# AMERICA'S USE OF SEA MINES

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# FOREWORD

By Ralph Decker Bennett, Ph. D.
Director of Research of the Martin Company

**(Formerly Director of Research for the Naval Ordnance Laboratory and later its Technical Director 1940–54)**

This volume is devoted to the history and use by the United States of one of the Navy's least spectacular and most effective weapons. The effectiveness of the submarine mine has not decreased with the coming of the space age. So long as cargo ships cross the sea, this unspectacular weapon will remain a major factor in control of the approaches to harbors, and the shallow straits between seas.

Robert Duncan has devoted most of his adult life to the generation and augmentation of competence in the application of growing science to the design, production, and use of mines for the U.S. Navy. He joined the staff of the Naval Ordnance Laboratory before it was known by that name, but in time to capitalize on the experience of the Navy with mines in World War I. He provided the technical leadership which was an important factor in keeping the art and science of mining alive in the Navy in the days of the depression. By so doing, he provided a basis for a hundredfold expansion of the Navy's effort previous to and during World War II.

The hundreds of technical people who had the privilege of joining in this effort under Dr. Duncan's leadership will be happy to see this accurate and factual record of achievement. The experience recorded between these covers will serve as a guide to those still engaged in the development of this type of weapon, and the achievements made during World War II will be an inspiration to any who might be responsible for again expanding our national effort in mining, should the occasion arise.

27 September 1961

# AMERICA'S USE OF SEA MINES

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(Retired 1956)

United States Naval Ordnance Laboratory
White Oak, Silver Spring, Maryland

January 1962

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## Illustrations

# PREFACE

The sea mine is a weapon which lies in wait for its victim. Planted under the surface of the water, possibly hidden in the mud and sand on the bottom, it may remain there for weeks or months until a vessel comes within its lethal range. The use of the term "sea mine" was first applied to vessels, loaded with explosives, which were built for special destructive missions. Currently, however, the term is applied only to underwater charges of explosives which are not propelled toward a specific target or manually guided once submerged in the water.

Used by the Confederates against the Federals in the Civil War, mines sank a goodly number of Federal vessels; used by the United States during World War I, they, in large measure, restricted German submarines to the North Sea; and, in World War II they starved the economy of Japan. It therefore seems desirable to make a study of how this country has used this weapon in the wars in which it has been involved. In doing this the author has tried to tell the story entirely objectively and has made every effort to avoid propagandizing, although he has spent a good many years of his life working on problems concerned with mine development.

Whenever the use of a new weapon, or of an old weapon used in a new way, is proposed, there is expected to be a difference of opinion between the enthusiastic supporters of the weapon and the users, particularly if their needed facilities are limited. In World War I this discussion occurred between the U.S. Navy and the British Navy. The British believed that the U.S. Navy was overly confident of what its newly designed mine would do. In this they were correct, but yet the mine as used was definitely worthwhile.

In World War II, the argument was between the U.S. mining enthusiasts and the U.S. war command, who were operating with limited facilities. The latter naturally had to be shown that mines would perform as the mine designers claimed they would. At the same time the mine enthusiasts believed that offensive mining should have been adopted much sooner, that mine design and mine production were inexcusably slow and that much effort had been very inefficiently applied.

There was some basis for these criticisms, but the mine enthusiasts failed to realize that the war command would naturally choose to use weapons that had proved themselves rather than offensive mines, which up until World War II, had been given very little opportunity in U.S. warfare to prove their value. The enthusiasts also had only a superficial knowledge of the problems which had to be solved by naval bureaus in determining the type of mines to be designed, and by a development laboratory which had but limited facilities and which was staffed by engineers and scientists most of whom had no experience in mine design and mine warfare.

This country was very poorly prepared for mine warfare when World War II started in Europe. As for an influence-fired mine and mine-laying aircraft, she was totally unprepared. By the time mine-laying aircraft became available from bases close enough to Japan, mines were available for use. There is no doubt that their design could have been improved, and that more could have been used had more been available, but at least their use practically put Japan on a starvation basis.

The author has expressly avoided naming the many individuals who contributed to the U.S. mining programs of World War I and World War II. Records available to him are not sufficient to insure that all those who played a prominent part would be included. However, over the years there are a few mine proponents who should be listed. During World War I, Capt. L. P. Fullinwider bore the brunt of the responsibility for the designing, testing, and procurement of the Northern Barrage mines, while Rear Adm. Joseph Strauss commanded the mine-laying squadron.

Between World War I and World War II Comdr. James B. Glennon (now Captain—retired) kept the interest in mine warfare alive. He spent several years in charge of the Mine Desk at the Bureau of Ordnance, he commanded a mine-laying destroyer, he was Officer-in-Charge of the Yorktown Naval Mine Depot, and from 1938 to 1943 was the Officer-in-Charge of the Naval Ordnance Laboratory, which was responsible for the development of mining material. He originated many improvements in mining material and continuously pointed out the effectiveness of mine warfare. During his administration of the Naval Ordnance Laboratory, most, if not all, of the new mines used in the Pacific Ocean were largely designed.

At the Naval Ordnance Laboratory, Dr. Ralph D. Bennett, a Lieutenant Commander, USNR (now a Captain, USNR), on leave from the Massachusetts Institute of Technology took a very active interest in the laboratory and its problems. He made several visits to universities and to industrial research laboratories to publicize the laboratory's needs in personnel and acted as its personnel officer in staffing it with high grade physicists and engineers. Later he became its Director of Research and, after his return to civilian life, its Technical Director.

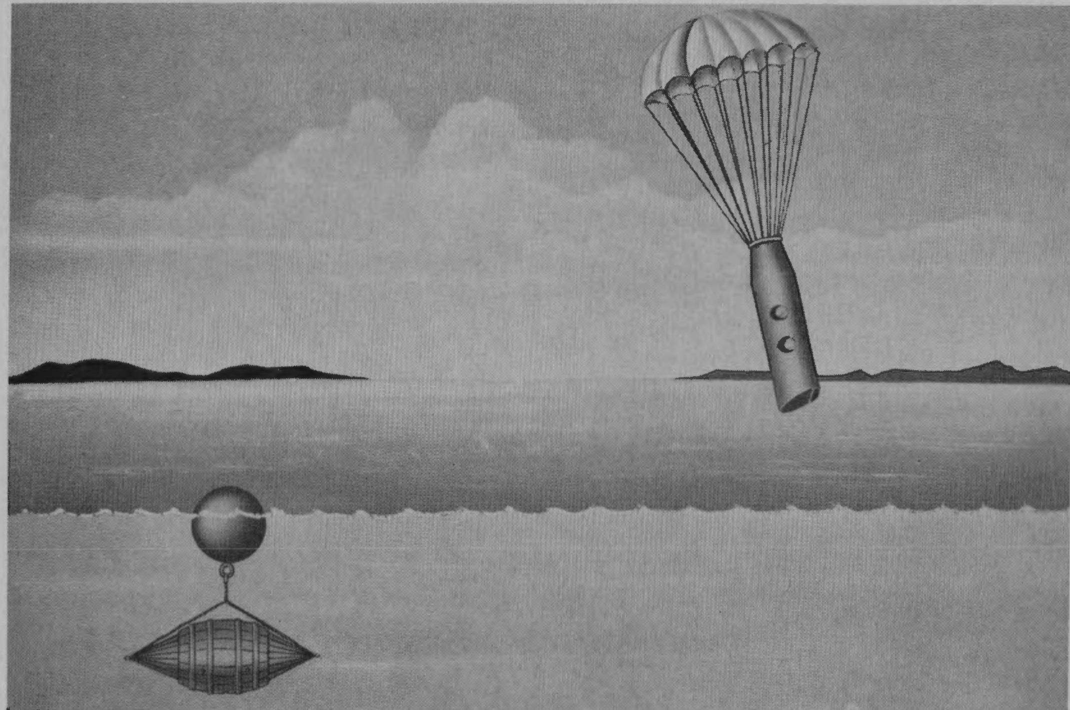
Dr. Ellis A. Johnson, on leave of absence from the Carnegie Institution, very effectively guided the study of the magnetic fields of ships and of methods of reducing them in nearby waters. Later, as a Lieutenant Commander, USNR, he served in the Navy Department and in the field as a mine liaison officer, where he was a very active proponent of the wide use of mines. He championed the proposal to attempt to starve Japan's economy by aircraft-laid minefields. When General LeMay was directed to carry out this project, Commander Johnson became his Mining Officer, and he and his staff were largely responsible for the location of minefields and the choice of mine types and their modification when necessary.

In the war command area, that is in the Chief of Naval Operations, Capt. C. L. Miller, as head of the Mine Warfare Section, actively encouraged the use of mines and served as a nucleus for the solution of many mine warfare problems.

Many, many others should be included as helping in the mining program of both World Wars. The naval officers at the Navy Department and at the mine depots and loading plants, who guided the use of mines and the production, handling and shipment of mine material, the officers and crews of surface and submarine mine layers, the pilots and crews of mine-laying aircraft, the technicians at the Naval Ordnance Laboratory and in the field, all cooperated to make mine warfare a success. They all gave their best to the project and many gave their lives.

The author wishes to take this opportunity to express his sincere appreciation of those who helped and encouraged him from time to time in the preparation of this book. Dr. Bennett, the former Technical Director, suggested that I attempt to sum up the use of mines by this country. Dr. Hartmann, the present Technical Director, continued and encouraged the assignment. Capt. J. S. Cowie, C.B.E., R.N. (Ret.) from the Royal Navy, reviewed the book and made some constructive suggestions.

In addition, the book was reviewed and modifications suggested by members of the Naval Ordnance Laboratory staff, the book was typed and retyped by NOL stenographers, the figures were prepared by the NOL editorial and photographic staffs. Mrs. Virginia Bloss has worked closely with the author and Mrs. Bertha Carter made a complete ozalid copy of the book for preliminary copies.



BUSHNELL'S KEG
1777

MINE MARK 25
1945

**Frontispiece.—U.S. mine development, 1777 to 1945.**

## CHAPTER I

# THE "BATTLE OF THE KEGS" JANUARY 1778

**A Ballad on**
**The Battle of the Kegs**
**by the**
**Honorable Francis Hopkinson**

Gallants attend, and hear a friend
Troll forth harmonious ditty;
Strange things I'll tell what late befell
In Philadelphia city.

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

As in amaze he stood to gaze,
(The truth can't be denied, sir,)
He spied a score of kegs or more
Come floating down the tide, sir.

A sailor, too, in jerking blue,
The strange appearance viewing,
First d***d his eyes, in great surprise,
Then said, "Some mischief's brewing.

"These kegs, I'm told the rebels hold
Packed up like pickled herring,
And they've come down t'attack the town
In this new way of ferrying."

The soldier flew, the sailor too,
And scared almost to death, sir,
Wore out their shoes to spread the news,
And ran 'till out of breath, sir.

Now up and down, throughout the town,
Most frantic scenes were acted
And some ran here, and others there,
Like men almost distracted.

Some "Fire" cried, which some denied,
But said the earth had quaked,
And girls and boys, with hideous noise,
Ran through the streets half naked.

Sir William, he, snug as a flea,
Lay all this time a-snoring,
Now dreamed of home, as he lay warm,
In bed with Mrs. Loring.

Now in a fright he starts upright,
Awaked by such a clatter,
He rubs his eyes, and boldly cries,
"For God's sake, what's the matter?"

At his bedside, he then espied
Sir Erskine, at command, sir,
Upon one foot he had one boot,
And t'other in his hand, sir.

"Arise, arise!" Sir Erskine cries,
"The rebels—more's the pity,
Without a boat are all afloat,
And ranged before the city.

"The motley crew, in vessels new,
With Satan for their guide, sir,
Packed up in bags, or wooden kegs,
Come drifting down the tide, sir.

"Therefore prepare for bloody war,
These kegs must all be routed,
Or surely we despised shall be
And British courage doubted."

The royal band now ready stand
All ranged in dread array, sir
With stomach stout to see it out
And make a bloody day, sir.

The cannon roar from shore to shore,
The small arms loud did rattle,
Since wars began, I'm sure no man
E'er saw so strange a battle.

The kegs, 'tis said, though strongly made,
Of rebel staves and hoops, sir,
Could not oppose their powerful foes,
The conquering British troops, sir.

From morn 'till night, these men of might
Displayed amazing courage,
And when the sun was fairly down
Retired to sup their pottage.

A hundred men, with each a pen
Or more, upon my word, sir,
It is most true, would be too few,
Their valor to record, sir.

Such feats they did perform that day,
Against those wicked kegs, sir,
That years to come, if they get home,
They'll make their boasts and brags, sir.

No, this is not to be a volume of poetry, but since the Honorable Francis Hopkinson,[1] a signer of the Declaration of Independence, gave us this facetious ballad concerning America's first use of mines, it seems appropriate to place it at the beginning of a book on America's use of this weapon.

David Bushnell had been working on underwater explosions while a student at Yale. He had found that gunpowder could be exploded underwater, and was sure that the underwater explosion of a charge of gunpowder against the bottom of one of the sea vessels of that date would be very serious. In 1777 a part of the British fleet was stationed at the Delaware River off Philadelphia, and Bushnell was authorized by General Washington to attempt to destroy some of them by the use of his newly invented sea mine (usually referred to as "torpedo" by Bushnell). The mine consisted of a charge of powder in a keg which was supported a few feet underwater by a float on the surface. In the keg with the powder was assembled a gun lock adjusted so that a light shock would release the hammer and fire the powder. The mine apparently appeared somewhat as shown in the frontispiece.

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[1] *"During the Revolutionary period, the Honorable Francis Hopkinson distinguished himself by satirical and political writings which attained such popularity that it has been said that few pens affected more than Hopkinson's in educating the American people for independence."—The American Encyclopedia. After the Revolution, he was appointed U.S. District Judge for Pennsylvania by President Washington.*

The story, as told by David Bushnell himself before the American Philosophical Society in 1799, is quoted below:

"After this (a description of his submarine, The Turtle) I fixed several kegs under water, charged with powder, to explode upon touching anything as they floated along with the tide: I set them afloat in the Delaware, above the English shipping at Philadelphia, in December, 1777. I was unacquainted with the river, and obliged to depend upon a gentleman very imperfectly acquainted with that part of it, as I afterwards found. We went as near the shipping as he durst venture; I believe the darkness of the night greatly deceived him, as it did me. We set them adrift, to fall with the ebb upon the shipping. Had we been within sixty rods, I believe they must have fallen in with them immediately, as I designed; but, as I afterwards found, they were set adrift much too far distant, and did not arrive until, after being detained some time by frost, they advanced in the day time, in a dispersed situation and under great disadvantages. One of them blew up a boat, with several persons in it who imprudently handled it too freely, and thus gave the British the alarm which brought on the 'Battle of the Kegs'."

Unfortunately, none of the British ships was damaged, but according to "The New Jersey Gazette" of January 21, 1778, the single explosion referred to by Bushnell did cause considerable excitement among the British officers and crew. The article, also written by the Honorable Francis Hopkinson, is quoted below:

"Philadelphia has been entertained with a most astonishing instance of the activity, bravery, and military skill of the Royal Navy of Great Britain. The affair is somewhat particular, and deserves notice. Some time last week, two boys observed a keg of a singular construction, floating in the river opposite to the city; they got into a small boat, and attempting to take up the keg, it burst with a great explosion, and blew up the unfortunate boys. Yesterday, several kegs of a like construction made their appearance. An alarm was immediately spread through the city; various reports prevailed, filling the city and the royal troops with consternation. Some reported that the kegs were filled with armed rebels, who were to issue forth in the dead of night, as the Grecians did of old from their wooden horse at the seige of Troy, and take the city by surprise, asserting that they had seen the points of their bayonets through the bungholes of the kegs. Others said they were charged with the most inveterate combustibles, to be kindled by secret machinery, and setting the whole Delaware in flames, were to consume all the shipping in the harbor; whilst others asserted that they were constructed by art magic, would of themselves ascend the wharves in the night time, and roll all flaming through the streets of the city, destroying everything in their way. Be this as it may, certain it is that the shipping in the harbor, and all the wharves in the city were fully manned, the battle begun, and it was surprising to behold the incessant blaze that was kept up against the enemy, the kegs. Both officers and men exhibited the most unparalleled skill and bravery on the occasion; whilst the citizens stood gazing as solemn witnesses of their prowess. From the Roebuck and other ships of war, whole broadsides were poured into the Delaware. In short, not a wandering chip, stick or drift log, but felt the vigor of the British arms. The action began about sunrise, and would have been concluded with a great success by noon, had not an old market woman coming down the river with provisions, unfortunately let a small keg of butter fall overboard, which (as it was then ebb) floated down to the scene of action. At sight of this unexpected reinforcement of the enemy, the battle was renewed with fresh fury, and the firing was incessant 'till the evening closed the affair. The kegs were either totally demolished or obliged to fly, as none of them have shown their heads since. It is said His Excellency, Lord Howe, has despatched a swift sailing packet with an account of this victory to the court of London. In a word, Monday, the fifth of January 1778, must ever be distinguished in history for the memorable BATTLE OF THE KEGS."

Other references indicate that the mines were released about Christmas Day in 1777, although they did not reach Philadelphia until January 5, 1778, indicating several days' delay because of the ice in the river. Also because of this ice the British ships had been brought in close to shore so the group of mines largely bypassed them.

Another side of the story appeared in the Pennsylvania Ledger of February 11, 1778, and is quoted to show the difference between a "liberal" and a "conservative" paper of that date. The Ledger said:

"The town of Philadelphia not being as fully acquainted with the subject of the ditti taken from a Burlington paper, as the ingenious author would have his readers believe them to be, it may be necessary to relate to them the fact. At the time it happened it was so trifling as not to be thought worthy of notice in this paper; and we do not doubt but our readers will allow this letter writer full credit for the fertility of his invention. The case was, that on the fifth of January last, a barrel of an odd appearance came floating down the Delaware, opposite the town, and attracted the attention of some boys, who went in pursuit of it, and had scarcely got possession of it when it blew up and either killed or injured one or more of them. So far the matter was serious, and the fellow who invented the mischief may quiet his conscience of the murder or injury done the lads, as well as he can. Some days after, a few others of much the same appearance, and some in the form of buoys, came floating in like manner, and a few guns were, we believe, fired at them from some of the transports lying along the wharves. Other than this no notice was taken of them, except, indeed, by our author, whose imagination, perhaps as fertile as his invention, realized to himself in the frenzy of his enthusiasm the matters he has set forth."

The sea mines used by Bushnell were definitely contact drifting mines in accordance with the definitions established in chapter II, and differed not widely from contact drifting mines at present in the U.S. mine armory. Their use in the Battle of the Kegs is believed to be the first use of sea mines (as the term is currently used) in the world, as the author has found no record of their use at an earlier date.

Apparently Bushnell did not make any further use of this type of mine during the Revolutionary War but he did attempt in many ways to damage British ships with subaqueous explosions, some before and some after the Battle of the Kegs. He designed and built a one-man-controlled and one-man-powered submarine, The Turtle, with which Ezra Lee tried to secure a timed explosive charge to the British man-of-war *Eagle* anchored off Governor's Island in 1776, but was not successful.

In 1777, he made an attempt to destroy the British frigate *Cerberous* up near New London by drawing an explosive machine against her by means of a towing line. The line was picked up by a sailor on a schooner anchored behind the *Cerberous* and the machine brought on deck where it exploded, demolishing the schooner.

Bushnell was encouraged in his efforts by Governor Trumbull of Connecticut, who helped finance him in his development work. In 1779, General Washington, in accordance with a recommendation from Governor Trumbull, made Bushnell a Captain-Lieutenant in the Corps of Sappers and Miners and in 1881 he was promoted to Captain.

After the war, he was discouraged because of the failure of his efforts and also because the American Government had in no wise rewarded him. He went to France for several years and then returned to Georgia as Dr. Bush, where he accepted the headship of a "most respectable school." Later he gave this up and became a successful physician. Only his very close friends knew that Dr. Bush was the Bushnell of the Revolutionary War until his last will was published.

## CHAPTER II

# MINES OF TODAY

Before we proceed further in studying how the United States developed the "kegs" of the "Battle of the Kegs" into weapons of war and how it has used them in warfare, a few basic definitions should be established.

The term "sea mine" was applied in the 16th century to vessels loaded with explosives which were sent on special destruction projects, either against an enemy fleet or against shore fortifications. These vessels were sometimes manned by small crews who were supposed to escape after the vessel had been finally located or the vessels were released at points where it was hoped the ocean currents or prevailing winds would bring them close to the items to be destroyed.

Bushnell's "kegs" were quite different weapons. They were particularly designed to attack a vessel below the waterline and to explode automatically on contact. Bushnell, in fact, called them "torpedoes," which term continued to be used in the United States up through the Civil War to include most all types of explosive charges delivered without the use of a gun.

There were harpoon torpedoes in which a harpoon, to whose line an explosive charge was connected, was driven into a ship by gunfire. It was hoped that the charge would contact the ship either through the tide or by the ship's motion. The Confederates established a "Torpedo Bureau" to study the use of underwater charges, and there were "spar torpedoes," which were explosive charges carried on spars pointing out from the bows of small vessels.

However, as of today, the term torpedo has been limited to a crewless undersea craft, self-propelled and self-steered at a specific target, carrying an explosive charge and arranged to detonate in contact with, or in close proximity to, its target, while a mine, or sea mine, refers only to an underwater explosive charge brought into contact with, or in proximity to, the target, by the random motion of the target or of the mine.

Of course, weapons have been and will continue to be developed which will fit neither of the definitions for torpedoes or for mines. Were Bushnell's explosive charges, which he hoped to secure to the hulls of ships by use of his "Turtle," "mines" or "torpedoes"? Such charges were still used by the British in World War II and were called "limpets." Since they were manually controlled until they were located on specific targets they could not fall into the class of mines as defined above.

As pointed out in chapter I, the first known sea mine (in accordance with current use) was a drifting mine consisting of a keg loaded with gunpowder hanging from a surface float. Other drifting mines have been used in which the charge case itself is of neutral buoyancy and a mechanism is provided to hold the mine at approximately a constant depth. The significant point is that these drifting mines are not anchored and are free to move with the water current.

Most mines used up through World War II, however, were buoyant Moored Mines. They are buoyant because each case with its charge and fittings weighs less than the water which it displaces, and are moored because each case is held in place, usually some distance below the surface, by an anchor on the bottom. Theoretically, such a mine can be used in any depth of water up to that in which the mine's buoyancy can support the weight in water of an appropriate mooring line.

Other mines are designed to have a total weight considerably greater than the weight of the water displaced and these lie on the bottom. These are called Bottom Mines, and are effective for surface ships only when planted in water shallow enough so that the explosion will do serious damage to the ship. These were used but little until World War II, but during that war many thousands were laid.

Therefore, from the standpoint of the position maintained in the water, we have the three types:

Drifting mines—free to move.

Moored mines—free to move within the limits permitted by the mooring rope and anchor.

Bottom mines—Lying on the bottom and not expected to move at all.

However, mines also differ by the way they are designed to be laid. Most mines have been laid from surface craft and usually are carried on boxlike anchors, or trucks, with wheels which ride on special tracks provided. Beginning with World War I submarines were designed for laying mines, and in World War II mines were laid in great numbers from airplanes. The mines to be used from each of these types of mine-laying craft were specially designed for that use. Beyond this in World War II mines were sometimes modified to be laid from PT boats which could not use the mines designed for use from other craft, and in World War I camels served as mine layers along the Suez Canal, but these types of planting will not be considered herein as typical.

Therefore, considering the planting craft, mines are distinguished as:

Surface laid mines—For laying from surface vessels.

