieved a range of 2,000 yards. This so impressed the British Navy that it equipped a number of warships as rocket-launching ships, which set devastating fires in Boulogne, Copenhagen, and Danzig during the Napoleonic Wars. British rockets also took part in the great Battle of Leipzig, and provided the "rockets' red glare" of which Francis Scott Key wrote.

Following Congreve, most European armies and that of the United States as well, formed rocket units in the first half of the 19th century, but then the 19th-century revolution in the design of cannon put the rockets out of business again, despite Hale's invention of the stickless spin-stabilized rocket. By World War I rockets were restricted to such auxiliary jobs as carrying lifelines in sea-rescue work, and signalling. Almost their only strictly military use consisted of fastening them to the struts of French and Russian airplanes and shooting them into German observation balloons to set them on fire. The French shot down the German airship LZ-77 with rockets, and almost got another which they pursued around the country with a rocket-launcher mounted on a truck.

## The Theory of Rockets

The principle of propulsion by means of the recoil of a jet was known long before the invention of rockets. Back in Classical times the Italiot-Greek philosopher Archytas invented a model bird of wood that flew round and round on the end of a string by means of some sort of steam-jet, and a few centuries later the great engineer Hero of Alexandria designed a kind of primitive steam turbine as a toy.

The force created by rockets and other jet devices was not understood until the time of Isaac Newton. People thought, as some still do, that the stream of gas pushed against the atmosphere as a boatman pushes against the bottom with a pole—although a stream of gas, having no structual strength, cannot push against things that way. The gas does not push against surrounding ("ambient") air except incidentally; it DOES push against the front end of the combustion chamber of the rocket. The resistance of the ambient air or other fluid slows up both jet and rocket, so that a rocket works better in a vacuum than in a gas or liquid.

Newton explained this effect by his third law of motion, stating that to every action there is an equal and opposite reaction. Therefore, when two things, such as a rocket and its charge, or a gun and its projectile, free to move, are forced apart by an explosion, the product of the mass and the velocity imparted to one (the momentum) will be the same as that acquired by the other. In 1680 Newton proposed a carriage driven by a steam jet.

After Newton, several people tried to put the reaction principle to work. In 1721 a Dutch professor, s'Gravesande, proposed the same thing, and in the middle of the 19th century Golightly in England, von Siemens in Germany, and others planned flying-machines driven by the same means. The mathematics of rocket flight were worked out in detail in the latter part of that century and the early years of this century, largely by a retiring Russian country school-master, Tsiolkovski, who died at a great age in 1936.

After Tsiolkovski's articles appeared, a number of technologists, such as Pyerelman and Rinin in Russia, Oberth in Germany, Esnault-Pelterie in France, and Goddard in the United States, developed his theories further. Goddard, who had done some engineering on signal rockets as an officer in the U. S. Naval Reserve in World War I, devoted his efforts after the war to the development of meteorological rockets for reaching extreme altitudes, and speculated about sending a rocket to the moon where it would mark its arrival by exploding a magnesium flare. With extreme secretiveness he tested rockets driven by a mixture of gasoline and liquid oxygen, reaching an altitude of 7,500 feet.

Between the two World Wars, such amateur groups as the American Rocket Society and the Verein für Raumschiffahrt ("Society for Space-Travel") or German Rocket Society performed much experimental rocket work. Germany under the Weimar Republic was a hothouse of radical engineering ideas, some good like lightweight streamlined rail-cars, others mere publicity-stunts like the rocket automobiles which the rocket engineer Valier persuaded the manufacturer von Opel to build. (Rocket propulsion is about the most impractical method imaginable for driving ground vehicles.) From 1929 to 1933 the German Rocket Society built and tested high-altitude rockets and worked on problems of ignition, nozzles, and parachutes for safely returning the rockets to earth. Hitler's accession to power ended the VfR; the anti-Nazi members left Germany and the rest were put to work for the German Army. The society's youngest member, Count von Braun, eventually headed the V-2 rocket project.

### Modern Military Rockets

Beginning in the latter part of 1941, the armed forces of Germany, Britain, and Russia (the United States lagged in this field), blossomed out with military applications of the rocket principle, all having worked on it for several years before the outbreak of war. Although rockets were still much less accurate than guns, they made up for this shortcoming by the fact that they could be fired from a simple, cheap, light launcher instead of a complicated, expensive, heavy gun. Therefore they could be used where lightness or a great sudden volume of fire was more important than accuracy.

The defense-minded British applied the rocket principle to anti-aircraft fire, with a Z-gun to fire explosive rockets on land, and a shipborne anti-aircraft rocket that dangled a long steel tape from a little parachute in front of dive-bombers. The Germans brought out their NEBELWERFER, a big six-barreled rocket projector on an anti-tank-gun carriage. The original NEBELWERFER fired 6-inch smoke-rockets; later models fired high-explosive rockets of that and larger sizes. The Russians beat back the German invasions with rocket-accelerated armor-piercing bombs launched from airplanes at tanks, and massed bombardments by a 30-barrel mobile rocket-launcher called the *katyusha.* When the Anglo-American air forces began heavy bombing raids on Germany, the German fighters fired salvoes of 8.27-inch rockets from under their wings at the bombers, a trick soon copied by the other belligerents. Had the Germans possessed a proximity fuze as well, they might have been able to halt the strategic bombing campaign against Germany with their air-to-air rockets.

The United States began rocket operations in the North African campaign with the Launcher, Rocket, M-1, otherwise the bazooka, a tube designed to be held in the middle by one man and fired from his shoulder, the exhaust flying out the rear. The projectile was a little 2.36 inch rocket with a hollow-nosed charge. Mining engineers had long known that an explosive charge presenting a concave surface against a face of rock or armor will blast a hole of surprising depth, since the concave surface acts on the explosion-waves somewhat like the reflector of a headlight. This phenomenon is called the Munroe effect from its discoverer. The bazooka rocket did not, therefore, actually penetrate the tank; it exploded on impact, punched a hole in the tank armor, and sent fragments of armor flying about the interior. The Munroe effect has been applied to bombs as well, and the bazooka was joined as an anti-tank weapon by the similar devices of other belligerents throwing their charges by means of a spring or a propellant explosive charge.