Aircraft laid mines—For laying from aircraft.

Submarine laid mines—For laying from submarines.

Mines may also be distinguished by the phenomena utilized to cause their explosion. Most mines have been designed to be fired by contact with a ship. Up until the beginning of World War I all such mines, so far as the author knows, required the case of each mine to actually come into physical contact with the ship. During World War I the U.S. Navy developed a mine in which contact with the case itself was not required, but the ship did have to make physical contact with a copper wire attached to the case itself, so it was in fact a Contact mine.

Also during the First World War attempts were made to design mines which would be fired by the approach of the ship but which would not require actual contact. A steel ship creates considerable change in the earth's magnetic field in the vicinity of the ship, also the noises made by the ship's machinery and propellers are transmitted directly into the water, so it appeared that both magnetic and acoustic detecting devices might be utilized to explode mines. Effective use of these, and other influences, was, however, not made materially until World War II, when thousands of mines so designed were laid. Such mines are known as Influence Mines. Both contact and influence mines are often referred to as automatic mines.

For mines planted within a few miles of shore, an electrical system can be arranged so that the mine's firing device can be wholly controlled by a shore station. The device may be completely neutralized, or any one or more mines can be fired, or a firing device in the mine may be placed temporarily in control. Such mines are referred to as Controlled Mines.

These considerations therefore distinguish mines as:

Contact mines—Those which require physical contact between the ship and some part of the mine.

Influence mines—Those which utilize a ship influence—be it magnetic, acoustic, pressure, etc.

Controlled mines—Those which are controlled from a shore station.

Referring to more recent wars, especially World War II, mines may also be distinguished as to whether they were designed for "defensive" or "offensive" use. Of course, there is no sharp dividing line, but for our purposes we will define a defensive mine as one designed to be used in waters controlled by the mine-laying country, while an offensive mine is one designed to be used in waters not controlled by the mine-laying country. Almost any mine, except the controlled ones, may be used either defensively or offensively, but some changes in design are desirable.

Up until World War II mines were considered essentially defensive weapons and were usually laid specifically to prevent the enemy from attacking a given area, which was sufficiently under the control of the country laying the mines to prevent the enemy from sweeping them. Such mines had to be designed only to defend themselves against the attacks of nature, such as wave action, sea growth, ocean currents, etc.

During World War II thousands of mines were laid for offensive purposes, that is, they were laid in waters not controlled by the country laying the mines and were designed to defend themselves not only against the attacks of nature, but also against specific attacks by the enemy. Much more complicated mine designs are therefore justified, but mine designers will usually find it necessary to compromise on the optimum complications

| METHOD OF FIRING | PLANTED BY | POSITION IN WATER | USE |
|---|---|---|---|
| CONTACT | SURFACE SUBMARINE AIRCRAFT | DRIFTING | OFFENSE |
| | | MOORED | OFFENSE DEFENSE |
| INFLUENCE | SURFACE SUBMARINE AIRCRAFT | DRIFTING | OFFENSE |
| | | MOORED BOTTOM | OFFENSE DEFENSE |
| MANUAL | SURFACE | MOORED BOTTOM | DEFENSE |

**Figure 1.—Classification of mines.**

used. These complications require special apparatus which demands space that could otherwise be used for explosives, and of course, every instrument added to the mine assembly increases the number of instruments which must operate perfectly to produce an operable mine. However, we can distinguish mines as either Defensive or Offensive, although the dividing line is not sharp.

A summary of this general classification of mines is given in figure 1. Methods of firing are listed in the first column, and methods of laying in the second. Contact and influence fired mines can be laid by any one of the methods of laying listed, but controlled can only be laid by surface craft. Position in the water is listed in the third column. Influence fired may be used in any one of the water positions, but contact can be used only with drifting or moored, while controlled can be applied only to moored and bottom. The uses are listed in column 4. Contact and influence mines can be used for both defensive and offensive use, although drifting is limited to offensive only, and controlled mines to defensive only.

A few other phrases used more or less regularly in mine parlance might well be defined here. When the "mine" is on the deck of a ship or in a submarine or in aircraft, the term usually refers to the entire mine assembly. If it is a moored mine this includes the charge case, the anchor, and other accessories. A drifting mine would include the charge case and a carrying truck, if such a truck were necessary, while mines planted from aircraft would include parachute packs and other accessories which would be released before the charge case takes its position in the water. To avoid possible misunderstandings, these units are referred to in official mine publications as "mine assemblies." After taking its position in the water the mine assembly is broken up, and from this point on the term "mine" refers only to the charge case itself.

With naval moored mines, the currently used "anchor" is a much more complicated item than that needed to hold the mine in position. (See pp. 51 and 52 and fig. 18.) It is often referred to as an automatic anchor and consists of a housing in which is assembled a reel of mooring cable plus a system of controls which are designed to automatically place the mine case at a predetermined depth beneath the surface. These controls may even hold the case on the bottom for a number of hours or days and then allow it to rise to a predetermined depth. For mines carried in surface craft the anchor also serves as a truck for carrying the case along the mine planting track. For controlled mines the anchors used are usually not automatic. The electric cable attached to the case and usually to the anchor so greatly complicate the assembly that automatic anchors cannot be used.

The launching of the mine assemblies into the water is usually referred to as "mine laying," sometimes "mine planting." Craft specially designed, or equipped, for carrying and launching mines are referred to as "minelayers," which is also applied to submarines or aircraft when they are being used for that purpose. A group of mines laid in a given area is called a "minefield," while a field of mines laid across an entrance to a port or across a lane of ship traffic is sometimes referred to as a "mine barrage."

When mines were practically all of the moored type, a minefield was usually destroyed by dragging a large wire sweep cable across the field, as shown in figure 2. Preferably two ships were used, but by using specially designed equipment to hold the outer end of the cable to one side of the ship, the work can be done by a single vessel. The sweep cable itself is specially constructed so that its surface is very rough and it usually cuts the mine mooring cable. This allows the case to come to the surface where it can be sunk by gunfire. The whole operation was appropriately termed "minesweeping," and this term has been carried over to the destruction of influence-fired minefields to which the term "sweeping" is not so appropriate. With these mines, especially bottom mines, which dragging cables could not touch, destruction is usually accomplished by artificially producing an influence which is like that produced by a ship, but at a safe distance from the minesweeper. This gives rise to a sharp competition between the mine designer and the mine-sweep designer. The first tries to produce a firing device which will distinguish between a ship influence and the artificial one, while the second tries to produce an artificial influence which will be so close to the natural ship influence that the firing device cannot detect the difference.

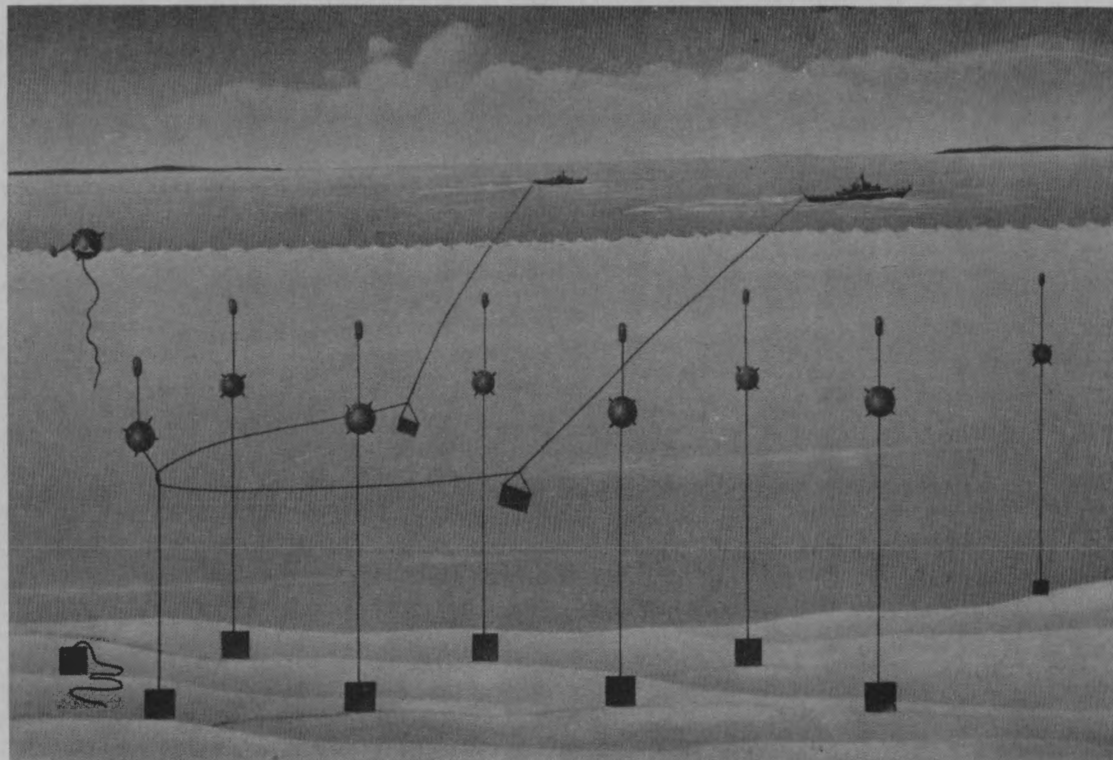


Figure 2.—Minesweeping operation.

## CHAPTER III

# MINE PHILOSOPHY

Moreover, since 1777, the general philosophy on the use of mines has changed radically. In those days their use was very unethical and they were often referred to as "devilish devices," while today they are considered legitimate naval weapons. This change of attitude has encouraged mine designers to improve the weapon and to build a great deal of intelligence into it.

Weapons used in wartime are usually chosen and developed in peacetime and those who choose them, naturally and usually unconsciously, base their decisions on factors which might have a different bias if the country were actually at war. The usual, and to the military forces the more desirable, weapons are missiles of the various types whose effect can be judged immediately, be it the stones and arrows of olden days or the projectiles and bombs of today. The captain of a ship, the commander of a submarine and the pilot of an airplane get much more satisfaction if they can see their projectiles or their torpedoes or their bombs destroy an enemy ship, than by dropping a mine and hoping that sometime in the future a ship will accidentally make itself the target of the mine.

Similarly, even in peacetime practice the projectile type weapons are more interesting and more thrilling than peacetime mine practices. With projectiles and bombs the handler sees what he has accomplished. In other words he sees the "fireworks." Even in torpedo practice the path of the torpedo is followed even though it does not explode. But with mines, the crew cannot get much exhilaration out of seeing a mine disappear in the depths of the ocean.

Also, mines have had to outlive the philosophy that their use is unethical even in war. Early in the 19th century both the British and the French maintained that mines were "sneak" weapons and that such "devilish" devices should not be used against even the enemy's military forces, and during the American Civil War, Admiral Farragut wrote, "I have never considered it (the use of mines) worthy of a chivalrous nation . . ." However, during that war the employment of mines became more general on both sides and they ceased to be considered so barbarous.

Those who opposed the use of mines usually argued that their use did not give the ship attacked a chance to defend itself. This is not the case as there are many ways in which a ship can defend itself against them, but this does require the use of men and material, which of course is a justified method of making war. Mines also involve the element of surprise, but surprise attacks have always been considered a wholly satisfactory method of offense.

Again, missile weapons have a target. The humanitarian nation can usually use missile weapons to attack only the military forces and not the population in general. Automatic mines have no immediate target. A ship makes itself a target by coming within the firing range of a mine. As mines began to be accepted as a satisfactory means of attack on military forces, the fact that the mine provided no method of saving the lives of passengers should its target not be a war vessel, was still considered objectionable by such countries as Great Britain, France, and the United States. In the International Convention Relative to the Laying of Automatic Submarine Contact Mines, held at the Hague in 1907, both Great Britain and America objected to the use of automatic drifting mines, but finally agreed to their use providing they would neutralize themselves within 1 hour after planting.

In the final agreement reached at this conference, there is a general restriction against the use of mines, but the regulations are not too definite. In the preamble it is stated that "Seeing that, while the existing position of affairs makes it impossible to forbid the employment of automatic submarine contact mines, it is nevertheless expedient to restrict and regulate their employment in order to mitigate the severity of war and to ensure, as far as possible, to peaceful navigation the security to which it is entitled, despite the existence of war." Other regulations forbid the use of "unanchored automatic contact mines unless they be so constructed as to become harmless 1 hour at most after those who laid them have lost control over them," the use of "anchored automatic contact mines which do not become harmless as soon as they have broken loose from their moorings," and "automatic contact mines off the coasts and ports of the enemy with the sole object of intercepting commercial navigation." A full discussion of the use of the mine as agreed to in international law is given in chapter IX of Captain Cowie's book "Mines, Minelayers and Minelaying."

On the other hand, mines are a relatively cheap and quickly developed weapon which can cause enormous enemy losses. It is therefore to the interest of the weaker naval power to develop and use them against the stronger naval force. In the Revolutionary War Bushnell tried to use them against the British. In the Civil War, the Confederates, with practically no navy, spent great efforts developing them and using them against the Federal Navy. Japan used them against Russia, and in World War II it was Germany, with practically no navy, who put mines to a new use in planting them for offensive purposes by aircraft against the shipping of every nation in the world.

Another reason is often used to discourage powerful navies attempting to develop mines as a war weapon. Once a mine is used, its secrets are compromised and the enemy is free to make use of them. Therefore, a powerful navy may open itself to injury by using specially new and effective mines. When Fulton proposed the use of mines to Great Britain in 1797 and was given some encouragement by Mr. Pitt, the Prime Minister, Lord St. Vincent, remarked that "Pitt was the greatest fool that ever existed to encourage a mode of warfare which those that commanded the seas did not want, and which, if successful would deprive them of it." Up until World War I both Britain and the United States have largely followed Lord St. Vincent's advice. Both countries had strong navies and apparently believed that their navies did not need such help as mines could give.

However, mines have gradually been accepted as legitimate war weapons. All countries use them now and vie with each other on the intelligence and effectiveness which they can build into them. The use of modern mines does demand that the enemy expend tremendous amounts of time and material to protect its ships as best it can. Their use also creates a continuous threat of a most unpleasant surprise even when the mine laying forces are not present, resulting in serious loss of morale even though no losses occur. These are legitimate wartime demands on the enemy. Humanitarian nations can reduce the effects of mine attacks on neutral and nonmilitary personnel by publicizing the areas where mines are laid.

Possibly mines are just as "barbarous" and "devilish" as they were considered to be 150 or more years ago, but the barbarousness of other modern weapons and their use, such as gas, flamethrowers, fire bombs and atomic explosions applied to nonmilitary areas, are so much more "devilish" that mines appear rather mild in comparison.

Today, victory depends so often on the material furnished to the military forces by those who might be called "noncombatants" that the enemy may legitimately call them combatants and consider that he has a wartime right to destroy them. This makes "total war," and our own country certainly made "total war" in its World War II victory over Japan.

## CHAPTER IV

# 1780 TO 1860

To return to our historical study, we find that the next American submarine explosive advocate after Bushnell was Robert Fulton, who was born in Pennsylvania in 1765. As a boy he neglected his studies in order to do sketching and to make mechanical experiments. While in his teens he was recognized as a painter in Philadelphia, and in 1786 he sailed for England with a letter of recommendation from Benjamin Franklin to Benjamin West, who at that time was a well-known painter in London. Working with him, Fulton made considerable progress as an artist.

In 1793 he suddenly gave up his artistic career to take up engineering as his life's vocation. His first interest was concerned with the building of canals to reduce the cost of transportation. From this he began to study the mechanical propulsion of surface vessels and then underwater vessels.

1797 he visited France where he remained until 1804. During his stay there he was at first strongly anti-British and began to try to apply his underwater boats to help France against Great Britain with whom it was at war. David Bushnell was also in France during this period and he and Fulton may have discussed the destruction of ships by means of underwater explosions. Fulton's proposal was that his submarine boats could carry mines (or bombs as he called them) and release them in the harbors and traffic lanes of England. He was thus nearly 150 years ahead of Hitler, who tried much the same offensive attack against England in 1938–39.

He received some support. He was allowed to try out a 20-pound mine on a 40-foot sloop. The sloop was blown completely to pieces. He built the Nautilus in which he, with two companions, descended to a depth of 25 feet and remained there for 2 hours. However, he failed to obtain authority from Napoleon Bonaparte to proceed further with his experiments.

Meanwhile Great Britain, through their secret service, had kept itself posted on what Fulton had proposed to the French government, and in 1803 it sent a secret circular to various naval commanders warning them of the possibility of an attack of this sort for it did not know whether France had adopted any of Fulton's proposals. It also opened communications with Fulton and induced him to return to England which he was apparently glad to do since Bonaparte had given him no encouragement.

He was welcomed in England, was paid a salary and was given funds and facilities for trying out his experiments. He suggested to the British that an attempt be made to destroy part of the French fleet which was anchored at Boulogne, using what we would now call "drifting mines." Each mine consisted of a watertight wooden box about 21 feet long and 3 feet wide and was loaded with approximately 40 kegs of black powder. It was bal-

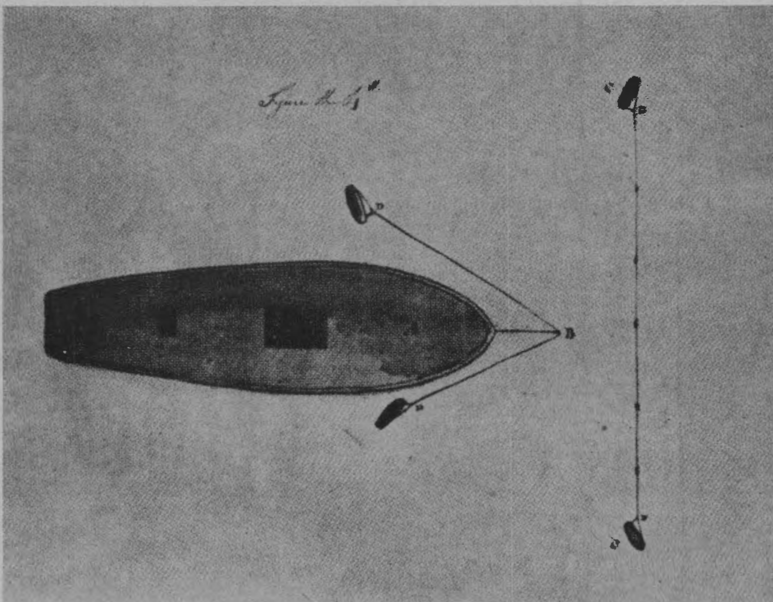


**Figure 3.—Use of drifting mines (as sketched by Robert Fulton, 1806).**

lasted so that it floated with the top surface just above the water level. A clock working mechanism, which could be released from outside the box, was arranged to explode the charge 5 or 10 minutes later.

At 9:15 p.m. on October 1, 1804 a number of small British boats with a number of these mines approached the French fleet at Boulogne. But the French had been informed of the plans and opened fire as soon as the boats came within firing range. The British finally released the mines after starting the timing delay and pulled back to their supporting fleet. The mines drifted down to the French vessels. In all, 12 of them exploded but did very little damage. A few sailors were killed or injured. Mr. Fulton called these mines "catamarans." The expedition is usually referred to as the "Catamaran Expedition."

Next, at his suggestion, the British attempted to destroy two French frigates by throwing a cable, with a mine connected to each end, across the bow of each anchored frigate. The mines exploded, but the frigates were not damaged. Fulton was sure that the failure to destroy them was because the mines were on the surface instead of against the hull beneath the surface.

In 1805 he was permitted to try another demonstration against a strongly built 200-ton brig, the *Dorothea.* The method was the same as that applied to the frigates except that the mines were made a few pounds heavy so that they would barely sink below the surface, while the tide and the supporting lines were expected to gradually draw the mines in against the ship. Figure 3 shows the general idea of how the mines were arranged on the *Dorothea.*

The experiment was conducted in the presence of a large group of spectators, amongst whom were a number of naval and military officers of high rank. Many of these were very skeptical of the power of the explosion, and one Captain remarked that, "If one of the machines was placed underneath my cabin while I was at dinner, I should feel no concern for the consequences."

When the explosion occurred, the brig was broken in two and "in one minute nothing was to be seen of her but her floating fragments" (quoted from a letter of Fulton's). Figure 4 is a copy of Fulton's drawing of the breaking up of the *Dorothea*.

The success of this experiment showing the vast power of underwater explosions, while highly gratifying to Fulton, alarmed the British naval authorities. They feared that such a mode of warfare might deprive them of their control of the seas. Six days after the *Dorothea* was blown up, Nelson destroyed the French and Spanish fleets at Trafalgar. Therefore England had no need of submarines, or of mines, or of Fulton. Lord St. Vincent's remark, quoted in chapter III, became much more meaningful. The British had the only fleet, mines were not needed, and might even reduce the prowess of the fleet itself.

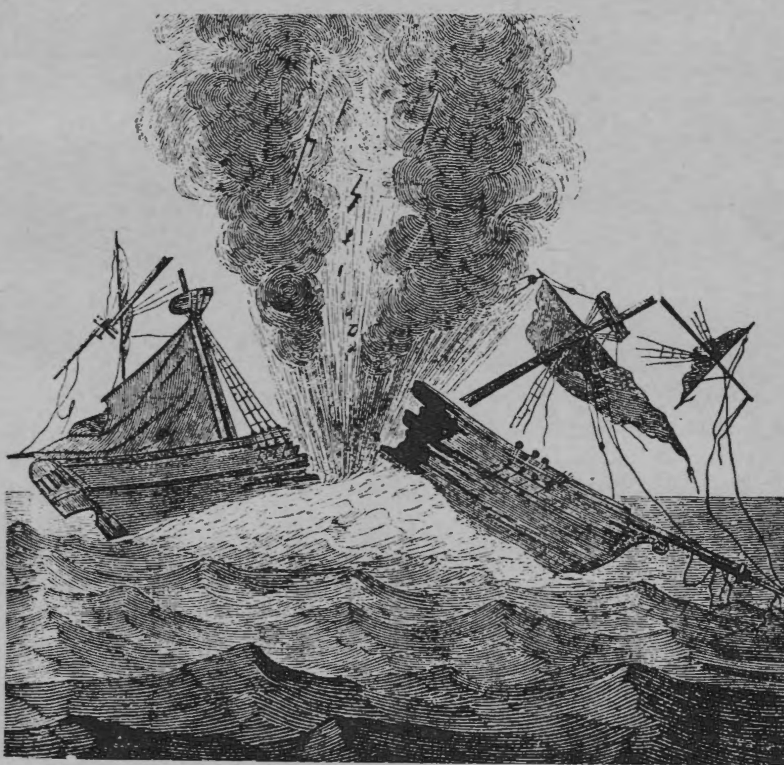


**Figure 4.—Demolition of the Brig *Dorothea* (as sketched by Robert Fulton, 1805).**

Both in France and England Fulton had many arguments with the government concerning his monetary awards. He believed that his proposals were very valuable and that he should be paid a modest fortune. Before he left England he asked for a final settlement of between 1 and 200,000 pounds and an annuity of 2,400 pounds for life for which he would agree to remain tranquil concerning the proposals and interest himself in other pursuits, although in a later letter he states that should America have need of his inventions, an annuity of 20,000 pounds per year would not prevent him offering them to his own country.

Some of his mine proposals are shown in figures 5 and 6. Figure 5 is a copy of Fulton's own sketch of a moored mine and shows how it is

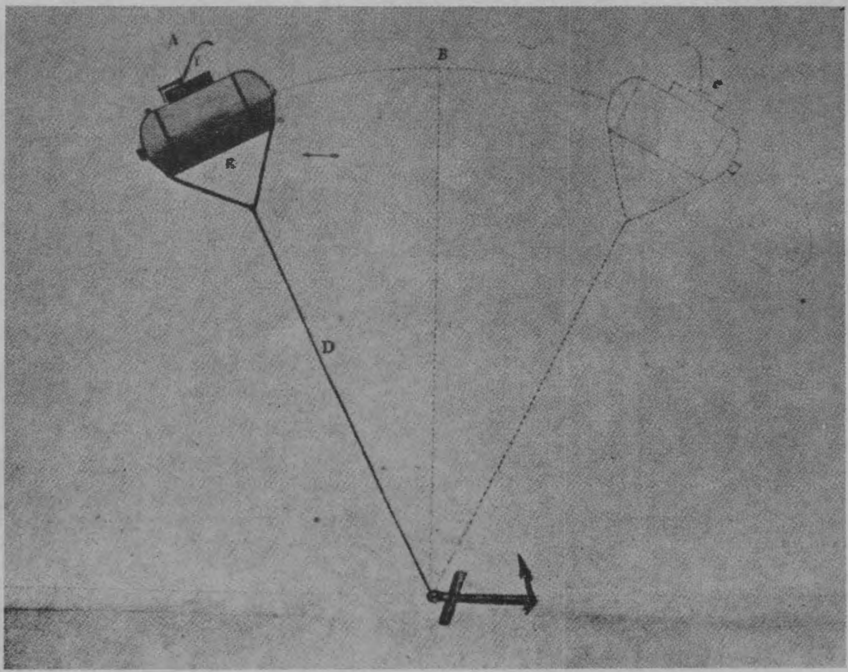



**Figure 5.—Fulton's moored mine (as sketched by Robert Fulton, 1806).**

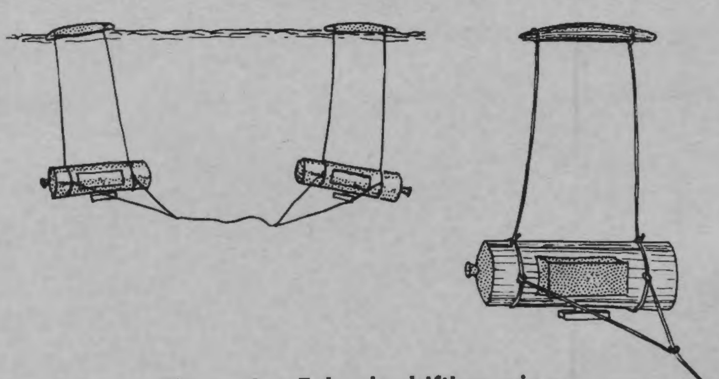


**Figure 6.—Fulton's drifting mines.**

affected by the tide. This is apparently the first proposal of anchoring a mine in a definite position. Figure 6 shows his proposal of bridling two drifting mines together which would increase the mines' attack area and would also increase the probability of the mines' actually coming into contact with the ship before exploding.

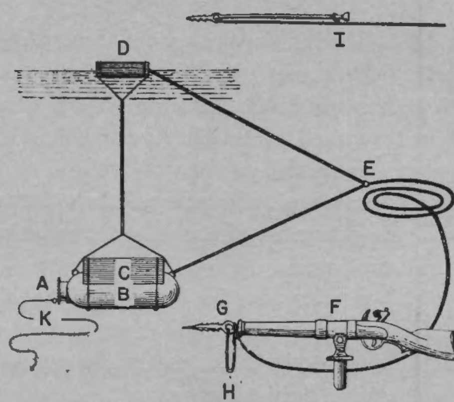
He returned to America in 1806 and within a few weeks proceeded to Washington, D.C. and presented his submarine and underwater bomb proposals to Mr. Madison, the Secretary of State, and to Mr. Smith, the Secretary of the Navy. These men were very much interested and granted Fulton funds for continuing his tests. In 1807 he succeeded in blowing up a brig in New York Harbor but only after several attempts. He was probably using the two mines bridled together as had been used with the *Dorothea*, but the bombs were improperly balanced and turned over and the priming powder fell out so that the gun lock spark had no effect. Fulton modified the bombs and the brig was blown to pieces, but the early failures had made the government skeptical of the whole scheme.

However in 1810 he was again permitted to attempt to destroy a sloop of war, the *Argus*, but her captain defended her using strong nettings reaching down to the sea bottom, large grappling irons ready to be dropped on any boat which came near and great knives fastened to the ends of long spars which could attack the personnel on an approaching boat. Mr. Fulton readily admitted that he could not succeed in his attack, but one of the government's representatives in making his report admits that "an invention which will oblige every hostile vessel, that enters our ports, guard herself by such means, cannot but be of great importance in a system of defense." However the government's committee would not recommend the government adopting any of Mr. Fulton's proposals.

On the other hand, his experiments did excite some anxiety in England. At this time there was some possibility of a rupture between the United States and Great Britain, and Lord Stanhope of the House of Lords, pointed out that an American inventor, who had made proposals to Great Britain, which were not accepted, for the destruction of ships by underwater explosions was now presenting these same proposals to America and that "it has been ascertained that it would not, on all average, cost 20 pounds to destroy any ship whatever."

During the War of 1812, Fulton again made proposals to the U.S. Government. One involved the planting of moored sea mines in harbors; another the use of mines secured to harpoons to be fired into the hulls of vessels and which would explode if the water currents or the movement of the vessel brought the mine into contact with the vessel, figure 7. There are some reports that the Americans did use some moored sea mines, and that the British approached the U.S. ports, especially that of New York, very warily, continually looking for mines.

Several efforts were made to destroy the English frigate *Plantagenet* in Lynn Haven Bay. Most of them were complete failures, but in one case a




A. FIRING LOCK
B. CASE FOR CARRYING EXPLOSIVE
C. CORK SLABS
D. FLOAT FOR SUPPORTING THE TORPEDO
E, I, H.-SHOWS METHOD OF ATTACHMENT
F. MUSKET
G. HARPOON
K. SAFETY LINE

**Figure 7.—Fulton's harpoon torpedo.**

Mr. Nix of Norfolk succeeded in floating a mine, using one of Fulton's proposals, to the bow of the vessel. Its explosion did some damage although it was not serious. Otherwise, no damage from mines used against the British is reported. However, the British ordered its cruisers to destroy every American vessel except those with flags of truce on account of the Americans' "inhuman and savage proceedings."

Fulton died in 1815 and during the next 15 or 20 years no one in the United States appeared to give any consideration to sea mines, but in 1829 Col. Samuel Colt, of revolver fame, began to experiment with mines, applying new advances in science and technology to Fulton's work. In 1841, Colt wrote that he could destroy any ships entering a harbor but could allow friendly ships to enter safely, and that he could do this without giving the invading enemy the slightest indication of the threat. He claimed that the whole expense of protecting a harbor like that of New York would be less than the cost of a single steamship.

Colt's main improvement over Fulton's moored mines was in the use of electricity flowing through a fine wire to cause the explosion. He was directed by the U.S. Government to carry on his work, under the supervision of the Secretary of War, and Congress appropriated a large (in those days) sum of money to cover the cost. Most of his work concerned the use of controlled minefields.

In June 1842, he exploded a mine in New York Harbor. He next blew up an old gunboat, and a little later in the presence of a number of government dignitaries he blew up an old schooner in the Potomac from a shore station 5 miles away. In every case he used a galvanic battery to furnish electricity. (Colt was not the first to use electric current for this purpose. In 1839, General Pasley, of Great Britain, had destroyed an old wreck by means of an underwater explosion initiated by an electric primer.)

While these tests proved the enormous possibilities of using underwater explosive mines as a weapon of defense, there is no record of any more tests, or of any detailed report of his work or of any drawings showing his arrangements of explosives, wires, batteries, etc. Among Colt's effects, however, were found drawings which indicated that he had studied the use of controlled mines as weapons of defense. One drawing proposed a device which could be attached to a mine so that a passing vessel would be indicated at a mine control station. Another proposed a mechanism in which the vessel would close the mine firing circuit if it made contact with the mine. However, no action was taken by Congress to continue the study. The development of mines had again stopped completely in the United States.

## CHAPTER V

# U.S. CIVIL WAR

Up to the time of the American Civil War sea mines had been used in several wars in Europe and Asia, but the actual physical damage occurring had been almost inconsequential. Fields of these "devilish" devices may have had their effects, but in most cases naval commanders had ignored known existing fields with no serious results. However, in the American Civil War mines were used on a relatively large scale by the Confederates and the losses in the Federal Navy were surprisingly large. Twenty-seven Federal vessels were sunk by mines while only nine were sunk by artillery fire.

The Civil War was a conflict between two belligerents, one of which was much better equipped as far as naval forces were concerned than the other. As is often the case, the Confederacy, the less well equipped one for naval warfare, began to study naval weapons which could be put to use more quickly and with much less expense than weapons which required the manufacture of guns and the building of ships upon which to mount them.

The Confederacy therefore organized what we would call today an Underwater Research Department and an Underwater Operations Department, and also offered relatively large prizes for the capture or destruction of Federal war vessels. Officially the new departments were referred to as the Torpedo Bureau and the Torpedo Corps, but the term "torpedo" in those days covered almost all kinds of uncontrolled and manually controlled underwater or nearly underwater weapons; but, of course, the power-driven torpedo of today was not included as it was not invented until some years later.

Relatively large explosive charges mounted on the ends of long spars extending out from the bows of small boats were used in many cases to bring the charges against the hull of an enemy vessel. The next step was to build specially designed boats which could maneuver with only a small section extending above the surface. These were called Davids (possibly after David Bushnell) by the Federal crews. These weapons could only be used at night and against anchored vessels. Several Federal vessels were damaged, although not too severely, but one was sunk. Usually the small attacking vessel was severly damaged, and many of them were sunk by the explosion of their own charges.

The Confederate Torpedo Bureau also adopted several types of mines, a few of which were fitted with automatic fuzes although most of the firing devices were controlled by shore observers. Photographs of a number of these, which were picked up shortly after the war from water which had been under Confederate control during the war, are shown in figures 8 and 9.

The so-called "Singer" mine is credited with being the most successful Confederate mine. It was a manually-laid moored mine, but the fuze was designed to be automatic and to explode the mine when it was struck by a ship. The cases were made of sheet iron and the charge was from 55 to 65 pounds of black powder. It carried a heavy iron cap on its upper surface which would be knocked off by a ship contact. As it fell it released a spring-driven plunger which struck a fulminating charge thus exploding the mine. It was provided with a safety pin which prevented its operation while being handled, but which was removed after the mine had been laid. When used in salt water, the firing springs, which were exposed to the water, soon became useless because of sea growth.

The usual firing device for controlled mines consisted of a match case imbedded in the powder charge, with an attached cord running out through the case to an observation point on shore. Pulling the cord would fire the mine. Later in the war many of the controlled mines were provided with electric detonators connected to batteries on shore. Many of these mines contained from 2,000 to 5,000 pounds of powder.

Drifting mines also used the match case type of fuze. Usually, two mines would be cabled together, the cable being attached at each end to the match case. These mines usually were not effective as the explosions often occurred at some distance away from the contacting ship.

A chemical type fuze was also developed in which a glass tube filled with sulphuric acid was mounted over a charge of chlorate of potash and finely ground white sugar. The glass tube was supposed to be broken by ship contact and the chemical action of the acid with the potash and sugar would generate sufficient heat to fire the powder charge. This type was similar to a fuze invented by Professor Jacobi, an eminent Russian chemist.

Many other types of mines and mine firing devices were developed and used. The story of their development and use is discussed in considerable detail in the book, "Submarine Warfare," by Lt. Comdr. J. S. Barnes, USN.

Mines of these various types were planted in defensive fields in the approaches to most of the Confederate seaport cities, and many were planted in the Potomac and Mississippi Rivers to prevent, if possible, the movement of Federal war vessels. One of the most ambitious fields was planted in the defense of Mobile, Ala. Some 80 or 90 mines of the various types were placed in this field (fortunately for Admiral Farragut's fleet, they were planted some time before he attacked Mobile). The *Tecumseh,* an ironclad vessel of 1,034 tons, led the attack. Just as she reached a point where her guns could reach the defending forts, she struck a mine which exploded and sank her in a very few minutes.

The *Brooklyn* was following the *Tecumseh*. Her captain saw the *Tecumseh* sink and saw other mines in the water. He altered the course of the *Brooklyn*

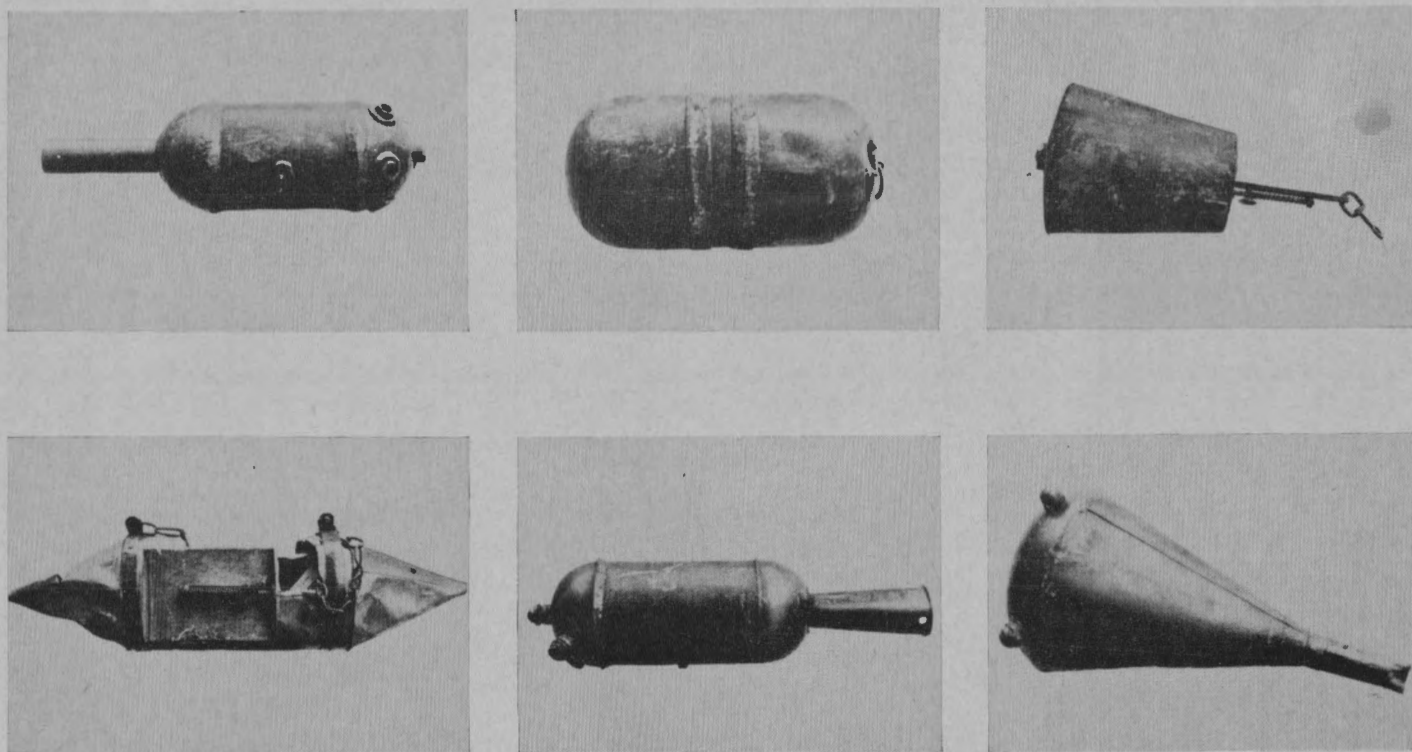


Figure 8.—Civil War mines.

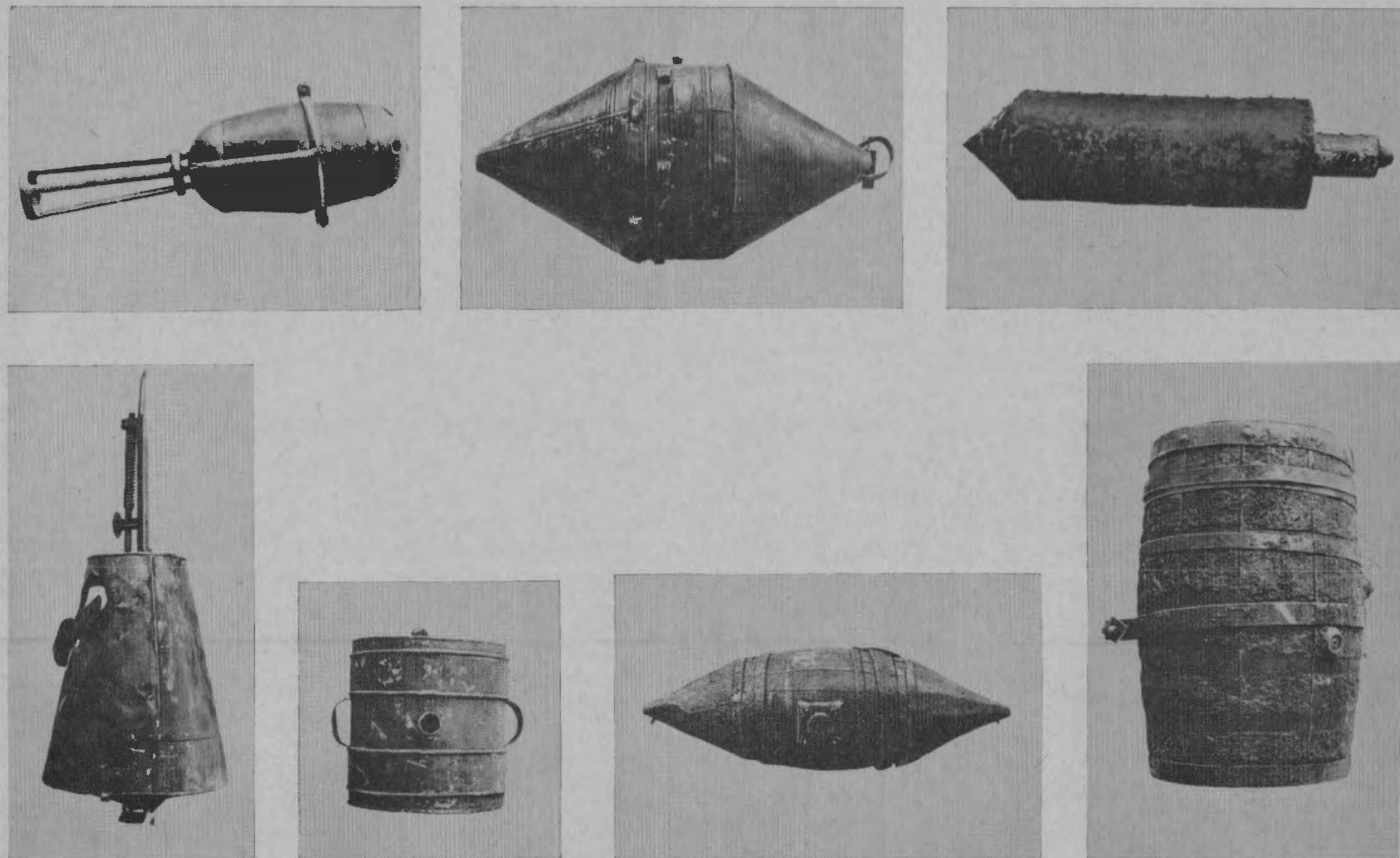


Figure 9.—Civil War mines.

and signalled to Admiral Farragut that mines were present. Farragut was furious and signalled to the *Brooklyn,* "Damn the torpedoes (mines), Captain Drayton, go ahead." No more mines fired. Later it was discovered that the mines were inert due to immersion and wave action.

It is impossible, of course, to point out what the course of the war would have been if the Confederacy had not used their mining program. Mines actually sank 27 ships and seriously damaged several others. This direct loss was serious, but not nearly as serious as the indirect loss on the Union war program. Many of the commanding officers were not as bold or as lucky as Farragut was. The existence of the mines exerted at first a paralyzing influence upon the Federals, and throughout the war they were often delayed in their operations while they tried to remove or destroy the mines. A couple of these incidents are given below.

During the winter of 1863–64 the Confederates had concentrated a considerable force in northeastern Louisiana. To annihilate these forces the Union dispatched land and sea forces up the Red River, but the naval operations were greatly delayed by Red River mines. Before they reached their base, the Union Army, making the land attack, had been defeated, and the navy vessels had to return under considerable harassment. One vessel was sunk by a mine. The delay to remove mines had probably caused the Union defeat.

Later, the Union dispatched an army and a naval force to attack Drury's Bluff on the James River. The fleet moved very slowly because of James River mines, and finally lost the *Commodore Jones* to an unswept mine. This further delayed the fleet, and it was finally forced to retreat because the Union Army had been defeated at Drury's Bluff. The slow advance of the fleet had given the rebels the chance to strengthen their forces there.

The Federalists made some effort to develop underwater weapons, such as rockets, spar-type torpedoes and electrically controlled mines, but failed to make any effective use of them.

# CHAPTER VI

# AFTER THE CIVIL WAR

The early development of mines in the United States was entirely an army project. Bushnell was made a Captain of a Corps of Sappers and Miners, under the U.S. Corps of Engineers after his ingenious attempt to mine British ships in Philadelphia in 1777–78. During the Civil War it was the Corps of Engineers of the Confederate Army which had charge of the development of mining devices for the Confederates. After the Civil War, Gen. C. A. Humphreys, Chief of Engineers, U.S.A., profiting by the successful use of mines by the Confederate Army, directed Gen. H. L. Abbot to employ Engineer Troops in carrying out practical trials and experiments in the use of submarine mines. In 1871 Congress added submarine mining to the duties of the Engineer Troops.

The engineers, under Abbot's guidance, spent several years on the project and made a very thorough study. It included a study of all available explosives, of damages to be expected, of available fuzes and detonators and of sources of electrical power. Their work is reported in considerable detail by General Abbot. His report makes very interesting reading as it shows how the material which he had to use and the available type of explosives and of usable electrical equipment have changed in the past 80 to 90 years. The engineers used a wide variety of testing equipment, new equipment was modified in accordance with the art then available, and all production materials were thoroughly tested and their use carefully considered.

Measuring apparatus was designed and built. The crusher gage, in which a piston is supported on a short copper pin and which measures the explosive pressure by the shortening of the pin, was modified to fulfill the special needs of the job. Various types of rings and frames for holding the gages near the explosive charges were tried out until fairly consistent results were obtained.

It was realized that all of these measurements were of little practical value unless they could be related to the actual damage to both wooden and armored vessels, and the fact that such vessels could not be obtained for test was regretted. However, both wooden and iron experimental targets were constructed. The wooden target was constructed of wooden beams 12 inches square and weighed about 12 tons. The iron target was built to the dimensions of an area in the bottom of the U.S.S. *Monarch*. It was 20 feet square and 3 feet thick. The bottom and sides were of $\frac{3}{4}$-inch iron while the top deck was of $\frac{1}{8}$-inch iron.