In the last year of the war the U. S. Navy brought into action a variety of formidable rockets: the 3-inch rocket to be fired from aircraft, the 4.5-inch and 7.2-inch from ships, the 5-inch from either, and the rocket depth-charges already discussed. Just before the end of the war the 11.5-inch "Tiny Tim" rocket was put into use, and larger types were in preparation. For ship-to-shore bombardment the Navy fitted a number of landing-craft as rocket-ships with a dozen or more multiple launchers that could be fired in various combinations, plastering beaches with explosives. Rockets proved even more effective from airplanes than from the ground, since a problem of rocket-fire is keeping the rocket on its course during the first few seconds when it is travelling slowly, and a rocket fired from an airplane already has a velocity of several hundred miles an hour.

All other nations' rocket developments, however, were put in the shade by the German V-2, or *Fernraketo* A-4: a 46-foot, 15 ton rocket with a warhead of 2,150 pounds containing amatol, an ultra-stable mixture of TNT and ammonium nitrate. A rocket research group under von Braun, with the technical advice of Oberth, developed this rocket at Peenemünde on an island in the Baltic Sea in the course of several years' work. During their research the Germans fired the rockets at Polish towns in conquered territory, complete with Poles, to test their effectiveness against civilian populations.

About August, 1943 the design of the V-2 and its companion weapon the V-1 had already been completed. The V-2 was built to climb vertically for the first 8 seconds. Then control-vanes tilted it gradually towards the target until it was rising at an angle of 45 degrees. The rocket motor continued to burn its alcohol-oxygen mixture for 71 seconds, at the end of which time the rocket was

22 miles up and going a mile a second. At the proper point the remaining fuel supply was automatically cut off. The rocket continued to coast upwards till it reached a height of 58 or 59 miles, then descended. Five minutes after launching it came down on its target, 200 miles away, at a speed of over 1,000 miles per hour. At this velocity the compression of the air in front of the rocket heated its nose dull red. Since it travelled faster than sound it could be neither heard before it hit nor intercepted once it had attained speed.

The V-2 was stabilized by four large fins on which it stood before firing, and guided by two sets of 4 vanes, a set of 4 small graphite vanes in the path of the exhaust gases, and a set of 4 large sheet-steel vanes on the after ends of the fins, which took over guidance of the rocket after it had attained speed. Gyroscopes driven by compressed nitrogen controlled its direction.

The V-2 proved to have a number of weaknesses. Its damage was no greater than that caused by an airplane bomb of the same weight of charge, and its accuracy far less; if all went well the rocket-men could just about count upon hitting Greater London. The mechanisms frequently failed, causing the rocket to fall back to earth, topple over on its side, and deluge the launching area with flaming alcohol, or to nose down and crash immediately after takeoff, sometimes blowing up an adjacent rocket-station. The gyroscopic mechanism deteriorated rapidly. Despite these shortcomings, however, the V-2 was a major scientific triumph, and performed about as well as could be expected of a weapon rushed into action before it was fully perfected by a nation already on the road to defeat. The Germans fired 4,300 of them, of which 1,230 hit London, several hundred more hit Antwerp, and the rest went wild.

At the time of the fall of Germany, the Germans had other rocket weapons under development, including a winged rocket for transatlantic bombardment; an air-to-air rocket guided by a long electric cable that unreeled from its mother airplane; an anti-aircraft rocket like a miniature V-2; and a rocket interceptor airplane that took off, not horizontally, but straight up by means of a steel launching tower resembling an oil-well derrick.

When Germany fell, the American Army collected a number of rockets and parts. A few months later an Army-Navy organization at White Sands, New Mexico, began a series of explorations of the upper atmosphere with these rockets, which, carrying cameras and meterological instruments, rose to heights over 100 miles and returned their instruments to earth by parachute. Rockets designed for even higher altitudes are under development.

### Other Uses of Repulsion

World War II saw the use of jet and rocket devices of many kinds besides those mentioned above. Early in the war the Germans used rockets to assist the takeoff of Junkers 88 bombers with extra-heavy bomb loads. Other powers soon imitated this scheme, the U. S. version being the now familiar JATO (jet-assisted take-off). Great Britain and Germany developed jet engines for airplanes: gas turbines driving air-compressors to feed air under pressure to the turbine, and deriving their thrust from the exhaust. The Germans led in this development too, getting a jet fighter and a light bomber into action in 1944. The British soon followed with the Gloucester Meteor, while the British De Haviland Vampire and the American Lockheed P-80 just failed to see action. Despite its high fuel consumption the turbo-jet engine proved so successful in giving high speed that in the years following the war the leading powers largely dropped development of propeller-driven fighter-'planes in favor of jets.

Another jet-propelled missile, The German V-1, flying bomb, robot bomb, or buzz-bomb, was a 25-foot craft comprising a 2,200 pound bomb with stubby wings, upon which was mounted an intermittent jet motor in the form of a long pipe with its front end closed by a grille of narrow flapper-valves of the type called "reeds." The buzz-bomb had to be launched by catapult or rocket-assisted take-off, but once it had attained 150 m.p.h. the kerosene-burning motor came into operation, accelerating the bomb to a maximum speed of about 360 m.p.h. A timing device shut off the motor when it had flown the required distance, and the bomb dove earthward. Although the bombs did great damage when launched against England in June, 1944, they were soon counteracted by anti-aircraft fire and fighter patrols. In a few months their launching stations on the French coast were captured, though the Germans continued to harass England by launching the bombs from airplanes. The United States ordered a large number of buzz-bombs for the final campaign against Japan, but never had occasion to use them.

From the turbo-jet it was only a step to the rocket-driven airplane, or man-carrying rocket. Such a craft, unlike the buzz-bomb and the turbo-jet airplane, carries its own oxygen and therefore can operate at any altitude as long as its fuel holds out. Although Chinese annals tell of an official, Wan Hu, who about the year 1500 blew himself to kingdom come by trying to fly a vehicle consisting of a pair of kites, a saddle, and 47 rockets, the first rocket aircraft actually to fly was the Rhön-Rossitten Gesellschaft glider. In 1928 this craft made a short test flight in Germany, pushed along by a couple of rockets.

The Germans got a small rocket interceptor airplane, the Messerschmidt 163, into action before the close of World War II; a sturdy craft with swept-back wings and no horizontal tail surfaces. About the same time the Japanese used an aerial suicide-craft, a manned flying rocket-bomb, against American ships. These "*baka*-bombs," as Americans called them, did a lot of damage, and would have done more except that they were hard to aim at high speeds. It is unlikely, however, that any people but the Japanese, whose moral code carried disregard for human life to extremes, could have found enough pilots willing to sacrifice themselves in this manner. The Germans built a suicide version of the V-1, with accommodations for a pilot, but never used it for want of volunteers.