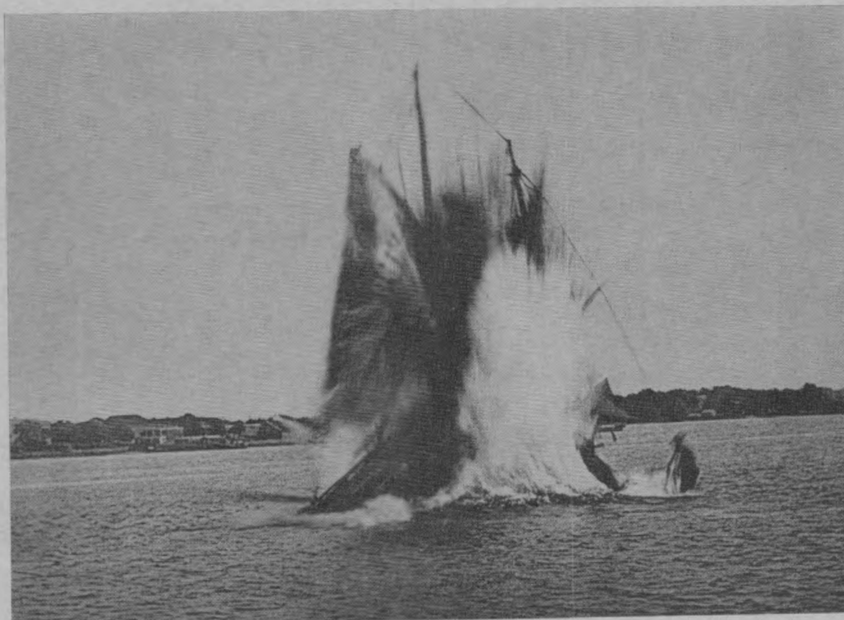


**Figure 10.—Destruction of the *Olive Branch*.**

Explosives available for use included explosive gelatin, gunpowder of various sizes, nitroglycerin, guncotton and dynamite. These were all tested using various size charges against the crusher gages mounted in the special mountings provided. The tests also included various types of containers and the possibility of one explosion firing others located a short distance away.

For controlled mines electrical fuzes are almost essential, so considerable study was made of the use of electrical power from frictional machines, from magnetic induction machines and from voltaic batteries. Each of these sources required specific types of detonators. For frictional (i.e., static) electricity the detonator had to be an open circuit so that a spark would develop. Electricity from magnetic induction machines could be of high enough voltage to produce a spark, or could be used to heat a fine wire, while for voltaic batteries only hot wire detonators could be used. All of these combinations were studied and tested. Hot wire detonators with voltaic batteries were chosen as the most satisfactory ignition system.

In 1878, General Abbot did try out his mines on an actual ship, and in making the test he used original techniques so that he could analyze the results very accurately. The vessel was the *Olive Branch,* a schooner drawing about 4 feet of water. She was anchored in water 15 feet deep and two charges each of 50 pounds of powder were placed 10 feet apart and 7 feet deep; that is, they were about 3 feet below the schooner's bottom. Six cameras were arranged to take photographs of the explosion, and were timed so that they would all operate at predetermined points within a few seconds after the explosion. The charges were exploded simultaneously and the first picture taken $\frac{1}{10}$-second later showed the bow and the stern of the schooner forced into the water with the middle of the vessel raised about 11 feet as shown in figure 10. About 2 seconds later the jet of water was 180 feet high and the whole phenomenon was over in a total of 5 seconds.

From the results of this detailed study controlled mines were designed and systems for defending harbors were proposed. The mines consisted of buoyant steel cases containing from 25 pounds up to 500 pounds of explosives and were to be anchored about 25 feet beneath the surface. Each was provided with a hot wire detonator and an electric cable to a battery on shore. A system of mines consisted of a group of 5 to 10 mines whose individual cables were connected to a junction box on the bottom from which a single multiple conductor cable was carried ashore, or sometimes the conductors from two or more junction boxes were carried to a master underwater box to which the shore lead was connected. A sample mine system is shown in figure 11, and a complete harbor protecting arrangement is shown in figure 12.

One of the difficulties with controlled mining is the fire control system; that is, how to determine from the shore control station when the enemy

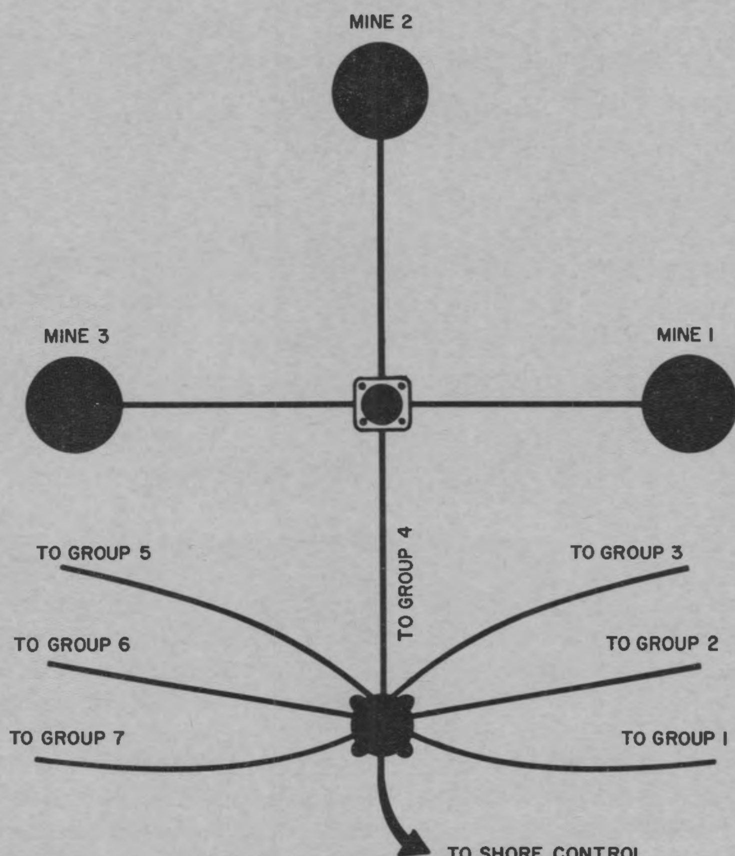



**Figure 11.—Triple group of controlled mines.**

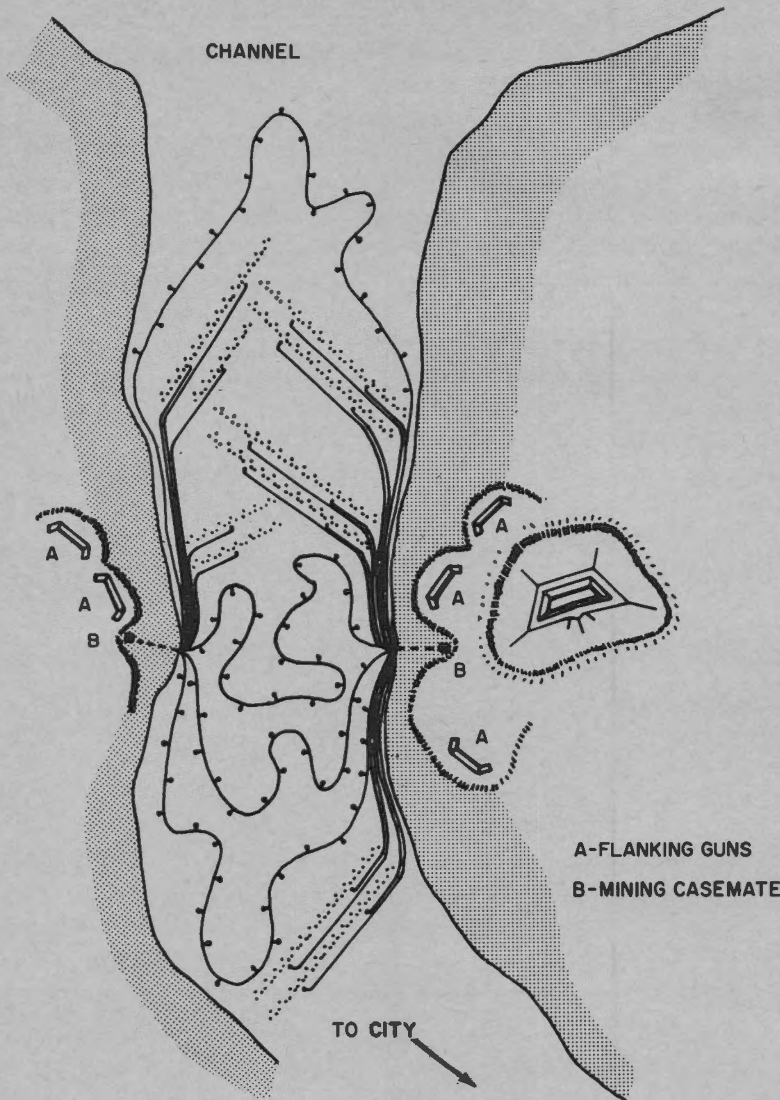



**Figure 12.—Controlled mine system for a harbor.**

ship is within the damage range of a group of mines. For daytime and with fair visibility ships can be located with triangulation stations, some of which are shown in figure 12, but at night or in foggy periods this system is of no value; nor is it for submarines which began to come into use some years after Abbot's work. On the other hand, the military demanded that no current of firing value be connected to the mine at any time except when firing was contemplated, but the use of very small currents through a contact maker in the mine was allowed. Such contact operations could be recorded on scoreboards in the control station but in order to use them, the mines, or floats from the mines, had to be near enough to the surface so that actual ship contact could be made. In shallow water mines could be placed on the bottom with floats, containing contact makers, moored near the surface. The U.S. system as designed first by General Abbot and his staff and later by his immediate successors provided for the use of any or all of these fire control systems, as might be desirable. Manuals were prepared and issued to the troops in 1875, and as improvements developed the pamphlets were modified in 1877 and 1887.

In 1898, during the Spanish American War, the U.S. Engineers made some attempts to install a controlled mine defense in New York Harbor, but apparently were not successful. The records available indicate that the equipment was in very poor condition and that there was an almost complete absence of technical "know-how." There is no record of attempts to plant fields elsewhere.

In 1891, an experimental field was planted in the Potomac River just off Fort Washington, a few miles south of Washington, D.C., and a mining casemate and watch tower were set up in the Fort. This was increased in 1899 just after the close of the Spanish-American War. The military station is now a Federal park, and in the museum in the old fort are photographs of the mine control room and the mine observation gallery. A plaque mounted on this photograph states: "Mines were planted in the river opposite Fort Washington, and a one-room control building and gallery were completed in 1891. In order to protect the mine control room, the casements were walled in with concrete and filled with earth. In 1899, a second room was added and a third at a later date. The photograph above shows the foundation of the mine control rooms and the observation gallery is seen in the other photograph." The photograph of the control room is shown in figure 13.

The poor situation existing in the Spanish-American War may have been the incentive to increase the experimental outfit at Fort Washington, and in 1906 and again in 1912 the mining manual was brought up to date; but the mining forces again failed to continue practices year-in-and-year-out in the use of the mining material, so in 1917 at the beginning of World War I, the stock material was again old and unserviceable, and the "know-how," if it had existed from 1906 to 1912, had to all intents become almost zero once more. No controlled mine fields were planted during World War I.

The Navy began to take its first interest in mines in the 1880's. The first record which the author has been able to find in "Excerpts of Bureau of Ordnance Reports" is that in 1887 naval defense mines "had been designed."

It is likely that this design work was accomplished at the Naval Torpedo Station in Newport, as in the year just previous to this that station is credited with experimental and design work on torpedoes, but some of this may have been on mines, since mines were often referred to in those days as "torpedoes."

**Figure 13.—Mining control room, Fort Washington, Md.**

In 1892 the Bureau of Ordnance Annual Report again refers to the Naval Torpedo Station continuing its work on mines and in 1898 we are told that "Gun cotton mines and mining outfits (were) prepared and issued." However, there is no record of any of these mines being used during the Spanish-American War. During the next few years there are notes in the reports almost every year that the Naval Torpedo Station is working on the design and manufacture of mines and in 1905 a definite step forward is announced in that the Bureau of Ordnance has obtained some data on the actual handling of mines in service, and during that year it issued a pamphlet on "Countermine Outfits." These were mines designed to clear a channel. They were planted in rows, and they all were exploded simultaneously from shore. Each mine was a cylindrical iron case holding 529 pounds of gun cotton, and the pamphlet outlines in considerable detail how they are to be laid out and fired.

The Bureau of Ordnance also became interested in automatic moored mines, during these years. Its early mines were manufactured by the Sauter-Harlé Company of Paris. In 1909, the Bureau issued a pamphlet describing the Mark 2 Naval Defense Mine which had been designed and manufactured by the French company. It used an automatic anchor which fixed the depth of the case at a predetermined level. (The operation of this type of anchor is described in chapter VIII.) The case carried approximately 175 pounds of gun cotton, while the firing pistol was a contact-inertia type. A sketch of the mine in its moored position is shown in figure 14. It was a current ordnance item for several years.

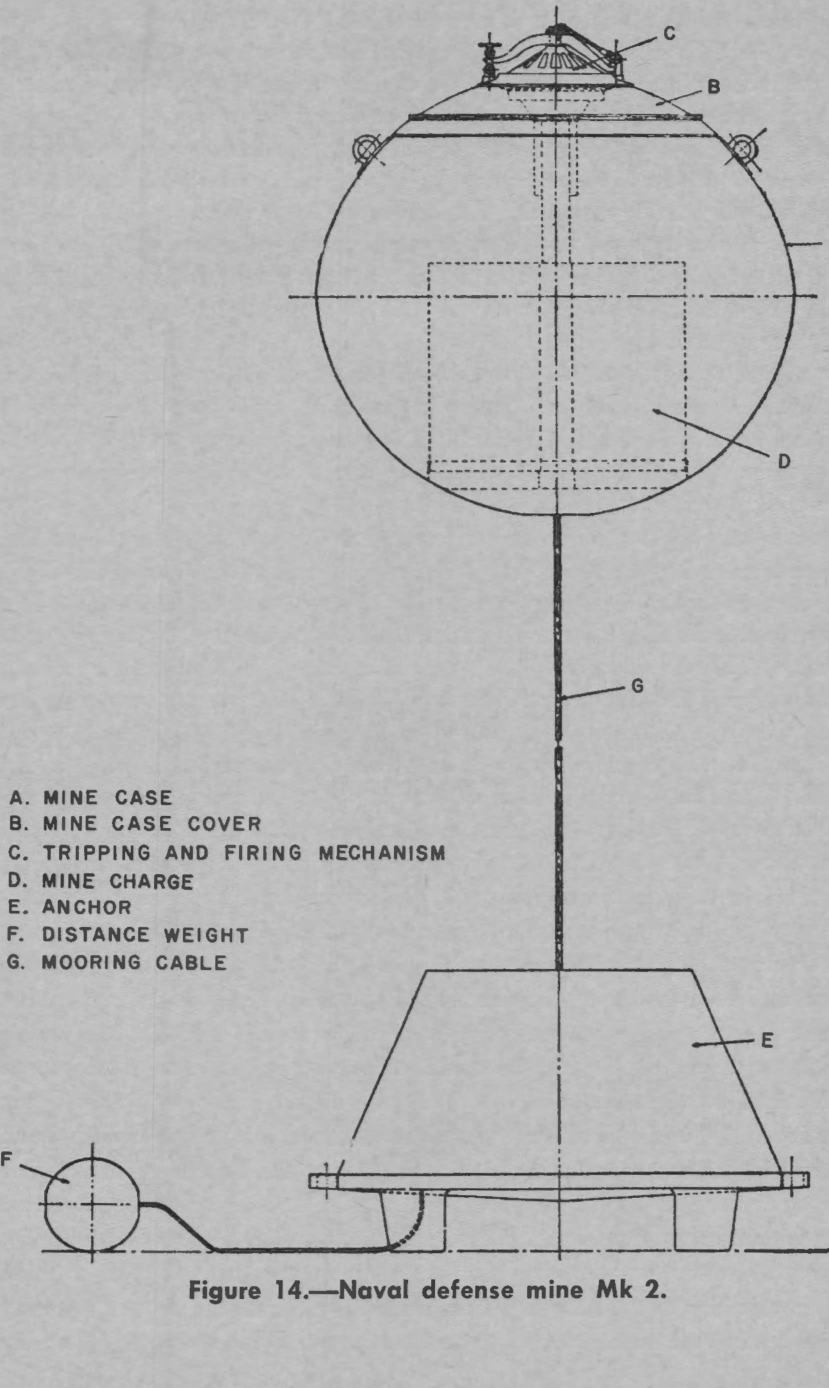



**Figure 14.—Naval defense mine Mk 2.**

About 1915 the Bureau began to manufacture its own mines using a design owned by the Vickers Company of England. The Bureau contract called for a payment of a royalty to the Vickers Company for each mine manufactured. A sketch of this mine (the Mark 3) in its moored position is shown in figure 15. The assembly, described in a pamphlet issued by the Bureau of Ordnance in 1916, is quite similar to that of today's surface craft moored mines. The anchor was an iron box which contained the depth taking gear and which rolled along railroad-like tracks on the minelayer. The case was a steel sphere, but the designers, making use of developments in the explosives field, were using TNT instead of gun cotton.

The ignition system was also made safer against premature operation than the earlier mines. As shown in the sketch, each mine carried a long lever carrying a cork float at its outer end, which extruded out beyond the case. It was expected that contact of the case with a ship would cause relative rotational motion between the case and the lever. This would permit the case to rise an inch or two and in so doing it would compress the firing spring and then release it against the detonator. The firing spring would therefore not be compressed when the mine was on deck or during the planting operation.

Interest in the Bureau of Ordnance continued to increase. Drifting mines were studied by the Naval Torpedo Station and two designs reached the stage of going through experimental tests. In 1915 a full-time mining officer was made part of the Bureau's officer staff, but, unfortunately, other problems which were apparently more urgent developed in 1916 and the officer was assigned to other duties. As early as 1907 Congress was requested to provide a "Mine Depot Ship" and a small experimental vessel was assigned to the Torpedo Station. By 1912, the Navy's first official minelayer, the U.S.S. *San Francisco,* was supplied with a "war allowance" of mining material and in 1913, the U.S.S. *Baltimore* (fig. 16) was fitted out as a second minelayer. Additional mines of the Vickers design were procured as rapidly as funds became available. In 1917, the Portsmouth Navy Yard was manufacturing 140 per week and hoped soon to reach a 500-per-week delivery rate.

During these 10 or 15 years, up to 1917, it appears, from a study of the Bureau of Ordnance report excerpts, that each Chief was reporting that the mine program was moving along satisfactorily and that the newly designed mine was dependable and satisfactory, but each succeeding year reports of modification or new designs were noted. Even during the 3-year period (1914 to 1917) after World War I started in Europe, during which time the Germans were using mines widely and the British were trying to bring their mine potential up to a more satisfactory basis, no effective mine preparedness program was started in the United States. Actually, when we entered the war we discovered that the mines we were manufacturing, which were very similar to the type which Great Britain had had at the beginning of the war, had been proved quite unsatisfactory by the British. Then the

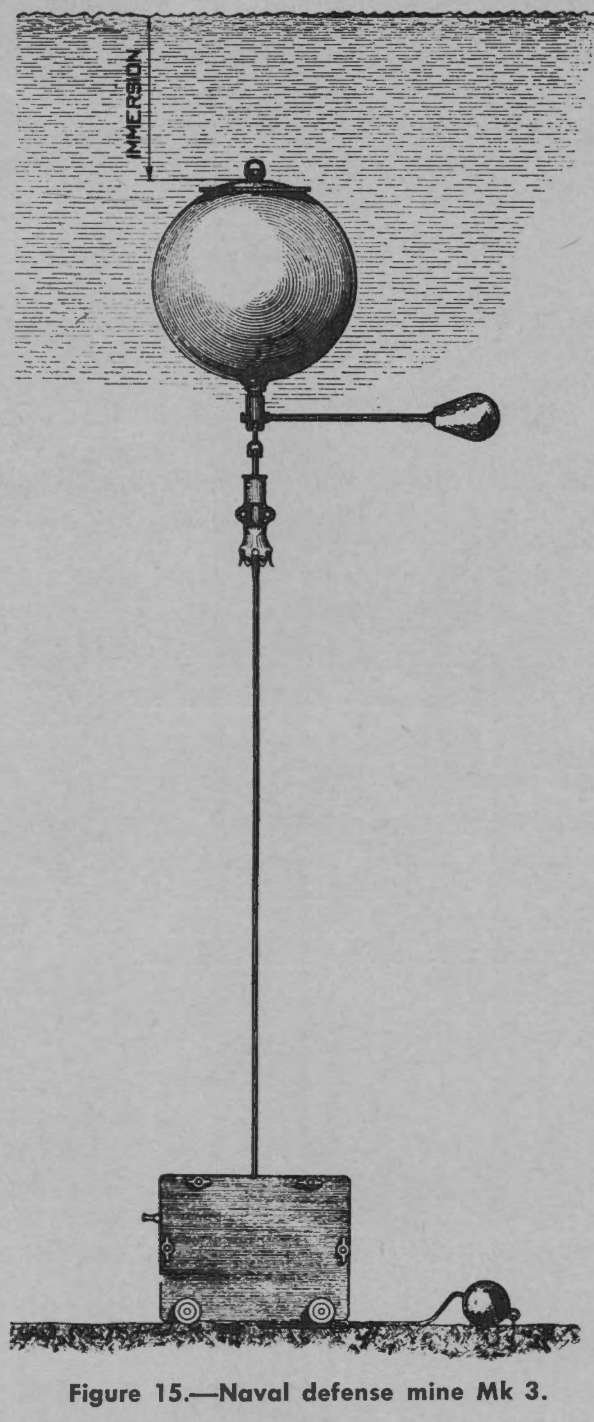



Figure 15.—Naval defense mine Mk 3.

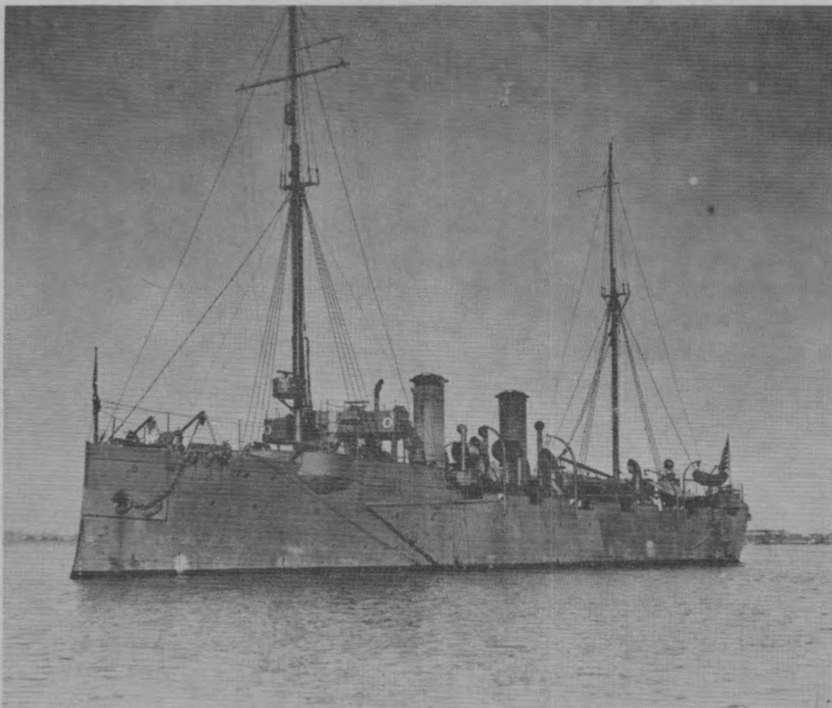


**Figure 16.—U.S.S. *Baltimore*.**

Bureau of Ordnance reports state that the U.S. mine potential is "very unsatisfactory."

In view of the fact that American ingenuity had been largely responsible for the pioneer development of this weapon, and that the Union Navy had lost a number of vessels from Confederate mines in the Civil War, it is surprising that the year 1917 found the United States in much the same position as it was at the conclusion of the Civil War.