The success of aerial rocket vehicles brings the possibility of navigation outside the earth's atmosphere, or even travel to other heavenly bodies. Men have speculated about such journeys ever since classical times. With present fuels space-navigation is feasible and sometime in the future it just may be possible to send a rocket to the moon, as Goddard planned. On the other hand, for attaining Venus and Mars present fuels do not contain enough energy.

For various reasons solid propellants are most practical for small and medium-sized rockets, while for large rockets like the V-2 liquid fuels are needed. The usual combinations are liquid oxygen with gasoline or alcohol. Equally powerful reactions can be obtained by the union of nitric acid with aniline or with vinyl ethyl ether, and these fuels are preferred for some applications; but it is hard to see how very much more energy beyond these could be obtained from chemical reactions alone.

## Guided Missiles

Men experimented for many years with torpedoes and other devices controlled from a distance by cables, but remote control did not become really practical until the development of electric relays and radio communication. During World War I the Germans made one interesting attempt at remote control. They sent a little unmanned motor-boat or surface torpedo against the British monitors bombarding the Belgian coast, controlled electrically from shore by a long cable that unreeled as the boat sped out to sea. The boat hit one of the monitors, but the monitor had such large bulges that the boat skittered up the side of one of these and exploded well above the waterline, blowing a hole in the side plates but otherwise doing little harm to the monitor.

Various nations experimented with radio control of airplanes prior to World War II, and during this war such work was pressed intensively. Airplanes were flown under radio control to test them to destruction. Great Britain and the United States built a number of small radio controlled airplanes as anti-aircraft practice targets, and fitted out a heavy bomber as a radio-controlled missile in an attempt to blow up the German submarine pens. This airplane crashed before it could be used. The U. S. Navy built and purchased a number of radio controlled "drones" large enough to be used as torpedo 'planes, either by dropping torpedoes in the usual way or diving into their targets like a kamikaze. These drones had a television set in the nose, so that an operator in a mother plane at a distance could, by looking at the television screen, pilot the drone by remote control as if he were aboard it. Drones were never actually used against the enemy, however.

By the end of the war several forms of guided missiles were in use, though still imperfect like the V-2. There were bombs with or without wings, propelled either by gravity or by a rocket motor, and guided either by radio signals or by a target-seeking device that guided the missile home by radar, infra-red receptors, or other means. The Germans, for instance, used a radio-controlled rocket-assisted glide bomb against ships. Except for a case or two where the machinery went wrong and caused the bomb to chase its own mother airplane, this weapon was quite successful. With it the Germans sank the Italian battleship *Roma* on her way to surrender, and wiped out a turret on the U. S. cruiser *Savannah.*

The United States perfected a simple radio controlled bomb, the Azon ("azimuth only") which was steered right and left from the airplane that dropped it. This bomb proved useful in the final Burma campaign against long narrow targets like bridges. The U. S. Navy sank several Japanese merchant ships with the Bat, a gravity-powered glide-bomb guided by target-seeking radar. Greater use of this missile was limited because we were "running out of targets" at this stage of the war. Other devices were under development at the end of the war, such as the Glomb, a small television-operated glider to be dived into the target; and the Gorgon, a 16-foot missile with wings of the canard or tail-first type and an aniline-nitric acid motor.

These developments will be pushed vigorously in any future war. However, the road to push-button warfare is hard, for these devices are so complicated and delicate, and require such critical adjustment, that the utmost effort is required to make them work. Moreover their electrical controls, their radar, television, and remote-control mechanisms, are subject to hostile interference such as artificial static. We may therefore assume that the remote-controlled, transoceanic rocket is still some time in the future, and that at the start of any war in the near future most missiles will continue to be launched within less than a hundred miles of their target by manned ships, airplanes, and ground installations.

# CHAPTER 10

# BOMBS

## Early Bombs

Throwing or dropping an explosive charge into the midst of the enemy has been known to warfare ever since the defenders of Kai-Fung-Fu, in the year 1232, lowered a bomb on the end of a chain into the midst of the besieging Mongols, sending the nomads into panicky flight—a siege action which also saw the earliest recorded use of rockets. Early hand-bombs, or grenades, were hollow iron spheres looking just like the bombs that cartoonists used to draw in the hands of a bewhiskered character symbolizing Bolshevism. In the 17th and 18th centuries special troops called grenadiers were trained to use them in siege operations, according to the method described in the famous old march song, "The British Grenadiers":

> "We throw them from the glacis
> About the enemy's ears . . ."

the glacis being the forward slope of fortifications of that time. British grenadier regiments have retained the name long after losing their special function.

A flying-machine would obviously be an ideal place from which to drop bombs. Although the balloon was reduced to practice in the 1780's, and Benjamin Franklin had speculated on the possibility of transporting armies with it, Napoleon declined to make use of the invention on the ground that "it was undignified for military men to meddle with gas-bags."

However, balloons were used by both sides in the American Civil War, and during the Franco-Prussian War, when Paris was ringed by the Prussians, the besieged kept in touch with the outside by balloon. The balloonists dropped a few small bombs on the Prussians as they drifted over their lines, while the latter futilely shot at the balloons with the first anti-aircraft gun, a long-barrelled 2.1-centimeter piece.

During the early months of World War I, aviators sometimes harassed ground troops by dropping handfuls of steel darts about the size of a pencil on them. Although these darts could inflict a nasty wound they proved of little tactical importance. Some of the larger airplanes carried a few bombs, as they had in the previous Italo-Turkish War. These were pear-shaped objects with a handle for heaving them overboard, and sometimes a long streamer of cloth to stabilize them in their fall. During the latter part of the war, airplane and airship bombs assumed a quite modern appearance: long, cylindrical, with a rounded nose and a tapered finned tail, and a little rotary impeller like a miniature airplane propeller to arm the bomb as it fell. These bombs were small by modern standards, the 110-pound German airship bombs dropped on England being considered large. Still, by the Armistice the Allies had planned bombing raids on Berlin and were making airplanes and bombs for the purpose.

## Modern Bombing

Crude as it was, the air bombing of World War I made a profound impression upon the more thoughtful minds of Western civilization, especially since the speed, size, and range of airplanes increased rapidly in the years following the war. A great war of words ensued. Some like

Douhet in Italy and Mitchell in the United States forecast the sinking of fleets and the obliteration of cities, if not of the human race, by airplane bombs, while others called such talk needless alarmism. When German aircraft levelled the village of Guernica in the Spanish Civil War, that was held to prove the pro-bomber argument. When small-scale German raids on Barcelona did little damage, though they badly panicked the Barcelonians, this was held to refute the claims of the "air enthusiasts."

With the opening of World War II, air bombing showed what it could do in the case of Rotterdam. After that city had surrendered to the German forces invading Holland against feeble resistance, the German Air Force, as a measure of terrorism, levelled the central section of the city and killed 30,000 people in a single raid.

Then the Germans tried to repeat their Rotterdam performance against Britain, and succeeded in their raid on Coventry. However, while Rotterdam had been undefended, the British brought into action an immense defense organization of anti-aircraft guns, barrage balloons, searchlights, radar, and their new interceptor fighters, the Hurricane and Spitfire, then the world's best. Although the Germans inflicted grave damage on London and other cities, their own losses rose to 185 bombers in one day, at which point they were forced to call off the campaign. Subsequently the British and American air forces visited similar treatment upon Cologne, Hamburg, Dresden, Berlin, and many smaller cities. In the RAF raid on Hamburg in July, 1943, such a large conflagration was set that thousands of civilians who escaped the bombs were killed by scorching and suffocation.

The lesson of this war with regard to the bombing of cities seems to be that air power can, against a weak defense, do everything that the "air enthusiasts" had prophesied and more; on the other hand, it is possible to defend a powerful country effectively against an air-bombing campaign, and even when it is not possible, a nation can still endure immense material damage and hundreds of thousands of casualties from air attack and still go on fighting.

The Germans began their campaigns with high-explosive bombs ranging up to 550 pounds in weight, and incendiary bombs, mostly 2-pound thermite bombs with thick magnesium-alloy casings that continued to burn fiercely after the thermite charge was exhausted. As the war progressed, bombs, like other weapons, got bigger, more complicated, and more varied. The Anglo-American air forces used bombs of 2,000, then 4,000, then 8,000 pounds, called by such propaganda names as "blockbusters" and "earthquake bombs." While several varieties of incendiary bomb were tried, the thermite-magnesium bomb remained the most effective against cities because of its intense 3,000-degree temperature. However, it had to be used in great numbers because over half the area of a city consists of streets and courts in which bombs fell harmlessly, and even the remaining bombs could be kept under fair control by vigorous civilian fire-fighting. On the other hand, the United States found a bomb of jellified gasoline effective against the huts and crops of the Japanese in the Pacific.

In the campaign in France, the U. S. Army Air Force was called upon to lay barrages of bombs to cover the advance of troops, since American artillery, which would normally be assigned this function, was rather weak—at least by Russian standards. Although these "carpet barrages" of bombs proved effective, their success may largely have been due to the lack of effective German air opposition, and it is doubtful whether this is on the whole an efficient way to use air power.

Many other things were dropped from the sky during the war. The showering of propaganda leaflets, an old art, reached new heights of ingenuity. For instance, against the Japanese forces in the Aleutians, the United States did not make the mistake of appealing to the Japanese to "come in and surrender and we'll give you a good hot cup of coffee," since the Japanese seldom surrendered and do not like coffee. Instead the Americans dropped paper cut-outs in the form of leaves of a tree that in Japan is regarded as a symbol of misfortune, printed with a Japanese poem in correct classical style: "As these leaves fall, so shall your fortunes decline; as they pile up on the ground, so shall your misfortunes be heaped up . . ." thereby appealing to the Japanese belief in the magical efficacy of a written formula. The British dropped little cards impregnated with wet phosphorus on Germany, which when they dried caught fire spontaneously and set woods and crops ablaze; and also counterfeit ration stamps to complicate civil administration. Finally the Germans at Sevastopol dropped pieces of agricultural machinery to bewilder the Russians, though it is not known whether this antic had any such effect.

**Bombs in Naval Warfare**

Life in the United States was enlivened in the 1920's by the great bomber-warship controversy, led by Brigadier-General William Mitchell, who pressed the claims for air power with such belligerence that he was finally court-martialled for insubordination. There were also tests of bombs against ships that settled nothing. They sank the obsolete anchored German battleship *Ostfriedland,* but proved ineffective against the hull of the *Washington,* the fourth of the *Marylands,* destroyed under the Washington Treaty.

Technical developments during the twenty years following brought Mitchell's prophecies true to some extent, but not entirely, because these improvements affected ships, guns, and fighter planes as well as bombing and torpedo aircraft. In World War II airplanes proved that they could sink any ship afloat, if there were enough airplanes or if the ship were at a disadvantage.

On the other hand, some air attacks against ships were disastrously defeated, the supreme example being the Battle of the Philippine Sea, in which the Japanese threw over 400 carrier airplanes against the U. S. fleet, and lost every one of them while inflicting only trivial damages. The *Yamatos* might have escaped with sufficient air coverage and the best modern anti-aircraft armament, as the German battleships *Scharnhorst* and *Gneisenau* escaped from Brest through the foggy English Channel despite the best efforts of the British Navy and Air Force to stop them.

Although an even more vigorous air power doctrine has been advanced in late years, protesting the use even of aircraft carriers and calling for winning wars entirely with land-based bombers, World War II did not support these arguments. It showed neither type of airplane all-important; the carrier-based airplanes, for instance, proved more effective in attacking a target out of range of land-based bombers, or concentrating a surprise attack against a limited target near the ocean. For many purposes a fleet, which nowadays means a group of carriers protected by gunnery and torpedo ships, is still the most useful instrument.

Aircraft bombs for naval use are essentially the same as those used on land. For attacking armored warships there are bombs with hollow-nosed charges and armor-piercing bombs which like armor-piercing shells have thick cases and relatively small charges. In fact, the Japanese improvised armor-piercing bombs by rigging ordinary 14-inch AP shells with tails and special fuzes.

The usual sizes of U. S. Naval Aircraft bombs are 100, 250, 500 and 1,000 pounds, since carrier operation limits the size of airplanes and their loads. Therefore the very large bombs carried by land-based planes are not ordinarily used in carrier operations, though the very large carriers now contemplated (65,000 to 80,000 tons) would make larger carrier-plane bombs possible. Except for a few special cases like the sinking of the *Tirpitz,* large land-based bombers proved rather ineffective against warships, since they either must fly high, in which case the bombs usually miss, or low, in which case they are likely to be shot down before they can bomb. Although the United States made great claims early in World War II for sinking Japanese ships by high-level horizontal bombing, the Japanese after the war produced records to show that only a few hits had been scored in this manner.

The most effective bombing technique against defended ships is dive bombing, originally developed by the U. S. Navy, in which the airplane dives at an angle between 45 and 75 degrees at the target, releases the bomb at low altitude, and pulls out of the dive. Such tactics require airplanes of sturdy construction so that they will not come apart during the pull-out. They also involve risk, since during the dive the airplane makes a fine target for anti-aircraft guns with proximity fuzes.