## CHAPTER VII

# WORLD DEVELOPMENT OF MINES TO 1914

It is of interest here to see what other countries were doing during the 19th century with the American invention of destroying naval vessels through the use of underwater and undirected explosive charges, in which the Americans themselves had taken so little interest. Mines have always been classed as one of the secret weapons, so that in studying their use by foreign powers, we have to depend largely on the uses made of mines, which is sufficient for the purposes of this work. No attempt will be made to make these comments all-inclusive. It is only desired to point out that a number of foreign countries did note the possibilities of the weapon and did develop various types of mines which were used with considerable success.

As early as 1839, Sir Charles Pasley destroyed the wreck of the *Royal George,* using an underwater charge fired by an electric current remotely controlled. The charge, which was placed in position manually, is usually referred to as a "wrecking mine." However, the explosion was probably the first using electricity to initiate the explosion. The current was furnished from a control station and the firing operation was very similar to the electric detonating system used today. He was several years ahead of Colt's work in the United States.

As early as 1848 sea mines were definitely used as defensive weapons in Europe, although usually without any serious effect on the enemy. In the war of Schleswig-Holstein (1848–50), a field was planted to defend Kiel Harbor. Wine barrels were used as cases, and the charges, of approximately 300 pounds of gun powder, were to be fired by electrically heating a platinum wire placed in the middle of the charge. The source of power was a separate wet battery placed on shore for each mine. A small buoy was located over each mine, and in case an enemy ship appeared a man in a rowboat was to indicate by a pistol shot code which mine should be fired. The Danes learned of the existence of this field, and made no attack on Kiel. Just how much the minefield affected their decision is not known.

The Russians used mines extensively in the Crimean War in the vicinity of Cronstadt and Sweaborg. The British had been informed that the Russians had planted a number of these "hell machines," but in 1855 a reconnoitering trip toward Cronstadt was made by the English steamers, *Merlin*

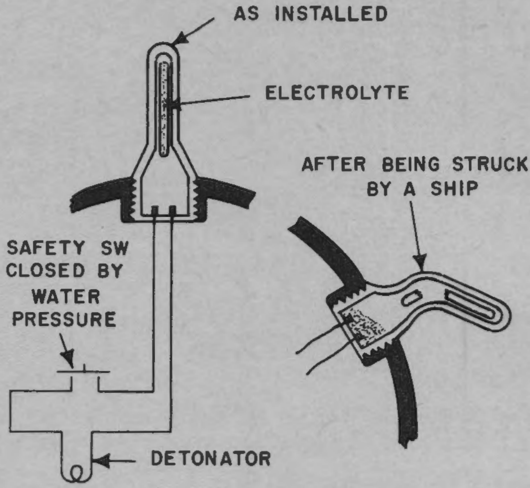



**Figure 17.—Hertz horn.**

and *Firefly.* Several mine contacts were made, and considerable damage occurred but apparently no lives were lost. Each mine contained about 75 pounds of powder but the cases may not have been 100 percent watertight and some of the powder may have been damp. Cronstadt was never attacked, and it is understood that the existing minefields were largely the reason. The mines used were of the moored contact type. The shock of the mine being struck by a vessel would cause the breaking of a thin walled glass tube containing sulphuric acid which would flow down into a quantity of chlorate of potash. The chemical reaction would then generate sufficient heat to explode the powder charge. This type of firing gear had been invented by Jacobi, an eminent Russian chemist, and was used by the Confederates in the American Civil War.

During the next half-century the Russians did considerable mine research and development work. They used mines against the Turks in 1877, and by the time of the Russo-Japanese War in 1904, were well equipped for mine warfare. They had adopted the Hertz type of firing gear (see next paragraph), and automatic depth-fixing anchors probably similar to those which had been invented by Great Britain.

In the Austria-German War, 1866, the coasts of Istria and Dalmatia were defended by what at that time were relatively elaborate fields, and in 1868 the Hertz horn (fig. 17) was invented which later became almost the standard way of firing contact mines. The lower end of the horn consists of electric battery complete except for the electrolyte. This electrolyte is contained in a glass tube which is housed in a soft metal horn, usually lead, which extends out from the mine case. When the horn is struck by a ship the lead bends over enough to break the tube, which allows the electrolyte, usually a potassium-bichromate solution, to flow into the electric battery, thus completing it. The terminals of the battery are connected to an electric firing scheme, usually a platinum wire in a mercury fulminate detonator.

In 1868 moored and drifting mines of the Jacobi type were used in large quantities in the war between Brazil and Paraguay. A Brazilian "ironclad" was sunk by one of these (in this connection "ironclad" only referred to surface armor, the hull was of wood). On the other hand, a whole Brazilian fleet passed over another minefield but fired no mines.

In 1870, during the Franco-German War, the Jode, Elbe and Weser Rivers were defended by minefields and thereafter the Germans attacked the mine development problem vigorously. At the beginning of World War I Germany was well equipped to wage mine warfare. She had controlled mines to use for harbor defense. She had accumulated large stocks of buoyant contact mines armed with Hertz horns, mounted on automatic anchors, which used hydrostats to lock the mooring cables. Most of her battleships and cruisers and many of her destroyers and some of her auxiliary craft were fitted to lay mines. She had also given some thought to laying special type mines from submarines.

In 1898, in the Spanish-American War, a small number of mines were planted around Santiago, Cuba, against the operations of the American Fleet, but no causualties occurred. The Americans made no use of mines in this war except to attempt to lay a field of controlled mines in New York Harbor.

However, in the next major war, Russo-Japanese in 1904, we find that mines have suddently become a major weapon. The Japanese had realized the value of submarine mines and had equipped their navy with a good supply of effective mines. The cases were armed with a contact inertia firing mechanism (a contact carrying pendulum free to move if ship contact was made) and were mounted on automatic depth-fixing anchors. Many of their destroyers and torpedo boats were equipped for mine laying, and some merchant vessels had also been modified into minelayers. Moreover, as has already been discussed in a preceding paragraph, the Russians also entered this war well prepared to carry on mine warfare. The results of mine warfare are therefore of special interest as this is the first war in which both countries entered the war fairly well equipped with mines and mine laying facilities.

Early in the war the Japanese began to use mines as offensive weapons. They were able to do this since their mines were equipped with automatic depth-fixing anchors and could therefore be laid in any water the depth of which was not beyond that permitted by the length of the mooring cable.

Probably their most successful offensive action might be called a "controlled" offense. Mine layers laid a field just outside of Port Arthur, and a day later a small Japanese decoy squadron lured a part of the Russian Fleet out of its port and were able to bring it to a location where it would probably pass over the minefields on its way back to port. A larger Japanese fleet then appeared on the scene, and the Russians, not prepared to battle a large fleet, withdrew to Port Arthur and passed directly over the minefields. Two large battleships struck mines. One was sunk with heavy loss of life, while the other was severely damaged but succeeded in reaching port. It was learned later that the Russians had observed the Japanese minelayers at work and had plotted their location, but possibly the fleet commanders considered mines useless weapons.

During the remainder of the war the Japanese contrived to lay mines repeatedly outside of Port Arthur, which the Russians continued to sweep away. In fact this area became almost a battlefield between the Japanese minelayers and the Russian minesweepers. In addition, the Russians repeatedly laid minefields in Japanese areas, and both Russia and Japan continued to lose ships. All in all, three battleships, five cruisers, four destroyers, two torpedo boats, one minelayer and one gunboat were lost while others were severely damaged.

Italy had not made any active use of mines during the period under discussion in this chapter, but she had displayed considerable interest and had developed several types of mines. One of these, the Elia, was later modified and adopted by the British and American navies.

Great Britain, the great naval power of this period, suffered a bit from mines in the Crimean War, but like most big-navy countries seemed to feel that her regular and long tried weapons were sufficient for her needs. The Royal Navy had (prior to 1873) developed a controlled mine system to be used as a defense for a temporary base. Two types were chosen, one to be fired directly from shore and another to be fired by an inertia firing device with power furnished by the control base. In 1873, an Admiralty Torpedo Committee was established and made extensive trials of other types of mines, but 3 years later recommended that only the two types mentioned above be retained.

Meanwhile, considerable experimental work was carried on in the H.M.S. *Vernon*, the Torpedo School at Portsmouth. Two important inventions were developed at this station during this period. The first of these was what the British called the "electromechanical" type and consisted of a mechanical or inertia type contact maker, with the electric power furnished by a battery contained in the mine case itself. This was apparently the first time that an electric battery was mounted inside the mine case. The other invention consisted of an automatic depth-fixing anchor. Up to this time moored mines were all laid with fixed length mooring ropes which had to be cut in length in accordance with the water depth. The automatic anchor was a mechanism designed to place the case at its desired depth within certain limitations fixed by the strength of the case, and the weight and length of the mooring cable. This made it possible for a mine planting vessel to steam on a line along which mines were to be planted and merely drop mines over at specified intervals. The distance between mines would be fixed by the time intervals and the ship's speed while the depth of the mines below the surface would be controlled by the automatic anchor. This type of anchor is described in more detail in chapter VIII.

These two improvements are of special value in automatic mines, but though invented by the English they were not adopted nor was any mine chosen for service use which could make valuable use of either invention, although, as pointed out, other countries did make use of it. In 1890 and again in 1891 the Commander-in-Chief of the Mediterranean requested automatic mines, but in 1894 it was decided to abandon mining and to keep the electromechanical mines for experimental and training purposes only. In 1900 the Commander-in-Chief of the Mediterranean specially requested an automatic mine design, and the H.M.S. *Vernon* was directed to develop the design. However, in 1903 the design was abandoned. The Navy still had its stock of mines of the 1873 lot which were considered of doubtful value, and control mining as a method of coastal defense was abolished and the Royal Engineering Corps of Submarine Mining was disbanded.

The general basis for the decision may be summed up as follows:

*a.* The success of controlled mining defense against torpedo craft was doubtful.

*b.* Increased range of guns made such defenses unnecessary.

*c.* Final decision should rest with the Admiralty.

*d.* Principal aim of fleet is to destroy the enemy's fleet.

*e.* Blockade mines could not seal up enemy harbors, and were therefore useless.

The use of mines in the Russo-Japanese War, however, did force the Admiralty to develop and standardize a British independent moored mine. It was a spherical mine carried on an automatic anchor and using an arm-operated firing mechanism. The old electromechanical mines were scrapped in 1907, when 1,000 of the new type became available.

In 1914, at the beginning of the First World War, the world's mine status was about as follows:

Germany had for many years studied mine development and had on hand a large stock of mines. She used the Hertz horn for firing device and an automatic anchor for independent mines. Practically all naval vessels and some auxiliaries were fitted to lay mines, and submarine mine laying had been studied. She also had available a supply of mines for controlled systems about her harbors.

Russia also had a large supply of mines for both controlled systems and independent fields. Many naval vessels were equipped to lay mines, and some mining from submarines had been tried out.

France and Italy had relatively small supplies of several mine types; Japan had not carried her development much beyond that of the Russo-Jap War, and most of the other smaller nations had small stocks of mines usually purchased from companies manufacturing mines for the larger European nations.

Great Britain still depended almost 100 percent on her fleet. She had about 4,000 of the so-called Navy Spherical Mines and had tried out some other types of mines adopted by other countries.

The United States' situation in 1917 for automatic mines was, as stated officially by the Bureau of Ordnance, "Unsatisfactory." A few thousand mines were in stock, and approximately 140 per month were being manufactured, but these mines were of a design which the British had discovered were not too satisfactory during the first 3 years of World War I.

CHAPTER VIII

# MINES FOR THE NORTHERN BARRAGE WORLD WAR I

The U.S.A. entered the war ostensibly because Germany was breaking the Rules of War established internationally (when there still appeared to be something chivalrous about wars). German submarines were sinking commercial vessels of all nations without making any effort to protect the lives of civilian passengers aboard and her minelaying ships were planting mines in locations frequented largely by commercial craft of neutral nations. The immediate and most urgent problem before the allies was to stop the ship sinking being caused by the German submarine fleet.

The British, with practically no mines available in 1914, had realized the tremendous value of the minefield weapon against submarines, had acquired fairly large quantities of mines, had developed fleets of minelayers and had laid many minefields to protect certain important harbors and passageways around Great Britain. The results had been fairly satisfactory. A number of submarines had been destroyed and, in general, submarines were avoiding these fields.

The possibility of laying a field of mines across the entrance to the North Sea had occurred to the British, but the number of mines required was so enormous and the possibility of success so dubious that the British decided not to do it. By the time the United States entered the war, the British were manufacturing about 7,000 mines per month and were hoping to soon reach 10,000 per month. The mines used were not entirely satisfactory. The British had had a relatively small supply of Vickers-Elia mines in 1914, which they had found were not suitable and so had adopted a horn type similar to that used by the Russians and Germans but had found it to be dangerous and not entirely reliable. In 1918, the U.S.S. *Baltimore* helped the British lay a field in the Irish Channel deep enough not to endanger surface craft. Skim sweeping a few days later proved that many of the mines were shallow and one mine exploded. This caused extensive countermining, apparently destroying most of the new field and it also reduced the assurance which the British fleet demanded that the area be safe to surface craft.

It is easy for a layman to feel that a minefield across the opening of the North Sea could completely seal the opening against the passage of German submarines, but this is not the case. With contact mines, when the ship and the case have to make actual contact, a 100 percent perfect mine can only protect a vertical area equal to a circle with a diameter equal to the diameter of the submarine, and, in general, mines fall considerably short of the 100 percent perfect requirement. Also, submarines had the ability in World War I to vary their depth down to from 200 to 300 feet beneath the surface and to create enough circles of say 60 feet in diameter to close up the outlet from the North Sea into the Atlantic would require an enormous number of mines.

To make the problem more difficult, the mines cannot be placed as close as 60 feet to each other. The explosion of one would seriously damage adjacent ones and might cause some of them to explode which could result in a chain countermining, thus destroying large sections of the field. Mines are always placed at presumably safe distances apart, and additional effectiveness is obtained by adding other lines of mines.

To digress a bit from the historical story, we may examine mathematically the defense characteristics of a minefield, and with mathematical license we shall assume the simplest possible case.

The mines are all perfect, they are all placed the same distance apart $(w)$ and are on the same level. The ships will pass perpendicularly through the line, and if surface ships their breadth at the mine level will all be $(b)$, or if submarines they will pass through with the widest part of the submarine of "$b$" width at the mine level.

If the center of the ship is more than $\frac{b}{2}$ feet from both a starboard mine and a port mine, the ship will pass through safely, so there is a distance equal to $(w-b)$ feet for safe passage—and a distance $b$ feet for unsafe passage. Therefore, the ship's chances of passing safely will be $\frac{w-b}{w}$ or the percentage of safety $=X=100\ \frac{w-b}{w}$ and the percentage of damage $=y=100-X=100\frac{b}{w}$.

The percentage for safety through the next line will be the same—so for two lines or

$$X_2=100\left[\frac{(w-b)}{(w)}\right]^2,$$

or for 4 lines

$$X_4=100\left[\frac{(w-b)}{(w)}\right]^4.$$

If the mines are placed 300 feet apart and the breadth of the ships is 50 feet, the—

Percentage of safety for one line = 83.3 percent.
Percentage of safety for two lines = 69.4 percent.
Percentage of safety for three lines = 57.8 percent.
Percentage of safety for four lines = 48.1 percent.

If we should consider the more difficult problem of submarines, who have a second (vertical) degree of freedom and also reduce the effectiveness of the mine to 50 or 75 percent, the safety area goes up very rapidly, so that the losses expected would be much lower than those shown above. The British decision that to create an effective field across the opening to the North Sea using their actual case-contact mine was beyond their resources is understandable.

However, regardless of the enormous development, production and planting problem, the U.S. Navy's Bureau of Ordnance, after studying the ship sinking data made available to the United States after this country entered the war suggested and pushed energetically the proposal to attempt to place a mine barrage across the openings into the North Sea. As early as May 9, 1917, a proposal was presented in this regard to the British, but it was not approved and on May 14, 1917, Admiral Sims stated that "bitter and extensive experience has forced the abandonment of any serious attempt at blockading these passages." Notwithstanding, the Bureau of Ordnance continued to study the problem and to seek some promising scheme for blockading the entrance to the Atlantic from the North Sea.

When the United States entered the war inventors all over the country tackled the problem of stopping the submarine menace. One of these proposed the use of a torpedo hanging vertically downward from a surface float with a long copper wire hanging vertically beneath the torpedo. If a noncopper ship made electrical contact with the copper wire, since both ship and wire were immersed in a chemical salt solution (the sea water) a small electromotive force would be generated. With proper connections and a sensitive relay mounted inside the torpedo, this electric current could release the torpedo from the float and start its engines. Theoretically she would dive downward, strike the initiating vessel and explode.

Naval authorities were confident that the seamanship requirement and the expense problems of the proposed scheme were impractical, but believed that the firing principle might be applied satisfactorily to a mine which would be particularly applicable to the North Sea problem. It appeared that the copper wire could extend both above and below the mine, to a distance fixed by the serious damage distance of the mine charge; probably 75 to 100 feet with a 300-pound charge of TNT. Such a mine, 100 percent perfect, would protect a vertical area equal in width to approximately the submarine's diameter and in height to the aggregate length of the two copper wires extending above and below the mine itself, plus the submarine's diameter.

The Bureau of Ordnance authorized the inventor to proceed with the development of a mine firing gear on this basis and by July 18, 1917, requested authority to build 125,000 of these mines at a total cost of $40 million. A month later, August 15, 1917, a detailed discussion of the proposed field took place with the Commander-in-Charge, Atlantic Fleet, and it was stated that the United States had already started the manufacture of 10,000 mines for its own use. The barrage proposal was considered at an

Allied Naval Conference in London on September 4 and 5, 1917, and the overall result was favorable to the United States undertaking the project, although in general the British Admiralty was not at all encouraging. But 10 days later, September 14, the Admiralty admitted that "any increase in the present rate of sinking might bring about an unsatisfactory peace" and that "some form of a barrage—must be reconstituted in such a form that enemy submarines cannot venture into it without considerable risk to themselves." This statement was about as far as they would go in approving the Northern Barrage of Mines.

On October 17, 1917, after much discussion of the Bureau's problem, the Secretary of the Navy finally authorized the Bureau of Ordnance to proceed with the procurement of 100,000 mines of this general type. Anticipating the favorableness of the final decision, the Bureau of Ordnance had already placed an order for 10,000 firing devices on August 9, 1917, and now proceeded to increase that order to 100,000. The U.S. Navy thus stepped into a $40 million operation requiring enormous quantities of material, enormous transportation requirements both inside and outside the U.S.A., many naval ships with corresponding crews to plant a minefield across 280 miles of ocean, something which had never been attempted before, to be managed by a group of naval officers, most of whom had had no experience in mine manufacture, assembly or planting. The British who had gained considerable experience with mines since the beginning of the war entered the project with little enthusiasm, but "fools step in where angels fear to tread."

The mines, with the exception of the firing device, were designed by the Engineering Department of the Bureau of Ordnance with the help and advice of a British mine expert. The mine was labeled Mine MK 6, because the few types of mines previously adopted by the Navy had used the Mks 1 to 4 inclusive, and the Bureau of Ordnance had adopted, but not designed, another mine as Mk 5. The firing device was called the K–1 device, later models being called K–2, K–3, etc., but almost all of the other mine accessories were labeled Mk 6 because they were designed for use with the Mk 6 mine. The design of the firing device was left largely to the inventor and to the engineers of the manufacturing concern. The Bureau of Ordnance furnished some testing space at the Newport Torpedo Station and the Navy furnished the U.S.S. *San Francisco* for testing the operation of the mine at sea.

A drawing of the mine, after being planted, is shown in the last sketch of figure 18. The iron box on the bottom is the anchor which holds the reel of mooring cable and the locking gear controlling the automatic depth taking of the case. At the side of the anchor is shown the plummet which is attached to a locking pawl in the anchor by the smaller cable shown. The length of this plummet cable fixes the depth of the case beneath the surface.

The case, a hollow steel sphere 34 inches in diameter contains 300 pounds of TNT, but it displaces sufficient water so that it has a buoyancy of about

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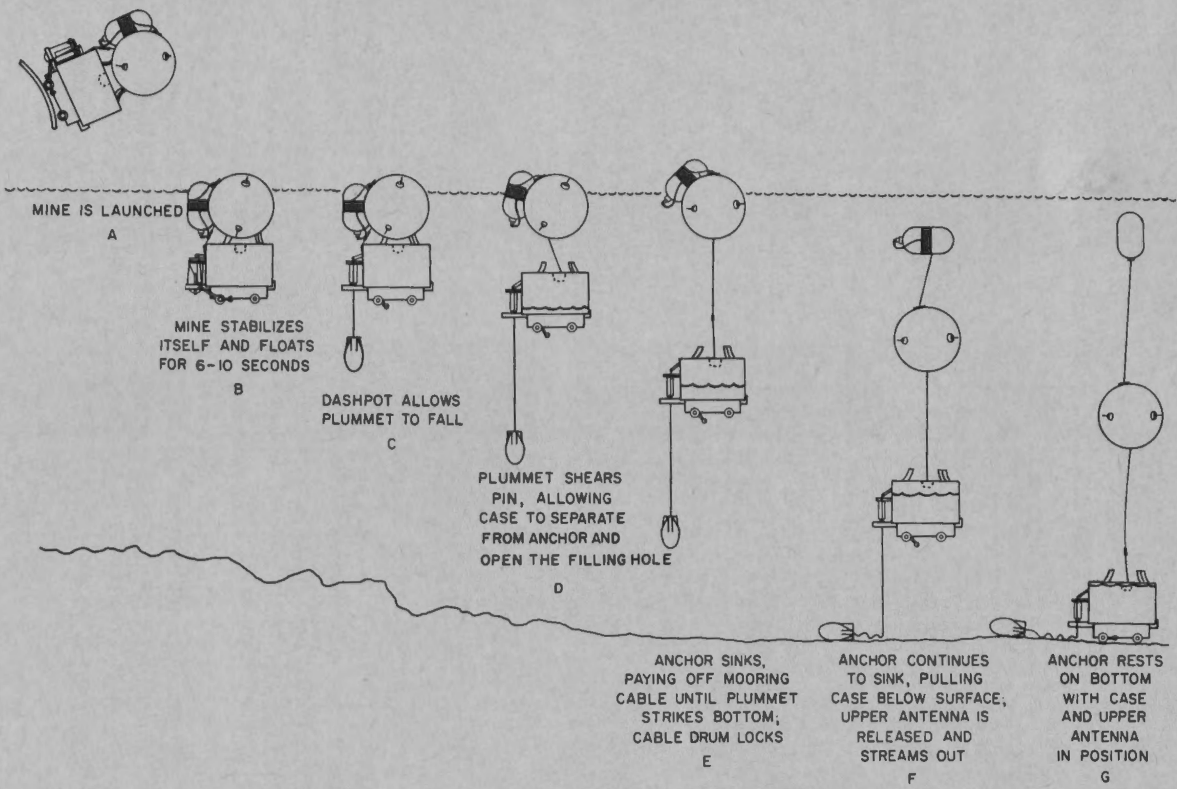



**Figure 18.—Mine Mk 6 planting sequence.**

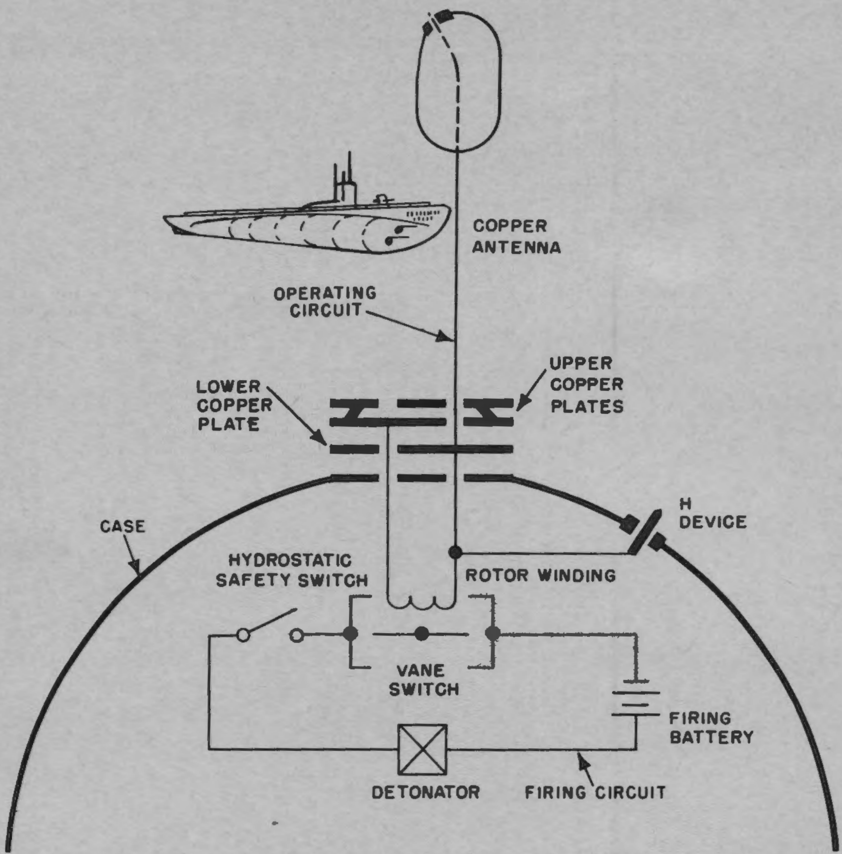



**Figure 19.—Operating and firing circuits of the K-device.**

300 pounds over and above the weight of the case, the charge, and the mine accessories mounted therein. From the case the copper antenna extends upward to a float, which may be 100 feet above the case, but is always submerged a few feet below the surface. This antenna is insulated from the steel float and the steel case. A connection from it passes through the firing device mounting plate, then to a sensitive relay and then back out through the mounting plate to a copper disk mounted on the outside. A mine was later designed, but not used during World War I, with both an upper and lower antenna, as was originally proposed for this mine, but even with a single upper antenna 100 feet long, the mine's danger area is more than twice that of a case-contact mine.