Early in World War II the Germans applied dive bombing to land warfare with the Junkers 87 or *Stuka,* a slow, strongly built single-engined light bomber, sometimes equipped with a siren to frighten people on the ground during its dive. During the North African campaign the U. S. Army used land versions of the Navy's SBD and SB2C dive bombers.

Against large modern warships, bombs alone were seldom successful in World War II because the ships were so strongly built and so minutely subdivided that they could absorb great superficial damage without sinking. On the other hand, torpedo plane attacks alone often failed because the airplanes were so often shot down by guns and fighter planes. The most effective attack was a good dive bombing to break up the anti-aircraft defense and damage the decks of carriers so that they could not service their airplanes, coordinated with a torpedo attack to open up the ships under water, while attacking fighter planes kept the defending fighters engaged.

### The Atomic Bomb

On the morning of August 6, 1945, a B-29 of the U. S. Army Air Force dropped on the Japanese city of Hiroshima an atomic bomb, developed in profound secrecy at a cost of two billion dollars during the preceding four years. The bomb, lowered by parachute, exploded at a height of something like 1,000 feet. Within a mile of the point below, the bomb killed nearly everyone, knocked down all the lighter houses (which burst into flame) and damaged even reinforced concrete structures to the point of uselessness. Within a radius of two and a half miles it killed about half the people, and smaller numbers farther away—about 100,000 altogether. The victims died from various combinations of concussion, fall of houses, fire, penetrating radiation (gamma rays) and sunburn. A few days later an improved atomic bomb, using plutonium instead of uranium, was dropped on Nagasaki, with similar results.

The following year, a task force of the U. S. Armed Forces conducted tests on two atomic bombs at Bikini Atoll in the Pacific. The bombs each sank a number of ships, from the large aircraft carrier *Saratoga* down to submarines. Even more important, several ships not sunk were made so radioactive, either by direct radiation or by the radioactive water splashed aboard them during Test Baker, that they could not be manned during the ensuing two years. In 1948 further tests on atomic weapons were conducted at Eniwetok, but no details were released.

The atomic bomb has been compared to 20,000 tons of TNT in explosive force. Actually its power to kill by radiation, and to contaminate objects in its vicinity with radioactivity, may be even more significant than its explosive power, especially since radioactivity gives no obvious external sign. This bomb is therefore the most important new weapon to come out of World

War II; in fact it is the most important single weapon in the world today. The only factors that prevent its being the "absolute weapon," as it is sometimes described, are that it must still be delivered by a bomber, which can be shot down, (rockets and guided missiles being still much too unreliable for the purpose), and that fissionable materials cannot yet be produced in quantities comparable to those of regular explosives.

## CHAPTER 11

## CHEMICAL WARFARE

### Early Chemical Warfare

"Chemical warfare" ordinarily means warfare by chemical reactions other than explosive ones. In this sense it has been used since earliest times. Primitive peoples, for instance, used the fire-arrow and the smoke-screen. When Julius Caesar was conquering Gaul, the Gauls threw into his camp incendiary missiles consisting of a red-hot clay ball with an iron rod for a handle. One Gaulish army retreated from its camp facing Caesar under cover of a smoke-screen. Incendiary bottles of crude oil thrown from catapults figured in some classical sieges and naval actions, along with vases full of venomous snakes, and burning sulphur was early found useful in smoking engineers out of their tunnels.

The Byzantine Empire developed the incendiary art to a high degree, using an inflammable liquid mixture called "Greek fire." They kept its composition secret, though it probably had a petroleum base. By spraying this substance from nozzles they fired the ships of the Arabs and Russians that attacked Constantinople.

The English fleet also used chemical warfare in the Battle of Dover in 1217, when they beat a French squadron under a sinister character called Eustace the Monk by getting to windward and throwing quicklime into the air, which, drifting down on the French, blinded them. In addition, medieval siege engineers made crude attempts at bacterial warfare by throwing dead horses and barrels of sewage into besieged places from their catapults in hope of starting a pestilence.

### Smoke and Flame in Modern War

Smoke-screens were improvised from time to time down to World War I. For instance, Gustavus Adolphus set up one by burning wet hay to cover a maneuver in 1632, and Charles XII of Sweden did likewise with burning tar-barrels in 1770. Prior to World War I, navies had experimented with making smoke-screens by damping their boiler fires so that the fuel was incompletely burnt and the funnels gave forth great clouds of smoke. Laying smoke-screens between larger ships and the enemy became one of the standard functions of the destroyer. Smoke-screens were used even more in World War II than in its predecessor, notably in the battles of the River Plate and Cape Matapan. In the former, the British light cruisers *Achilles* and *Ajax* used smoke in attacking the *Graf Spee*; one would lay a screen, and the other would dash through it to fire several 6-inch salvoes, then back out of sight before the German ship could get her slower firing 11-inch guns on the target.

On land, smoke was used a little in the opening months of World War I, mostly by setting haystacks afire and such improvised means. Regular smoke shells came into use in 1916 and thereafter became more and more important. After the war, experiments were performed with spraying titanium tetrachloride and other substances from airplanes to lay smoke curtains—a military development that found civilian application in the art of sky-writing.

Smoke was used on an enormous scale in World War II. The U. S. Armed Forces developed generators that sent up great clouds of "smoke," (really a mist of oil droplets), which were used in such operations as crossing the Rhine in the spring of 1945 and capturing Japanese-held islands in the Pacific.

A thousand years after the Byzantines had routed their enemies with Greek fire, the Germans re-introduced the flame-thrower (German, *Flammenwerfer*) in World War I. This device consisted of a tank containing a petroleum mixture of about the consistency of kerosene, a flask of compressed nitrogen to expel the liquid from the container, and the necessary tubing, valves, and igniter. In the earlier models a soldier carried the apparatus on his back, and stood to be burned if a bullet punctured the fuel tank. Although the weapon was useful in getting at enemies holed up in a dugout where they could not be reached by explosives, it was rather ineffective because its range was only 15 or 20 yards and nine-tenths of the fuel burned up before reaching the target.

In World War II, however, U. S. scientists found that by thickening the oil almost to a jelly with aluminum oleate and other substances, they could make flame-throwers much more effective. The range and accuracy were increased, and 90% of the fuel reached the target instead of burning up prematurely. Flame-throwing tanks mounting a large, high-pressure apparatus, used in the invasion of Peleliu in the Pacific and elsewhere, could burn up anything combustible within a hundred yards.

### Poison Gas

Gas, like smoke, has been used since ancient times. Thucydides reported two cases in the Peloponnesian War of the use of burning sulphur fumes in sieges, but poison gas did not become important until World War I. Lethal gases were outlawed by the International Peace Convention at the Hague in 1899. However, within the first year of World War I many of the provisions of this treaty were broken, mostly by Germany, and in April of 1915 the Germans launched two attacks with chlorine gas released from containers in the front-line trenches and blown to Allied positions by a favorable wind. While the first attack sent French colonial troops into shrieking flight, the second had less effect, for the Canadians on whom it was employed rallied and contained the German attack despite their casualties.

At first the victim of a gas attack had no protection other than a handkerchief wetted with whatever liquid was available and held to the nose. Soon, however, the belligerents all provided their troops with gas-masks or respirators. These contained filters to keep out smokes and absorb the true gases, since a "poison gas" may be either a true gas, the vapor of a volatile liquid, or a fine smoke. The usual filter material was powdered charcoal, since charcoal, like platinum, has the power of absorption. That is, certain gases cling to its surface in a dense film. Gases include *lachrymators* or tear-gases, *suffocants* or lung-irritants, *vesicants* or blisterers, and *sternutators* or sneezing-gases.

While many gases were tried in World War I, most turned out to be impractical. For instance, hydrocyanic acid ("prussic acid") is one of the fastest killers known, but because of its low density it rises and blows away before it has a chance to do much harm. Other gases turned out to be too expensive, or too hard to make in quantity, or they were destroyed by the explosion of the gas-shell, or they decomposed on contact with water, and so forth.

Only two gases came near to meeting all the requirements: phosgene (carbonyl chloride, a suffocant) and mustard gas (dichloroethyl sulphide, a liquid vesicant). Phosgene, while deadly if inhaled, could be guarded against by a good mask, though by mixing phosgene with a sternutator it was sometimes possible to make the enemy remove his mask to sneeze. Mustard, while seldom fatal, was a great incapacitator, as it blisters any part of the body it touches, and a severe dose might blind. Gas-shells, which did not require a favoring wind, soon replaced stationary gas-tanks.

In the years following World War I persons agitating against war and militarism made the public's flesh creep with tales of wiping out whole cities in the next war with a single bomb containing a new and deadlier gas. The unfamiliarity and stealth of poison gas made it more repugnant to most people than more familiar weapons, so that gas warfare, like the crossbow and gunpowder before it, was denounced as inhumane. In 1925 the Genova Protocol forbade gas warfare among the nations, though the United States and Japan refused to ratify this treaty.

Actually both the effectiveness and the cruelty of gas were much exaggerated. In World War I, among well-trained troops a gas-attack would not produce more than 2% casualties, and of these only a small proportion was fatal, and nearly all the rest recovered completely. Among the total British gas-casualties of that war only about 3.3% were fatal. Moreover gas rarely leaves a victim permanently disabled—certainly far less often than wounds from bullets and shells. While some gas-cases died years later from pulmonary diseases, there is no proof that they did so more often than other people. A war fought without explosives but with gas would be more humane than the other way round.

Nevertheless a horror of gas persisted with such effect that, although the Italians sprayed mustard gas on the unprotected Ethiopians and the Japanese experimented with gas on the Chinese, gas was not used at all in the major theaters of World War II. All the major powers, including the United States, made large quantities of gas just in case, and issued masks to their soldiers and to civilians in air-raid areas, but still gas was not used, though it would have saved many American casualties in the capture of Japanese-held islands like Tarawa. The United States and Britain forebore for fear of political repercussions at home, and Germany probably refrained for fear of retaliation, since having the weaker air force, she stood to lose more.

In addition, despite the prophets of doom, gases had improved but little since World War I. The only significant new gases were the nitrogen mustards, which though less effective in some ways than ordinary mustard, have the property of blinding the victim in small concentrations, temporarily or permanently depending upon the dose. Also gas warfare is less useful in mobile operations like those of World War II than in the static warfare of the previous great war. Finally, for gas attacks on large cities very large quantities would be needed, so that it was more damaging to drop an equivalent weight of high explosives and incendiaries, which destroyed property as well as harassed the populace.

Despite its shortcomings gas cannot be left out of account in planning for a future war, since it might prove decisive in a pinch. Nations continue to seek gases that will penetrate other countries' masks, and to provide their own soldiers with masks that will stop any gas the enemy might send against them.

# CHAPTER 12

# SIGHTING AND RANGING

## Early Gunsights

The early gunner had no sights. He merely squinted along the barrel of his cannon or arquebus (hand firearm) and guessed. Sights were first applied to sporting rifles in the form of a simple knob on top of the barrel near the muzzle. By the time of the American Revolution the rear sight, an open V-notch, had been added, and these sights enabled the colonists to gall the British who had not yet adopted sights, holding that the right way to fight was standing in neat rows and banging out volleys at such close range that sights were unnecessary. When the British captured a Morgan rifleman, complete with coonskin cap and sighted rifle, they took him to England and sent him on a tour of the island to give demonstrations of marksmanship as part of a recruiting drive. But the sight of the frontiersman's shooting convinced the alarmed British civilians that war with such dangerous savages was not for them.

The European powers finally became convinced of the need for sights early in the 19th century. Not without opposition, however. A British officer commanding Irish troops protested that if his men were given muskets with sights and taught to use them, there soon would not be a landlord left alive in Ireland.

In the late 19th century small-arm sights were improved by making the rear sight adjustable so that it could be raised for firing at longer ranges. In the 20th century sighting was further complicated by the combination sight of the modern rifled musket: an open sight for short ranges combined with an adjustable peep-sight for longer ranges, plus a lateral screw-adjustment for windage. And for snipers some nations provided rifles with telescopic sights—small telescopes with cross-hairs in the tube, bolted to the barrel of the gun.

Cannon sights, which came into general use early in the 19th century, were at first similar to small arm sights, except that they were usually mounted on the side of the gun barrel instead of on top. The development of recoil-absorbing mechanisms in the 1860's and 70's, along with rapid-firing breech loaders, made it possible for members of the gun crew to sight the gun continuously as it was loaded and fired, instead of having to roll it back to battery after each shot. To take advantage of this fact, guns were equipped with telescopic sights.