Since seawater is a salt solution, it may be considered the electrolyte of a voltaic battery, but since the metal system exposed thereto is all copper, no current develops. If a steel ship touches the antenna the battery is completed and a small current flows through the relay which closes an electric circuit containing the firing battery and the detonator. The two circuits, i.e., the "operating" and the "firing" are shown in figure 19.

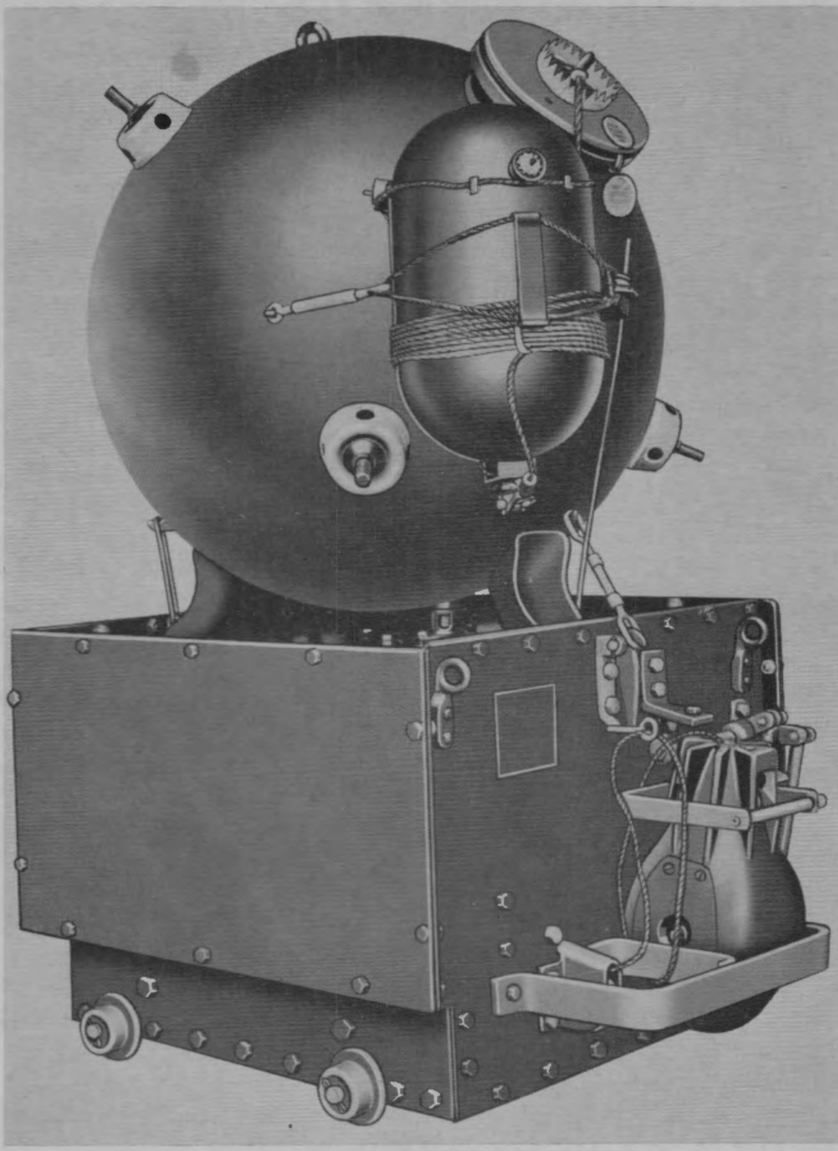


**Figure 20.—Mine Mk 6.**

Three safety devices were provided, one a time delay to mechanically hold the firing switch open for a few minutes after planting, one hydrostatic to hold the switch open until the case was several feet beneath the surface, and a third to keep the explosive steps open until the case had reached considerable depth.

A photograph of the complete mine assembly is shown in figure 20, while the operation of the automatic depth fixing operation is shown in figure 18. The plummet hangs on the side of the anchor and is mechanically supported in that position while the assembly is on the minelayer's tracks. As the assembly falls away the plummet is still retained in this position for a few seconds by a dashpot. The whole assembly at this stage is buoyant because the anchor contains very little water, and fills but slowly since a filling hole is kept closed by the position of the case.

When the dashpot releases the plummet it falls away unreeling steel cord from a spool inside the plummet. The cord passes through a case-anchor releasing device and the upper end is secured to a pawl which can lock the mooring rope drum inside the anchor. As the plummet reaches the end of its cord its pull releases the case from the anchor and holds the locking pawl away from the mooring rope drum. The anchor then sinks leaving the case on the surface until the plummet strikes bottom. As its cord slackens, the pawl locks the mooring rope drum, so that the anchor, which is now full of water, pulls the case below the surface a distance equal to the length of the plummet cord. As the case sinks a hydrostatic float-release operates and allows the float or floats to rise, unreeling the antenna. The MK 6 had only a single upper antenna.

Largely to encourage secrecy, and partly to use as many different manufacturing plants as possible, the mine assembly was made in small parts and finally assembled at a naval station. Most of the parts were such as to fall in line with auto manufacturing work and so were assigned to auto plants. After some progress in manufacture the Bureau of Ordnance found that it could easily exceed an original requirement of 1,000 new mines per day.

To ship mines to England at the rate of 1,000 a day required a plant where these cases could each be loaded with 300 pounds of TNT at that rate. The Navy had no such loading plant and the large explosive manufacturing companies, enormously expanded to meet Europe's requirements, had no plants where this demand could be met in addition to the other war demands of both Europe and U.S.A. The Bureau of Ordnance and the Bureau of Yards and Docks studied the problem and finally decided to build a new plant at St. Julien's Creek, Va., where the Navy already had a small ammunition depot. The plant was on the river, and the water was dredged deep enough to allow seagoing ships to load at the docks. Ground for the plant was broken October 25, 1917, and it was ready for operation in March 1918. It consisted of 22 buildings, among them a storage building capable of storing 5,000 empty cases; a melting plant with automatic machinery to melt and pour at least 300,000 pounds of TNT per day into 1,000 mine cases; a cooling building and an explosive storage building to hold 4 million pounds of the TNT, a heating plant and a wharf.

During the loading operation it was found that the capacity of 1,000 mines per day could be exceeded. At one time, 1,500 mines were loaded in 24 hours. During the barrage project 73,000 mines, involving the handling of 22 million pounds of TNT, were loaded at this plant without accident. An additional 17,000 mines were loaded at a commercial plant before this plant was ready for operation. A loading plant of this type and capacity had never been built before either in this country or abroad. Safety precautions were installed and the pressure of the heating steam was limited but there was no time to experiment with these details before placing the plant in operation. Its success is a credit to the careful study of the problem by the plant's designers and the meticulous care of its operators.

As has already been pointed out, the mine parts were manufactured in different plants well scattered over the country, and each manufacturing contract covered only the assembly of the specific mine accessories covered by its contract. During the manufacturing only a relatively few mines were completely assembled in the U.S.A., some to serve for spot checks on the material being manufactured and some to use for experimental tests by the U.S.S. *San Franscisco.* Otherwise, all of the material, except loaded cases, was shipped to a shipment base from which it was loaded into vessels bound for assembly bases in Great Britain. The loaded cases were loaded directly into the ships at St. Julien's Creek for delivery to these mine assembly bases.

To ship 1,000 mines per day required a ship loading capacity of from 1,500,000 to 1,700,000 pounds per day. The Bureau of Ordnance and the Bureau of Supplies and Accounts studied the needs and leased a Southern Railway pier at Primus Point, Va. This pier is 875 feet long and 270 feet wide and can accommodate seven cargo vessels of the type used. These vessels averaged about 3,000 tons dead weight capacity and when loaded drew less than 20 feet depth. Twenty such vessels were assigned as mine carriers and were modified to provide for arming, for additional crew space and for additional fuel capacity. In general, a cargo consisted of 2,000 mines and about 500 tons of other naval supplies. It was hoped to ship at the rate of at least 3,500 mines per week but this was later increased to about 6,000 per week. Of the 24 carriers only 1 was lost. The *Lake Moor* was sunk by submarine April 11, 1918, with about 1,500 tons of mine material. Unfortunately, most of her crew were also lost.

Those planning the barrage anticipated that the mine planting fleet could use 3,500 mines per week so that all of the auxiliary assembling details were worked out to furnish more than this, up to 1,000 per day if necessary. In order to handle the material being shipped from America and get it ready to transfer to mine planters in Britain, elaborate assembly bases would be required to completely assembly at least 3,500 mines per week. The Admiralty appointed a Board on October 6, 1917 to investigate and report on suitable assembly bases. On October 26, the Board recommended two large distilleries in Scotland, the Dalmore at Dalmore and the Glen Albyn at Inverness. Some modification was needed and special shops had to be provided. Satisfactory arrangements were worked out with the Admiralty; some material was furnished from America and some from Britain. On February 9, 1918, the U.S. flag was hoisted over the Inverness Base (Base 18), and on February 12, over the Invergoden Base (Base 17).

Mine assembly parts were discharged from the mine carriers at Carpach or at Kyle. Those landing at Carpach were delivered by lighters to Base 18, while those at Kyle were shipped by rail to Base 17. The first load of parts reached Carpach April 5, 1918, and loaded cases reached Carpach May 21 and Kyle May 29. The mine assembly plan was similar to that used in automobile manufacture. An anchor or a mine was moved along various stations on a track and at each station various parts were added. The original estimates for the time required for transportation in Britain and for assembly were far too great. The two bases were designed to furnish 3,500 mines per week but could, when necessary, assemble 6,000 per week.

In planting fields of this type, mines are assembled as fixed ammunition and are planted by dropping a mine off the stern of the ship at such intervals, determined by the ship's speed, to place the mines at desired distances apart. Each layer then lays a line of mines in length equal to the number of mines laid times the distance between each mine. Any delay in the furnishing of mines to the dropping device, will, of course, create a gap in the field.

At the initiation of the barrage project the Navy, due to its peacetime lack of interest in mining, had but two minelayers, the U.S.S. *San Francisco* and the U.S.S. *Baltimore,* which together could carry but 350 mines. In order to meet the proposed demand of planting 3,500 mines per week, the Navy desired to obtain enough planters to carry at least 5,000 mines at a single loading. Eight additional commercial vessels were obtained and were modified to serve as minelayers. To get the needed mines aboard, two decks usually had to be used, and therefore elevators, or ramps, must be installed. Several other nations had tried and abandoned elevators, but a large elevator company in this country designed an elevator which would carry two to four mines per minute from one deck to another.

The sudden expansion of the mine force from 2 ships to 10 ships required a similar expansion of trained crews. The Bureau of Navigation established a special training camp for minelayers, to which 1,050 men were assigned and as each new layer went into commission her crew was drawn from this camp. The new minelayers, after 4 to 5 months of remodeling and a very rough and dangerous trip across the Atlantic, finally arrived at the two mine bases in Scotland on June 2, 1918, only a day or two after complete sets of mine parts became available.

## CHAPTER IX

# THE NORTHERN BARRAGE— PLANTING AND RESULTS

When the United States entered the war and proposed to develop a new mine and build enough to lay a barrage 250 miles in length, the British were inclined to be pessimistic and at first discouraged the whole project. A few months later they appeared more optimistic. Whether it was because submarine sinkings were so serious that they were willing to try anything is hard to tell, but in any case the Planning Section of the Admiralty drew up a definite plan for the barrage and submitted it to the U.S. Navy in September 1917 and asked for general comments.

The barrage as proposed ran from Aberdeen to Norway and was divided into areas as follows:

**Area B**—Next to Aberdeen, to be mined by the British using British mines. Deep mines only would be used—leaving the surface clear for surface craft.

**Area A**—Extending toward Norway from the eastern end of Area B; the area to be mined from the surface down to 200 feet and the world notified of this dangerous zone. American mines planted by American ships were to be used. This section would require 36,300 American antenna-type mines.

**Area C**—Extending from the eastern end of Area A to the Norwegian water area—using American mines, if possible, but the surface to be left clear. 18,000 American mines or 45,000 British mines would be required.

The Bureau of Ordnance assumed that this would be the final plan and ordered its manufacturers to meet its requirements. The mine assemblies would differ in the amount of mooring rope on each anchor. Steel mooring cable was one of the most difficult items to obtain. Cable companies were loaded with demands for cable for other purposes. Therefore to save cable the Navy grouped the anchors into several lots each wound with a different length of cable, always somewhat greater than would be actually required and in planning shipment the Bureau of Ordnance would always ship anchors with cable lengths applicable for the area in which those mines were to be used. The Bureau's plans assumed that there would be no basic changes in the proposed barrage.

Actually these plans were not approved by the Chief of Naval Operations until November 1, 1917, but he had authorized the Bureau of Ordnance to proceed on October 15, although the Bureau of Ordnance had already proceeded in September.

As late as October 23, the Admiralty had again given its approval of the plan as proposed in September. However, the British Admiralty continued to study the project. They did not want to permit any action which would prevent the Grand Fleet from operating freely in the entrances to the North Sea. They were still hoping that the Grand Fleet would have the opportunity of meeting the German Fleet in battle. Minefields must therefore be carefully located, and the mines in the deep fields must be proof against breaking away and coming to the surface in active condition. The British had found that their own mines were far from proof against this failing. Their studies led them to change the location of the barrage and to reduce to some extent its completeness. The new plans were submitted to the U.S. Navy Department December 7, 1918, and since they were based on broad strategical and technical grounds, the U.S. Navy Department reluctantly accepted them; since as noted in a U.S. Navy memorandum "it was deemed best by the Grand Fleet upon which will rest the responsibility for support and patrol."

The U.S. memorandum also pointed out some of the tactical objections to the new plans. It stated that:

"It will be noted that the original line extended from mainland to mainland, while the new line extends from island to island and has in it passages completely navigable to submarines. This condition is, in our opinion, undesirable.

"The proposed character of the barrage does not provide for the full accomplishment of the mission. The proposed barrage will not close the northern exit from the North Sea because—

'(*a*) The barrage is not complete in a vertical plane in areas B and C.

'(*b*) The barrage is not deep enough.

'(*c*) The Pentland Firth is open.

'(*d*) The waters east of the Orkney Islands, for a distance of 10 miles, are open.

'(*e*) Patrol vessels on the surface are not sufficiently effective in barring passages to submarines.'

"The barrage is to be a great effort. It is our opinion that nothing short of a sound design will justify the effort.

"The requirements of a sound design are the extension of the barrage complete in the vertical plane from coast to coast."

The new areas A, B, and C were now defined as:

**Area B.** A 20-mile-wide section extending 50 miles to the eastward of the Orkney Islands, and to include only deep mines; that is 65 feet to 100 feet. British mines were to be used.

**Area A.** A 50-mile-wide section extending 134 miles east-northeast from the end of section B, to be mined from 10 feet down to as near 300 feet as U.S. mines will permit. All U.S. mines in this area.

**Area C.** A 50-mile-wide section extending east-southeast 60 miles from the eastern end of section A, to be mined from 65 feet down to 200 feet. British mines to be used.

Figure 21 shows the geographical location of the three areas, while Figure 22 indicates the depth of mines proposed for each area.

Aside from the tactical objection to the newly proposed barrage the Bureau of Ordnance found that to prepare the mines for it considerably increased the manufacturing difficulties. In the newly proposed area, the water was in general deeper than that occurring in the areas of the first proposal—so that in the mine anchor delivery program, longer mooring cables were often required. The Bureau feared that this would delay the mines' delivery dates.

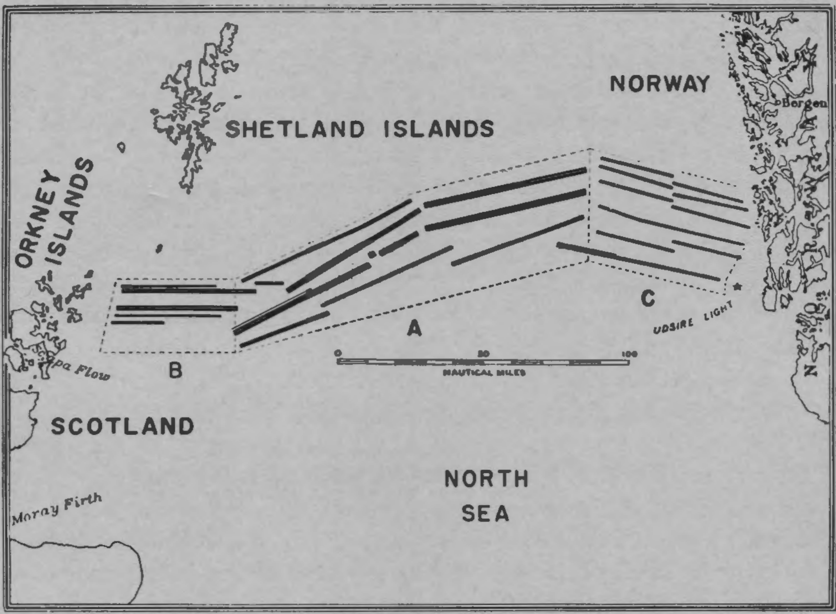



Figure 21.—Location of Northern Barrage.

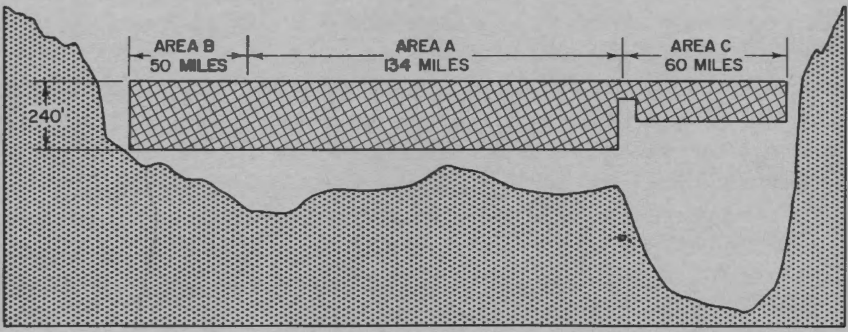



Figure 22.—North Sea Barrage vertical projection.

There was considerable criticism among U.S. naval offices over the Admiralty's final decision. The barrage finally agreed to was quite different from the original proposal. It was felt in American naval circles that the Admiralty and the British Grand Fleet had no great faith in the new American mine. In particular, the assignment of the British mine, which the Americans though was an inferior one, to both ends of the barrage, and the decision that the American part of the barrage was not to be patrolled, was most discouraging to the U.S. Navy planners and, as one said, "the faith of its (the Barrage's) proponents in its effects was no longer felt to be justified". The United States argued continuously for a more complete minefield, but the British wanted to keep certain areas absolutely safe for the use of surface craft and of the Grand Fleet, and were not as confident of the safety of the area over the deep fields as the Americans were. They would prefer to reduce the fields' effectiveness against German submarines in order to assure more safety to their own surface vessels.

As the mine planting program progressed, it was found that the British were entirely correct in their fear that the new U.S. mine, built in enormous quantities without complete development testing, would not be entirely dependable. American mine cases broke loose and were washed ashore, many leaked and sank, and the firing devices often prematured and frequently produced chain countermining which, of course, produced breaks in the field. On the other hand, a large percentage remained effective and the German submarines did not know where the relatively small gaps were.

The discussions concerning the Northern Barrage are covered here in a very general way to show something of the confusion which existed during the planning of the project. Such disagreements are bound to occur when two countries, or even two services of the same country (as occurred in U.S.A. during World War II) attempt to make use of a new weapon (here fields of mines) whose relative performance and operational value have not been demonstrated. Both United States and Great Britain had allowed themselves to be drawn into a war with practically no mines against the enemy, whose submarine tactics, completely in opposition to international war agreements, demanded the effective use of great quantities of mines. The British had had 3 years of experience developing and using mines. They knew that mines often performed not the way their designers had intended them to do, and were therefore skeptical of their performance until it had been proved. The U.S. Navy had suddenly developed a new mine in which it had great confidence and was building great quantities of them for use before performance tests had been performed.