Although the telescopic sight goes back at least to 1857, when a British Army officer introduced it, it did not prove practical as long as it was mounted on the barrel because the shock of firing broke the lenses and the telescope. Therefore, it had to be removed from the gun for each round. About 1890, however, the sight was mounted on the non-recoiling part of the carriage. No longer did the gunner have to strain his eye trying to focus on a near and a distant object at the same time; all he had to do was keep his eye to the eyepiece and the cross-hairs on the target, which he could now do during firing because the carriage would no longer come leaping back. In the 20th century, sighting of cannon was further improved by providing two sighting telescopes, one on each side of the gun. Two gun-aimers, the pointer and trainer, sighted through these scopes and moved the gun vertically and horizontally respectively with crank mechanisms.

### Fire Control

Unless the gunner is shooting within stone-throwing range he cannot point his cannon directly at the target, because the projectile travels not in a straight line but in a paraboloid trajectory like a thrown baseball. In shooting with open sights at close ranges with a rifle one can make allowances for distance by showing more or less front sight in the notch of the rear sight, but for long range artillery fire such methods will not do because the gun barrel will be aiming at the sky. Therefore, sighting telescopes are pointed straight at the target, and the distance is determined by the angle between the line connecting the telescope and the target (the "line of sight") and the axis of the gun barrel.

Assuming that the gun and the target are at the same altitude above sea level, the gunnery officer knows that for every angle of elevation of the gun barrel the gun has a corresponding range. These angles and ranges are recorded on a table which the commander of the gun uses. If the target is higher or lower than the gun, additional corrections are necessary. For ordinary guns the maximum range occurs when the angle between gun-axis and the horizontal (the "elevation" or "quadrant angle") is between 43-½ and 45 degrees, though for very long range guns the quadrant angle of maximum range may be above 45 degrees.

Prior to World War I few guns were built to be fired at elevation of more than 10 or 15 degrees, because they were not considered accurate enough to make longer range fire worth while. However, battle ranges have increased from 100 yards in the American Civil War to 5,000 in the Russo-Japanese War to 20,000 yards in World War I to 30,000 to 40,000 yards at present, though over 30,000 yards the natural dispersion of shells in flight makes such fire too inaccurate to be profitable against so small a target as a ship. Now most guns can fire at elevations of maximum range, or, if they are for anti-aircraft use, even higher.

How far is the target? The enemy will hardly let one measure the distance with a surveyor's tape. On land one can scale off the distance at least approximately on a good contour map, and then correct one's aim by observing whether the first shots are over or short. In the early 20th century the increasing range of guns made it impractical to "spot" ranges in this manner from the gun itself; instead, an observer near the target sent back word between shots of how the shells were falling. In World War I these observers sat in captive balloons and telephoned their observations to the ground.

At sea optical range-finders came in about 1898, the first type being the stadimeter, a wide-angle telescope with index marks etched in one of the lenses. Knowing the length of a hostile ship, one could look at it through the instrument, observe the angle that the hull subtended, and deduce the range. While this method is still used to some extent in submarine periscopes, for surface gunnery it has been superseded by range-finders based on triangulation.

Triangulation is the principle by which one unconsciously estimates distances with one's eyes. Knowing the base of a right triangle and the angle made by two non-perpendicular sides, one can compute the altitude. Most range-finders have a base of 3 to 30 feet, with lenses (usually in the form of many-sided prisms) at the ends and the eyepiece or pieces in the middle. Range-finders for field artillery are of moderate size because they must be portable, a one meter base finder being common. Fixed coast defense batteries, on the other hand, use separate observers hundreds of yards apart as the lenses of their system, thus attaining extreme accuracy.

The first type of triangulation range-finder was the coincidence type, generally employed in World War I and still used to some extent. In the coincidence range-finder the observer looks with one eye and sees a split picture, the upper half displaced horizontally from the lower, and by turning a knob he brings the two halves of the picture into coincidence. In the later stereoscopic range-finder, the observer looks with both eyes and focuses them upon a set of "reticle marks" which he sees, and by turning the knob he brings the image of the target to the same apparent distance from his own eyes as the marks. This type of range-finder has largely replaced the coincidence finder.

Simple range-finding is not adequate for naval gunnery, since both gun and target are moving, and when a number of guns are firing the crew of one gun cannot correct their fire by spotting because they cannot tell which are their own splashes. Furthermore, long-range shooting requires corrections for wind, barometric pressure, and other factors that are not practical for each gun crew to make separately.

To overcome these obstacles, director fire was adopted in the decade preceding World War I by the navies of Great Britain (introduced by Admiral Sir Percy Scott), Germany, and then the other powers. This meant that one man or group of men in the upper part of the ship controlled the fire of all the guns of one battery. Originally the gunnery officer merely signalled the range to the gun crews, who continued to load and fire as before. Then the gunnery officer signalled by a buzzer to the gun-pointers when to fire. Then about 1910 the director proper appeared, a kind of master gun or gun-sighting apparatus which was kept on the target and whose movements the other guns duplicated. The gunnery officer ran the director and actually fired the guns by a master electric key.

A modern director is a structure looking like a small turret without guns, mounted on the superstructure or atop a mast. The director crew keep their sights on the target, and the position of the director is transmitted electrically to the turrets and indicated by dials and pointers. The turret crews follow the movements of the director with their turret controls, trying to match the pointers indicating the train and elevation of their own guns with those indicating the aim of the director. In a more recent system the director crew directly controls the movements of the guns.

In addition a crew in the plotting room of the ship, below the armored deck, takes the data sent down by the director and other observers and by means of calculating instruments figures the corrections for the speed and direction of the ship and the target, windage, barometric pressure, rotation of the earth, wear on the gun barrel, temperature of the powder, and anything else that might significantly affect the flight of the shells. They then transmit these corrections to the guns. A large modern battleship may have two main battery directors, several auxiliary directors in the fire control tower and the turrets, two plotting rooms, four anti-aircraft battery directors, two main range-finders on the superstructure and another in each turret, projecting from the upper rear corners like a pair of ears. Any main battery director can run any or all of the main battery guns, and likewise with the anti-aircraft directors and AA guns.

Ships of other types have less elaborate installations. Electrical circuits are in duplicate, and if these are destroyed entirely the director communicates with the plotting room and the turrets by voice tubes, signals, or even by messenger. In addition, following World War I most cruisers and battleships were equipped with small float seaplanes that could be catapulted off to spot the fall of shells by radio.

## Radar

The biggest recent change in methods of sighting and ranging is that due to the invention of radar, which like most great recent technical developments was the produce of many minds in many laboratories. Several of the pioneers in electrical engineering like Hertz, Marconi, and Tesla noticed that electromagnetic waves intermediate in length between short radio waves and infra-red radiations could be directed like light beams and reflected from obstacles. Karl

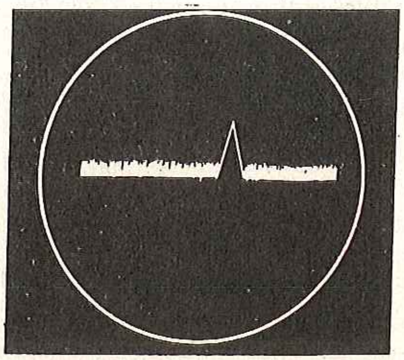

Figure 11.—**Radar.** The "R" oscilloscope presentation.

F. Braun invented an improved cathode ray tube wherein the stream of electrons could be bent by electromagnetic fields and the point of its impact against the end of the tube made visible by coating the glass with a fluorescent material. From this the radar oscilloscope was developed. And a detecting instrument similar to radar was "invented" in the early 1920's by Edgar Rice Burroughs for one of his Martian novels.

During the 1930's the governments of Great Britain, the United States, and Germany fostered experiments to create a reliable detector that would locate airplanes not visible to the naked eye. The sound-detectors that had been used for the purpose had become almost useless when the increasing speed of airplanes made it necessary for the gunners to lead the direction indicated by the detector by 20 degrees or more. Although all three of the countries named were active in the development of radar, Great Britain perhaps led the others by a small margin, since she had the most to fear from air attacks.

By the outbreak of World War II Britain was encircled with radar stations—"radiolocation" they called them, "radar" (for "radio detection and ranging") having been named subsequently by an American naval officer. These devices sent out pulses of electromagnetic waves, detected the echo, and showed the distance of the object producing the echo on the oscilloscope. They defeated the German bombing campaign against Britain in the fall of 1940 by enabling the RAF to throw its modest forces against the Germans whenever they appeared, without wearing themselves out by continuous patrol. Similar apparatus was installed experimentally in Hawaii, and the crew of one radar set actually detected the approach of Japanese airplanes for the Pearl Harbor raid, the greatest defeat ever suffered by American arms. In accordance with the over-confident and unwarlike spirit of most Americans at the time, however, this crew assumed that the approaching air fleet must be American and disregarded the warning.

Early radar sets indicated the distance to the target only by means of a jog or hump in the luminous line that appeared on the oscilloscope —a "pip" or "blip." Later sets indicated direction as well; in the Plan Position Indicator (PPI) the antenna rotated so as to give a veritable map of the surrounding area on the oscilloscope. Ships blossomed out with masses of antennae called "bedsprings" and other names from their appearance, and radar was installed

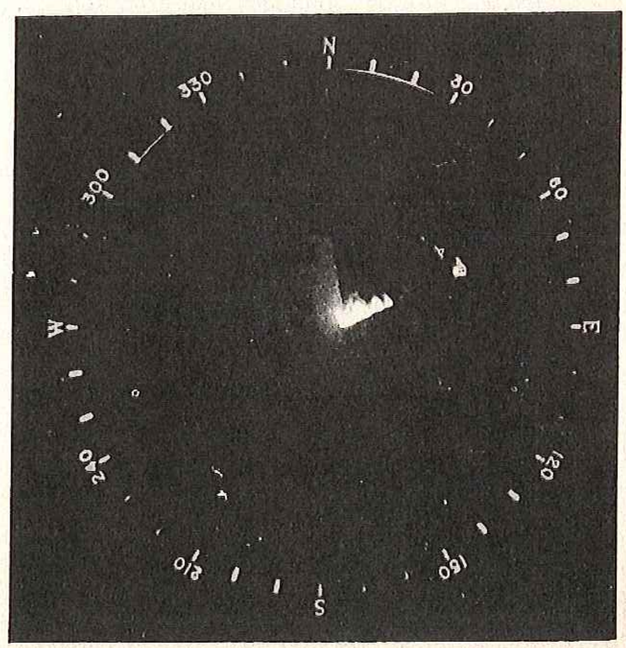


Figure 12.—**Radar.** The Plan Position Indicator oscilloscope shows both bearing and range.

in airplanes. The resonant cavity magnetron, a British invention, made possible the use of micro-waves, that is, waves 3 to 10 centimeters long, in radar. While short-wave radar had less range than the long-wave radar, it gave better definition at shorter distances and thus enabled the operators to pick up submarine periscopes. A failure of German technology was that the Germans never made an effective radar of this type.

Radar was soon integrated with fire control, since it provided a surer method of determining ranges than optical instruments and worked regardless of night, fog, or long ranges. In later radar sets the operator could watch the shells of his ship speeding through the air and exploding, and detect shorts and overs by the splashes. As an example of the clarity of radar observation, in the Surigao Strait night action, when some of the Japanese ships had been set afire by shells and torpedoes, the captain of the leading United States destroyer called down from the bridge to his commodore, who was watching the radar 'scopes: "Hey, come up here for the sight of your life!" To which the commodore replied: "No thanks; I can see it better right here!"

The use of radar and the swiftness of modern naval engagements, especially sea-air battles, have brought into existence a new organization, the CIC or combat information center, on warships. The CIC filters out the multitude of items of information that come in over the radar, the range-finders, from the spotting planes, and so on, and reduce them to manageable proportions to enable the commanding officer to make intelligent decisions. It is in effect a sort of synthetic brain with the radar and other instruments as sensory organs, the operators as the lower brain centers, and the captain as the cortex or deciding part of the brain.

By the end of World War II small radars were being installed on turrets, gun mounts, submarines, and airplanes. Elaborate anti-radar measures were in use, such as dropping showers of strips of aluminum foil ("window" or "chaff") from attacking airplanes to confuse the radar 'scopes, and setting up radar decoys like buoys with kite-like aluminum structures that would show a pip like that of a ship. Altogether, next to the atomic bomb, radar was perhaps the most important single device to come out of World War II, and in any future war it will undoubtedly play an even larger part.

## THE NAVY'S FUTURE WEAPONS

The previous twelve chapters have discussed the weapons which man has known and generally employed up through World War II. As in the past, each new conflict seems to give added impetus to discovering and improving new weapons.

Ideas that were in the experimental stage after the first World War became operating equipment in World War II. In a similar manner, new ideas and potential weapons for offense and defense have emerged from this past war. Some, such as the atomic bomb and the rocket, have already made their initial appearance; others are still in the experimental stage.

Constant research and experimentation are now being carried on in atomic weapons, guided missiles and other weapons to improve and exploit their potentialities. Since many of these are in process of development, any discussion of them now would be premature.

When these experiments result in actual operating equipment and techniques, it is intended that additional chapters concerning them and their relation to naval warfare will be added as security permits.