However, once decisions had been reached and the project approved, the British gave the U.S. Navy all the help they could and the two countries cooperated and worked very closely during the completion of the project. The British and American mine laying squadrons usually worked together under the escort of a group of British destroyers. However, the British were obligated to lay and maintain other fields and their destroyers had many

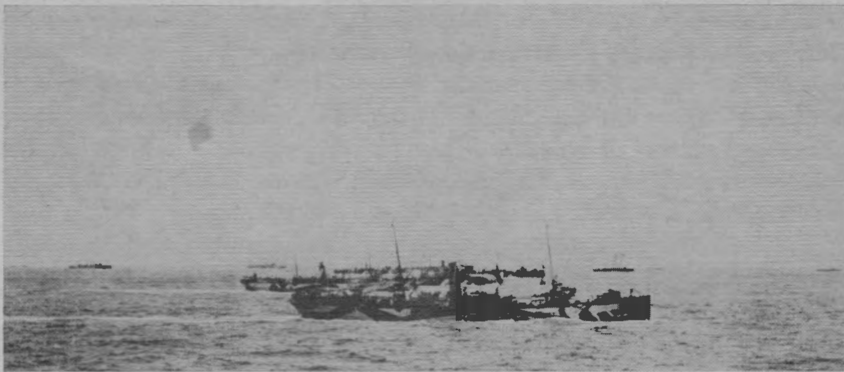


**Figure 23.—The American Mining Squadron planting mines.**

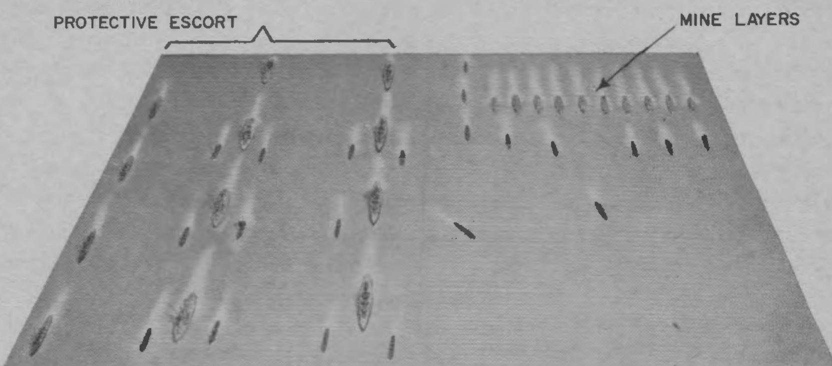



**Figure 24.—Model of an actual minelaying operation.**

other duties, so that at times during the laying project the American layers were delayed somewhat waiting for the British destroyers to escort them.

The story of the actual planting of the barrage can be told in a relatively few pages. On June 6, 1918, the British and American minelaying squadrons carried out their first Northern Barrage mine-laying excursion. The squadrons were guarded by British destroyers. Figure 23 is a photograph of the mine-laying fleet. Both squadrons continued to operate as rapidly as possible. The U.S. group averaged one trip per week. It was delayed a bit from time to time, usually because of waiting for escorts from the British Grand Fleet or for the British mine squadron. No serious trouble developed among the minelayers. There were no mine explosions, either at the assembly bases or among the mine-laying craft. The British laid their areas and in a number of cases both mine squadrons worked together on a single mine-laying project. On one excursion 5,520 mines were laid by the American squadron in 3 hours and 50 minutes. Figure 24 is a photograph of a very accurate model of an actual mine-laying operation.

The barrage program was changed in minor ways as the laying continued; more mines were laid here and there if an area was discovered which German submarines were using. Laying continued without cessation up to October 26, 1918, and the American squadron was ready for its 14th excursion on October 30, but were delayed by weather conditions for a few days, and then the war situation clearly indicated that the end was very near so that all minelaying was discontinued. Altogether, the U.S. Navy planted 56,611 mines of American manufacture and the British planted 16,300 mines of British manufacture.

The U.S. Navy has no way of knowing just what percentage of mines became effective. If any of the automatic features covered in the description of the mine given in chapter viii fail to operate satisfactorily, then a floating mine, a sunken mine, a dead mine, or a premature, may occur. The fault most often noticed during the planting operation was premature firing. On the average some 4 to 8 percent would fire immediately after the laying operation. The British furnished the U.S. Navy testing areas, and the U.S. mine forces carried out much experimental work, which because of the urgency of the project had not been carried out in the United States, but the minelaying was not delayed by the experimental tests.

Admiral Strauss, in summing up the final status, reported: "Had it been possible to carry out mine-laying operations as fast as the necessary mining material was received and assembled, the American portion of the North Sea Barrage could have been completed by the latter part of September, 1918. The frequent delays, due to the necessity of waiting for escort to be supplied by the Grand Fleet, or for the British mine squadron to complete its preparations so as to be able to go out at the same time, prevented the barrage from being completed prior to the signing of the armistice with Germany on November 11."

Area A, mined by American mines, needed 6,400 additional mines, about 15 percent; area B, a British responsibility, was not mined until late in the project; while area C was the weakest area in the barrage. It was proposed to mine this to a depth of 200 feet, but the British completed it only to a depth of 125 feet. In these two areas, which the British had agreed to cover, they requested and received help from the U.S. Navy. The British and U.S. Navy each laid about 15,000 mines in these areas. Throughout most of this period there was an open lane along Norway. It was finally mined by Norway about October 7, 1918.

Areas B and C were never mined against surface craft, but were supposed to be continuously patrolled to catch any submarine that might try to pass them on the surface. However, it was never possible to maintain these controls continuously. There was too great a demand for suitable patrol ships in other antisubmarine work and in escorting convoys. Apparently the Germans were able to keep a fairly accurate record of the locations where mining was being done. As the United States progressed on area A, German submarines chose to pass through areas B and C which were poorly mined and some sections not at all. As area B was completed the submarines tried other lanes to the Atlantic, the one through Norwegian water appearing to be the most popular. This remained up to within 1 month of the end of the war. A surprise mine-laying project was carried out in area B on September 7, 1918, when it was realized that German submarines were choosing this passage. On September 8 the *U–92* was sunk in this field and another submarine was so severely damaged on the way to the Atlantic that she was forced to return to her base. She returned by passing through area A which was also poorly mined.

As pointed out above, a mine barrage can never "close" a passage. In the final status of the Northern Barrage, if every mine planted remained effective, a submarine passing through at a level of 50 feet or less had theoretically one chance in three of not striking mines, while at depths from 50 to 250 feet she had two chances out of three. Considering the ineffective mines and prematures, the chances were much greater, possibly twice, but even with these chances a German submarine commander has stated that mines were by far the most dreaded of any antisubmarine measure used by the Allies in that World War.

The barrage was without question one of the largest projects undertaken by the Navy in World War I. Was it worthwhile? How much submarine damage resulted? How much would have resulted had it been completed? Did it shorten the war? Did it speed up the day when the German sailors and submariners revolted? These are questions which operational strategists can argue about indefinitely and never get an answer. We know it sank at least six submarines, and possibly more, and we know at least that many were sufficiently damaged that they were compelled to return to their bases. Those that reached the Atlantic were delayed by picking their way through the weak areas thus wasting valuable time and fuel. The barrage must therefore have decreased materially the number of ships sunk during the last 6 months of the war. The barrage was never completed. Had it been completed and had the war lasted 6 months or a year longer the value of the barrage could be more accurately evaluated. In any case every estimate made of ships and cargos saved indicates that the enormous cost was well worthwhile.

Admiral Strauss, in summing up the effort, remarked as follows: "The mine as a weapon of nautical warfare now presents greater possibilities than ever before. The United States in less than 1 year was able to construct a squadron of minelayers and produce sufficient mines to keep them constantly employed, laying on each excursion in less than 4 hours more mines than the United States had ever possessed prior to her entry into this great war. Too much credit can not be given to those who designed the mine. Clever, simple, and effective, this mine proved, perhaps, the most efficient single weapon against the enemy's submarines. Equally as remarkable as the invention of the mine itself was the development and production by the Bureau of Ordnance. Any complicated instrument of this nature, ordinarily, requires years of experiments and modifications before it finally becomes sufficiently satisfactory and reliable to allow it to be used. Time, however, was the supreme factor. Every minute counted in order to save the merchant shipping and the wise forethought and judgment of those to whom the production of the mine was entrusted should go down in history as one of the most worthy achievements of the war. Minor defects and difficulties, of course, were encountered in the actual operation and handling of the mines, but these were also met and solved on the spot by the U.S. mine force."

The old story of mines had again been demonstrated. The U.S. Navy had lived through a long period of peace without getting in any way interested in sea mines as a weapon of war. Other countries had used them with considerable success. World War I broke out and the Germans used mines in quantity. Great Britain, starting the war with practically no stock of mines, became interested, developed new mines, and used them fairly widely, but when the United States finally entered, 2½ years later, it had a stock of only three or four thousand of a type which Britain had found entirely unsatisfactory.

However, within a few months after the United States had declared war, the U.S. Navy proposed embarking on a mining project away beyond anything that had ever been attempted before. Once approved by the British, every section of the U.S. Navy allowed nothing to prevent its carrying its share of the load. The Bureau of Ordnance built and assembled the mines, the Bureau of Yards and Docks designed and built the mine loading plants, mine assembly depots, etc., the Bureau of Ships procured the mine carriers and the minelayers, the Bureau of Personnel developed and managed special training schools, while the Bureau of Supplies handled the whole business end most acceptably.

The U.S. Navy's activities in the tremendous effort of designing, manufacturing, transporting and laying the mines in this enormous field can not be concluded without a few paragraphs on how these mined areas were again made safe for water transportation. The method of destroying these moored minefields by sweeping the area, using two tugs to drag a heavy sweep cable over the area, has been very briefly described in chapter II and figure 2. The operation is a much more dangerous one than the laying operation. During a mine-laying excursion the minelayers are usually protected by a screen of cruisers or destroyers, and the area is ordinarily not sufficiently crowded to force the minelayers to operate close to where mines have been laid. When sweeping, at least one of the sweepers must necessarily travel over a mined area.

The sweepers did use one safety precaution, which was supposed to make it impossible for a sweeper to cause a mine to explode even when it actually contacted one of the mine firing horns or the antenna. Ordinarily the electric potential of iron is negative to that of copper when both metals are placed in the same electrolyte. However, it had been experimentally proved that if the positive terminal of the sweeper's electric generator was grounded to the ship's structure and the negative terminal connected to

**Figure 25.—Mine exploding close to a minesweeper.**

a towed insulated lead several hundred feet long, with the last 2 or 3 feet bared of insulation, the ship's natural potential could be artificially raised to about that of copper, when a current of approximately 100 amperes was flowing through the circuit. The rotation of the rotor in the K devices used during the war was limited to the direction of rotation produced when the copper antenna could send its current to the iron ship and could not operate if the iron structure had an electric potential higher than that of the copper. Therefore, an excess of current through the protective circuit would only serve to lock the rotor in the open position.

This protective circuit did not prevent mine cables becoming tangled with the sweep cable, forcing the mine assembly to be drawn into the sweeper for the untangling operation. Of course, the mines themselves are all equipped with safety devices to make the mines harmless when they are lifted out of the water, but after several months in sea water such devices often become locked with sea growth. Several mines exploded during these untangling operations seriously damaging the sweeping ships and in one case killing the ship's Captain and injuring members of the crew.

Most areas were swept at least twice, and some areas as many as three times. In the first sweep, the sweep wire was usually set at a depth to strike only the antenna. Ordinarily, this would fire the mine, and oftentimes this explosion would cause other mines to explode, some of which might be very close to a sweeping ship. Figure 25 shows a photograph of such an explosion. In other sweeps the cable was set lower to cut the mine mooring cables.

By September 1919 the barrage was considered completely swept and safe for sea transportation. Between 75 and 100 ships, including submarine chasers and trawlers, had been used in the minesweeping operation. Upon its completion, Admiral Strauss received a congratulatory message from the Secretary of the Navy which included the following: "—This most arduous and dangerous work, one of the greatest and most hazardous tasks undertaken by the Navy, and which has been carried on with cheerfulness and integrity, will go down in the annals of history as one of the Navy's greatest achievements—."

## CHAPTER X

# MINES IN GENERAL—WORLD WAR I

Aside from the Northern Barrage, the Germans and the British both planted a great many mines during the war. The Germans had adopted mines as a valuable naval weapon as early as 1870, and had proceeded with development work in designing mines and minelayers. In 1914 they had a good supply of mines assembled with automatic depth taking anchors, and all her battleships and cruisers and a large number of her destroyers and auxiliaries were fitted to lay mines. They had also given consideration to the design of a mine-laying submarine. All of the mines used the Hertz horn as a firing device.

By the time war was actually declared a German minelayer, the *Koenigin Louise* was well on her way across the North Sea with a load of mines, and laid what was probably the first World War I minefield off Lowestoff on the night of 4 or 5 August, 1914. She was sunk the next day by the British cruiser *Amphion*, which only a day or two later was sunk by one of the *Koenigin Louise* mines. Quick work as far as the use of mines was concerned. Throughout the war the Germans continued to lay mines in regular shipping lanes in the European area and some of her commerce raiders carried mines to all parts of the world. She also fitted several of her submarines to lay small minefields here and there. One of these planted a field off the east coast of the United States. The U.S.S. *San Diego*, an American cruiser, was sunk by one of these mines.

The British war vessel losses to German laid mines were considerable. Five battleships: the *Audacious*, the *King Edward VII*, the *Russell*, the *Irresistible*, and the *Ocean*, as well as a considerable number of cruisers, destroyers and other smaller craft were sunk by German mines. The *Hampshire*, one of the cruisers, was lost while Lord Kitchener, the British Secretary of War, was aboard. His death was a very damaging blow to the Allies.

Turkey, Germany's ally in that war, had purchased a relatively small supply of both independent and controlled mines from foreign sources, but those few played a very important part in the defense of the Dardanelles when they were attacked by the British in 1915. There two British battleships and one French battleship were sunk by these mines, which practically stopped the whole Dardanelles campaign.

Meanwhile, the Allies were not entirely helpless. Like the Germans, the Russians had been using mines since 1850. The results of the Russo-Japanese War had vindicated the need of mines, so that by 1914 the Russians had a large stock of both independent and controlled mines, some fitted with Hertz horns and others fitted with an inertia-type firing gear. They used these around their own harbors. In 1916, 11 German destroyers attacking a Russian force at a Baltic port were defeated by a minefield although not a single shot was fired. Only 4 of the 11 escaped. At another time a German battle fleet was turned back by mines in their attempt to take control of the Gulf of Riga. Three of their greatest ships had to be returned to a navy yard for extensive repairs.

The Italian naval staff had for many years shown considerable interest in mining and by 1914 had supplies of several types of mines and a number of minelayers; but had apparently set up no definite policy for their use. These mines were used in the Mediterranean during the war.

As pointed out above, Britain had never shown any marked interest in mining. However, only a few days after war was declared, she found a German minelayer laying mines very close to her coastline and a day or two later one of her cruisers was sunk by a mine explosion from this field. More fields were planted by the Germans within the next few weeks but they were discovered promptly and swept by the British, but some sweeping vessels were lost. However, the fact that the Germans were planting small minefields with no warning brought pressure on the Admiralty to follow suit at least to some extent. The British objected to using mines indiscriminately for humane reasons, they had no supply of satisfactory mines, and were also forced to consider the freedom of the Grand Fleet in her use of the North Sea. In fact, one of the early fields planted by the British had to be swept to permit the Fleet to carry out certain operations.

However, after due consideration, the British decided to—

*a.* Adopt controlled mining for harbor defense.

*b.* Procure a satisfactory mine and build thousands of them.

*c.* Use them as widely as possible to restrict the use of German submarines without unnecessarily limiting the broad and general use of the Grand Fleet.

With this policy in mind, the British proceeded to—

*a.* Adopt a Hertz-type mine assembly.

*b.* Procure 7,500 Russian mines left in Port Arthur after the Russo-Japanese War.

*c.* Modify many suitable craft for surface minelayers.

*d.* Modify several submarines for minelayers.

*e.* Design and build special mines for use from these submarines.

They laid several mine barrages, the most valuable ones being across the Irish Channel, they worked with the Americans in establishing the Northern Barrage, and they laid many small fields in the neighborhood of Heligoland. The Irish Channel Barrage sank at least 10 submarines, and their use of

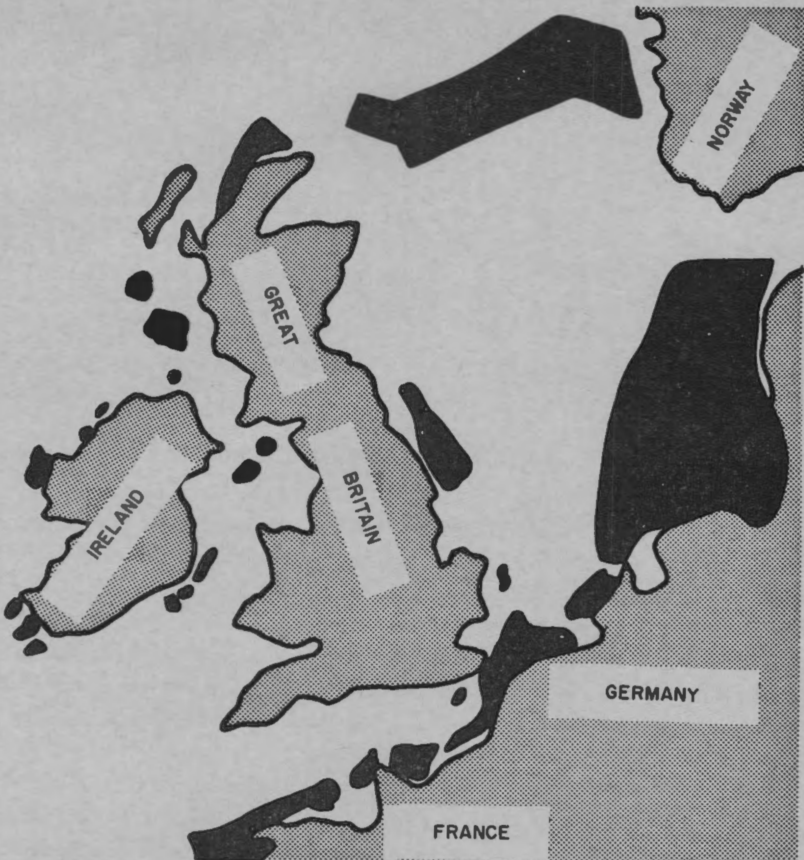



**Figure 26.—Areas mined by the Allies west of Europe.**

mines in other fields sank many German ships, but its more important result was to restrict the freedom of the German submarines, and to drive them either to the surface or to locations where they could be found and destroyed by other means. Figures 26 and 27 give some idea of the areas mined by Great Britain and the Allies. The U.S. Northern Barrage is included in figure 26.

In addition, the British began working on what we now call influence mines, i.e., mines whose firing devices are operated by physical fields generated by the ship, but which do not require contact of the mine and the ship. A magnetic mine was developed and a few of them manufactured. Some were laid by the British in 1918 off Zeebruge and off Ostend.

A number of additional minefields were proposed by the U.S. Navy. The activities of the German submarines in the Mediterranean had become very serious. It was evident that there were from 75 to 100 submarines in this general area.

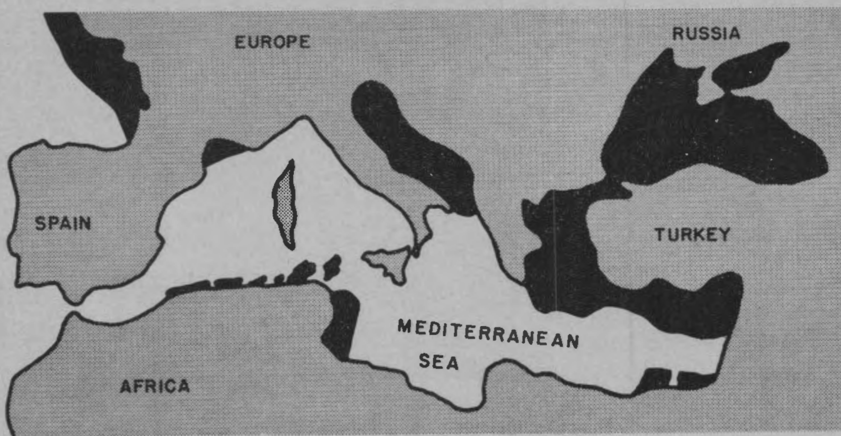



**Figure 27.—Areas mined by the Allies south of Europe.**

The U.S. Navy therefore proposed that an energetic mine barrage campaign in the Mediterranean be started just as soon as the minelayers could be spared from the Northern Barrage. It proposed the possibility of five mine barrages which were discussed at an Allied conference at Malta on August 6, 1918. The laying of these barrages would curtail the flexibility of the use of the Allied fleets in the Mediterranean and, as was to be expected, there was much discussion and some serious objections.

The five fields proposed were:

(*a*) **The Dardanelles field.** Here the British had been maintaining various small fields, each usually laid without warning, and considerable success had been achieved. Since the ends of any barrage laid in this area would be in enemy territory it was agreed to leave these fields entirely to the British.

(*b*) **The Adriatic barrage,** to be laid from coast to coast across the Straits of Otranto. This would force the German submarines to pass through this barrage on each excursion. However, the depths of water were greater than any in the Northern Barrage, much of it nearly 3,000 feet deep. The Bureau of Ordnance had been trying to develop a mine to meet this requirement and on the day of the conference had notified Admiral Strauss that it could do so. However, the French and the Italians objected to this location and recomended another which involved much water of nearly 3,600 feet in depth. This was beyond what the United States could furnish. However, Admiral Revel, the Italian Chief of Naval Staff, later agreed to the U.S. proposal and plans were made to lay this barrage. Bizerta, Tunis, was chosen as the base of operations, but in order to speed up the project it was decided to have the first mines assembled in Scotland. Two of the U.S. mine cargo boats were loaded with construction material and ordered to Bizerta. Meanwhile at Bizerta, the French were doing all in their power to advance the base assembly plant. However, war developments were such that on November 7 orders were issued to discontinue all work. The two cargo carriers which had not reached Bizerta returned to Inverness, Scotland, and were unloaded. In the interim the Bureau of Ordnance had ordered 30,000 mine assemblies for the Adriatic Barrage. The anchors carried 3,000 feet of mooring cable and a 100-foot length of lower antenna which formed the top 100 feet of mooring rope. The mines also involved other minor modifications and were called the Mk 6 Mod. 1. When the barrage was canceled the order was reduced to 3,000 assemblies.

(*c*) **The Cape Bon-Sicily Barrage,** extending from Cape Bon, Tunis to Sicily. The U.S. Navy believed that a barrage so placed would very effectively restrict submarine operations in the Mediterranean, but the countries maintaining fleets in this area, Britain, France, and Italy, demanded large gateways which would largely nullify the barrage's effectiveness. This proposal was therefore abandoned.

(*d*) **The Aegean Barrage.** The U.S. Navy also proposed a barrage in the Aegean Sea to block openings between various islands. This proposal was approved by the Allied conference and was to run from Euboea Island to Andros, Tinos, Mykoni, Nikaria, Themina, Furni, and Samos Islands, and thence across to Cape Kanapitza, with the proviso that the responsibility for the provision of material, the laying and the maintenance of the field be carried entirely by the United States. The end of the war canceled the proposal.

In addition a barrage near Gibraltar was considered, but because of the deep water and strong currents in this area, it was not considered worth the effort of designing a suitable mine for the purpose.

The United States also offered special assistance to minefields for which other Allies were responsible. The net from Otranto and Fano Island going to a depth of 200 feet was to be strengthened by the U.S. Navy laying four rows of mines below it, and the British requested assistance in the Dardanelles field by having surface mines laid between Imbros Island and Cape Gremea. The war did not last long enough for either of these projects to be started.

To sum up the mining campaign of World War I we find that the total number of mines laid by both belligerents and neutrals amounted to approximately 240,000, viz.:

*a.* The British laid 128,000 mines.

*b.* The United States laid 56,000 mines.

*c.* The Germans laid 43,000 mines.

*d.* The Russians laid mines in the Baltic, the Black Sea, and the Gulf of Finland; the French and the Italians in the Mediterranean and the Adriatic.

*e.* Many of the neutrals laid mines to protect their own coastline waters.

These mines caused the sinking of 200 warships, without including an unknown list of German submarines or of allied merchant vessels. Of these, 11 were battleships or large cruisers with tonnages of more than 10,000. In addition, the operation of naval vessels was greatly hampered and restricted and a great deal of the naval and economic power of the countries at war were expended in attempting to keep their sea lanes clear of mines.

## CHAPTER XI

# BETWEEN WORLD WAR I AND WORLD WAR II

The war was over. The Navy, try as hard as it could, had not been able to make much use of the usual naval weapons, i.e., large guns, torpedoes, etc. In fact, probably its greatest contribution, and one which had undoubtedly hastened the end of the war, had been the major use of an old American weapon, which had aroused only an insignificant bit of interest in America until 1917. The sea mine, unglamorous in peacetime, but effective in war. What would be the future American policy on the further development and use of this weapon?

The Army's controlled mines had been in such shape that none could be planted during the war. Luckily the Germans apparently did not know of the poor mine defense of our harbors or else her submarines were too busy elsewhere. The Navy started in 1917 with nothing useful but found itself in 1919 with stocks of thousands of mines of the Mk 6 type, with an enormous loading plant, with mine assembly plants, with mine depots, and with many minelayers and minesweepers.

Other new types of mines had been suggested, and some had been developed into a usable state by European countries. Mines had been designed for laying from, and some had been laid by, submarines. The proposal to use the magnetic and acoustic fields of ships to operate mine firing devices had been made and some few magnetically operated mines had been planted, but the U.S. Navy had been too busy with the Northern Barrage to do more than consider these possibilities.

The military services certainly did not intend at this time to allow the mine to pine away with little or no development in the future. Within the next few years, by joint action of the Army and the Navy, mine defense areas were established to protect the country's important harbors and coastal cities. The Army accepted the responsibility for the areas in which controlled mines were to be planted, and the Navy the responsibility for the areas where automatic mines were to be used.

The functions and principles of use of both Army and Navy mines were fixed as follows:

*a.* To effect the destruction or serious damage of hostile vessels which approach within effective range.

*b.* To supplement the offensive action of other weapons in repelling hostile naval attack.

*c.* To prevent the close approach or entry into a harbor of hostile surface vessels under cover of night, fog, or smoke, when by reason of invisibility of the ships from shore, other weapons of the Army and Navy are wholly or partially ineffective.

*d.* To limit or prevent the navigation by hostile submarines of specific channels or water areas.

*e.* To restrict the freedom of maneuver of hostile naval forces in formation.

*f.* By the moral effect of an unseen threat, to enforce a constant element of caution and uncertainty in the planning and execution of all hostile naval operations within the water areas known, or believed, to be protected by minefields.

*g.* To give warning of hostile submarine activities or of the presence of hostile surface vessels.

While the recommended uses are:

*a.* Controlled mines should be used to close such portions of harbor entrances as lead to channels required for the use of friendly naval forces and friendly commercial shipping, or which include a debouching area required by our naval forces. In addition, controlled minefields should be limited to distances not to exceed 10,000 yards from the shore and to depths not greater than 250 feet.

*b.* Contact mines should be used to close all portions of harbor entrances navigable by hostile naval forces, not required for use by friendly naval forces or commercial shipping, particularly to block off large areas or routes of access in deep water or far offshore, except where the set of tides or currents is such that contact mines which have broken loose will be likely to be washed into areas which will endanger friendly naval forces or commercial shipping.

The Army controlled system demanded a 19-conductor cable, which, for some reason or other, was very difficult to manufacture and maintain. It was partly because of this that the Army mines in the years 1912 to 1917 had been planted and tested practically not at all. After 1918 the Army was still hampered by the failure to obtain this difficult bit of material, and it was not until 1926 that a new development was perfected which permitted each controlled mine to be scanned in turn using only a single-conductor cable.

The Army moved its development and maintenance work from Fort Totten, N.Y., to a Submarine Mine Depot at Fortress Monroe, Va., in 1931, and development and planting practices were carried out there. By 1939 a system, embodying the elements and reliability of an automatic telephone system, was ready for use, and by 1941, local mine depots in each of the areas where the Army was responsible for defensive minefields had material in store and had adequate facilities and experienced personnel for planting mines as required by the joint Army and Navy schedule.

The Navy's first problem after World War I was the storage of the material purchased for, but not used in, the war. It established a large overall storage mine depot, area approximately 17 square miles, near Yorktown, Va., where it placed most of its leftover material plus that which was received from existing war contracts. It also delivered to local mine depots over the country and in our island possessions the material needed to satisfy the Navy's responsibilities in the mine defenses of important harbors. It established mine-laying squadrons in its peacetime Navy and arranged for them to carry out regular mine-laying exercises giving them a score based on the percentage of successful mines, and in order to keep the personnel of the mine depots fully acquainted with mines, the mine layers from time to time planted groups of mines assembled by mine-depot personnel. This provided for the upkeep of material and the training of personnel for the use of the World War I mines.

As the Bureau of Ordnance attempted to develop its new mine assembly in 1917, its staff was hampered in that no Navy organization was available to become responsible for the experimental development and design. The work on the antenna firing device was taken over completely by the inventor at the scientific apparatus company by which he was employed. The Navy furnished him a ship to use in his tests and some little laboratory space at the Newport Torpedo Station. The other parts of the assembly were designed by Bureau of Ordnance engineers with the help of a naval officer from Great Britain. Moreover, when other types of mines had been suggested, such as mines designed for planting from submarines or mines resigned to use the ships' magnetic or acoustic fields, they were considered too secret to assign their development to non-government laboratories.

To meet these needs the Navy began in late 1917 to build a special laboratory whose main mission would be to design and develop mines. The building was built during the next year and was partially occupied before the war was over in November 1918. It was a two-story building 120 feet long and 60 feet wide, located in the Washington Navy Yard. Because of some objections at the Bureau of Ordnance toward the term "laboratory," the building was called "The Mine Building" (fig. 28). The first floor consisted of a machine shop, an assembly shop and a laboratory, while on the second floor were offices for the staff and a room designed to be used as a drafting room for approximately 25 men. A year or two later a mine testing tank, 25 feet in diameter by 50 feet high, was erected beside the building. The top of this tank is shown in the photograph. This was provided with portholes so that a mine could be planted and its operation watched by observers. It was patterned after a British tank, but lack of available funds forced the Navy to build it much smaller than the British and to omit many valuable pieces of test equipment.

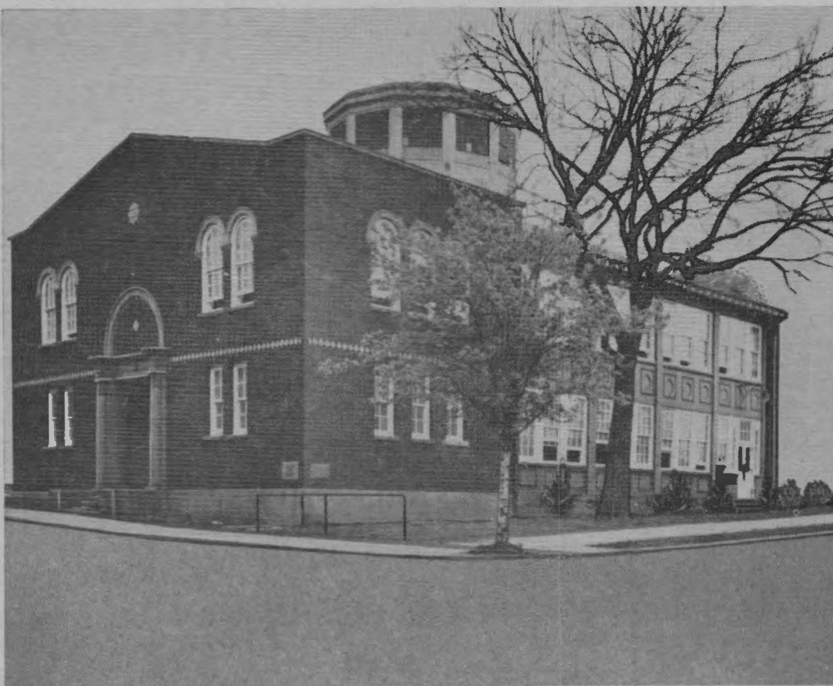


**Figure 28.—Mine building.**

The Navy also assigned the laboratory another valuable test facility which the Mine Building used continuously up to the beginning of World War II. In order to sweep the mines from the Northern Barrage the Navy had built a number of so-called "bird" minesweepers, so named because they were named after birds. They were sturdy vessels of about 1,000 tons displacement, were about 300 feet in length, and were fitted not only for sweeping, but also for laying mines. The Mine Building was assigned the "Cormorant" (fig. 29). She was of great service testing mines and mine accessories. The Bureau of Ordnance arranged that her Captain be an Annapolis graduate and he was able to carry on many tests without a representative from the staff of the Mine Building.

But the United States and Allies had won a war—"the war to end wars." The country wanted to get back to "normalcy," to reduce taxes, and to stop "unnecessary" defense spending. Congress operated obediently. It cut the Navy's fund. It was then the Navy's problem to decide how to spend what funds it had. The Navy believed that a minimum fleet should be kept in readiness and to do this the money for research and development projects had to be reduced. Thus, the Navy, in the 1920's, was already finding trouble in keeping its mine development work proceeding as it had hoped to do in 1918. The Bureau of Ordnance had hoped to maintain in the Mine Building a staff of from 20 to 30 technical people and an artisan staff

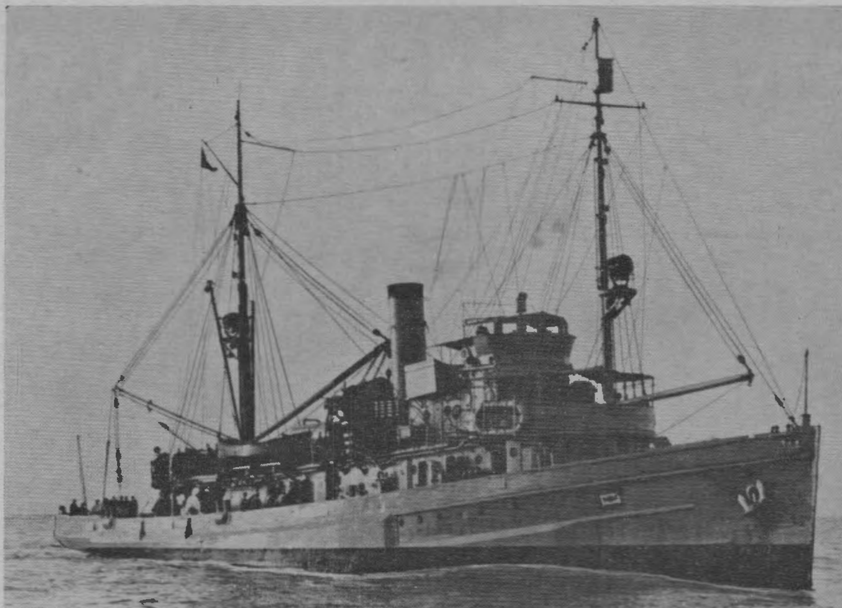


**Figure 29.—U.S.S. *Cormorant*.**

of from 50 to 75 mechanics. It got the building, but much of its equipment was machine tools which had been replaced by other Gun Factory shops during the war. It never got the technical staff.

Another Bureau of Ordnance section had assigned development work on fuzes and pyrotechnics to a university group during the war. As funds became scarce this work was withdrawn from the university group, and the Bureau of Ordnance used the unused spaces in the Mine Building to house it. The Mine Building then became a laboratory devoted to two main projects; that is, Mines, and Experimental Ammunition.

The major mine projects which had been undertaken or considered by the Bureau of Ordnance during the war were now assigned to the Mine Building. These are listed below, but with a technical staff of only two or three engineers and physicists, many of the projects were merely carried on the books. The Navy believed that the most important job was the maintaining and the improving of the stock of material from World War I. This was true and it also obviated the cost of new material for which very little funds were available.

The hold-over projects were:

*a.* A study of the Mk 6 mine, and a modification of the design where necessary to make its operation more dependable. The use of this mine in Northern Barrage had proved that there were faults that called for redesign, but there had been no opportunity to correct them at that time. The Bureau's policy was to keep 50,000 mines completely ready to assemble for actual planting. This was more of a job than it might appear. Practice

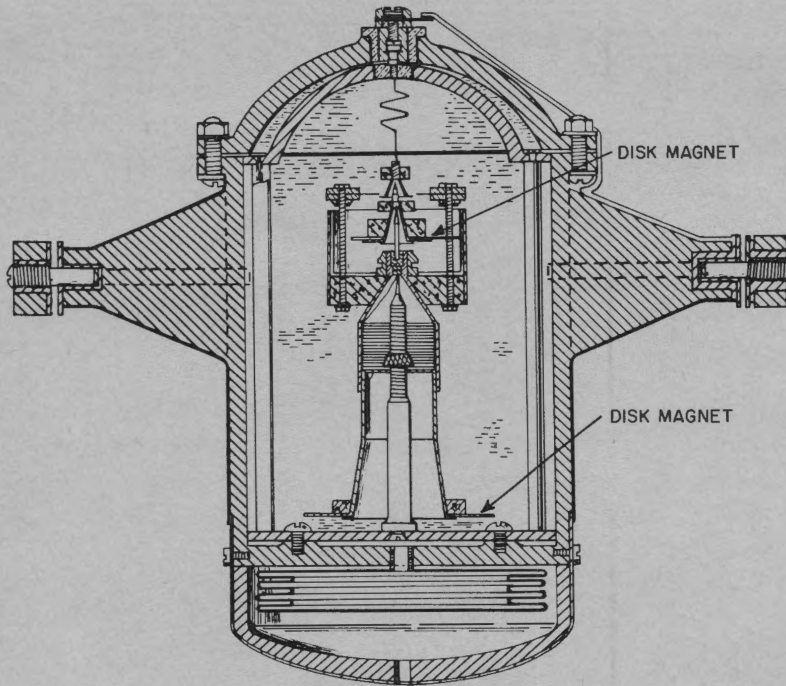



**Figure 30.—Early magnetic firing device.**

mine plants and general depot overhaul were continually bringing to light unexpected faults of material.

*b.* The design and manufacture of 25,000 improved K-type firing devices. This was the second modification of the initial one used in the Northern Barrage and it was known as the K–3. The most important modification was a provision to allow the contact maker of the relay to rotate in either direction. In the earlier devices, the contact maker could rotate in but one direction since in normal ship contact the operating current would always flow in the same direction. This simplified the use of the electric protective device (described on p. 64) since an excess of current would merely lock the rotor more securely in the open position. With the K–3 type the protective current had to be adjusted to hold the ship's potential very close to that of copper. The manufacture was carried out by a contractor with the staff of the Mine Building serving as an advisory and testing group.

*c.* The completion of the design and the manufacture of 1,000 magnetic mine firing devices. This was America's first attempt to develop an influence mine firing device (fig. 30). The sensitive element consisted of two small contact carrying disk magnets, although one was considerably larger than the other, mounted to rotate in horizontal planes on the same vertical shaft. With two specific magnets their relative rotational position depended on their magnetic moments, the ambient magnetic field and their distance apart. If the magnets were close together the small magnet would be controlled by the larger one, and would lie with its south pole near the larger one's north pole; while if they were far apart both magnets would be controlled by the existing field. By fixing the distance between the two magnet planes, a position could be found where the relative rotational position would be highly sensitive to small variations in the ambient magnetic field. The sensitivity, i.e., the change in the ambient field required to cause the firing contacts to close, could be adjusted by varying this distance. However, no provision appeared feasible to automatically adjust the mechanism for the magnetic field in which it was planted. This was serious, for if the device were manually adjusted for planting in the latitude of Norfolk, Va., it would fire prematurely if planted in the latitude of Washington, D.C.

*d.* The measurement of ships' magnetic fields. This was accomplished on 1 or 2 ships by noting the changes in the horizontal fields around a drydock which occurred when the ship was moved into the dock. It furnished sufficient information to justify a tentative sensitivity operating requirement for the magnetic firing device.

*e.* The design of an acoustic firing device. This never passed beyond the gathering together of a few possible experimental parts.

*f.* The design of a supersensitive detonator, so sensitive that the small current, produced when a steel ship strikes the copper antenna of a K-device mine, would fire the detonator directly. A few of these were manufactured, but they were not satisfactory. The work was done by a contractor. The Mine Building again served in an advisory and testing capacity.

*g.* The design and manufacture of a thousand Hertz horn-type mines, utilizing a larger case and a larger charge than the Mk 6. The project was completed by a contractor, and the Mine Building again served in an advisory and testing capacity.

*h.* The design of a 21-inch cylindrical mine to be laid by discharging it from a standard torpedo tube. This project was partly finished and was then dropped for several years. The requirements were later modified and a design was completed in the 1930's.

During this 20-year period, 1919 to 1939, some new mine problems were assigned to the Mine Building. In World War I both the British and Germans had designed and used two types of mines to be laid from submarines. One type consisted of a cylindrical mine that could be planted from 21-inch torpedo tubes (see item *h* above). In addition, both countries had built special mine-laying submarines which could lay a much larger and more efficient type of mine The Navy finally obtained authorization from Congress to build a submarine of this type. The Bureau of Ships (then the Bureau of Construction and Repair) designed and built the ship at the Portsmouth Navy Yard, Kittery, Maine. This design included the mine handling equipment. The Mine Building was directed to design the mine assembly to fit the mine handling equipment designed by the Bureau of Ships.

A complete model of the Mine Building design, based entirely on blueprints of the ship, was sent to Portsmouth Navy Yard and was tried out

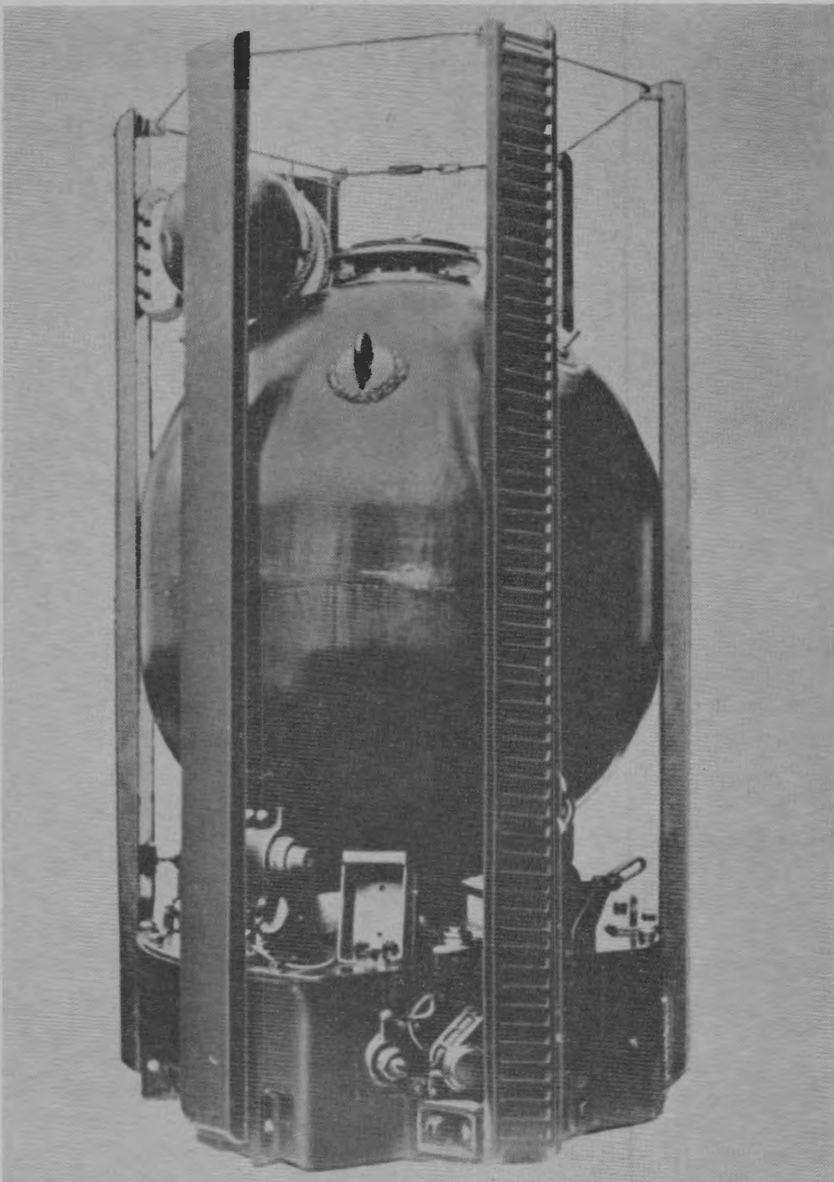


**Figure 31.—Mine Mk 11.**

in the ship before it was commissioned. The mine and the ship's handling equipment passed all tests successfully, so several hundred complete mines (fig. 31) known as the Mine Mark 11 were built by the Naval Gun Factory. However, it was assumed by both the mine designers and the ship constructors that ample service tests of the mine and mine handling gear would be carried out in the presence of both so that final details of the design of the mine or the mine handling gear might be modified as found necessary.

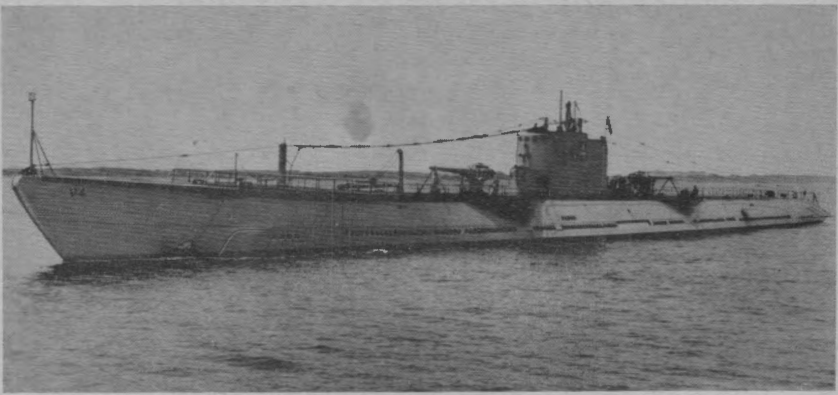


**Figure 32.—U.S.S. *Argonaut*.**

However, the "powers-that-be" ordered otherwise. When the boat (the *Argonaut,* fig. 32) was finally fit for sea, it was ordered at great haste from Portsmouth to Hawaii and was permitted to stop at Washington only long enough to take aboard a load of mines. No actual mine layings were ever made in the presence of the mine designers or, so far as is known, in the presence of the ship constructors either. When the ship actually started practice plants a number of mine modifications were suggested by the ship's officers. The captain of the submarine requested that a mine designer be sent to Hawaii, but the Chief of the Bureau ruled that no travel funds were available. However, the correspondence from the *Argonaut* describing the faults that existed with suggestions for modifying the mine design were thoroughly studied by the Naval Ordnance Laboratory staff and certain modifications were authorized. Also, the Naval Constructors approved certain modifications of the mine handling gear. The resulting modifications showed definite improvement, but the procedure was exceedingly slow and could not be as satisfactory as it would have been if the mine designer, the ship constructors, the mine and the ship could have been in close contact. The *Argonaut* made many successful test plants, but no service mines were laid in World War II as early in the war the ship was turned into a submarine cargo carrier. It was later sunk by the Japanese.

In the 1930–40 Navy building program, a number of new submarines were authorized and 21-inch tube mines were included in the armament of each submarine. The problem of development, design and responsibility of manufacturing was assigned to the Mine Building (now renamed the Naval Ordnance Laboratory). The work, started in World War I on mines of this type, was therefore continued, making such modifications and improvements as necessary to meet the requirements of the new mine. The final result was the Mk 10, Mod 1, which consisted of a cylindrical case and a cylindrical anchor married as shown in figure 33.

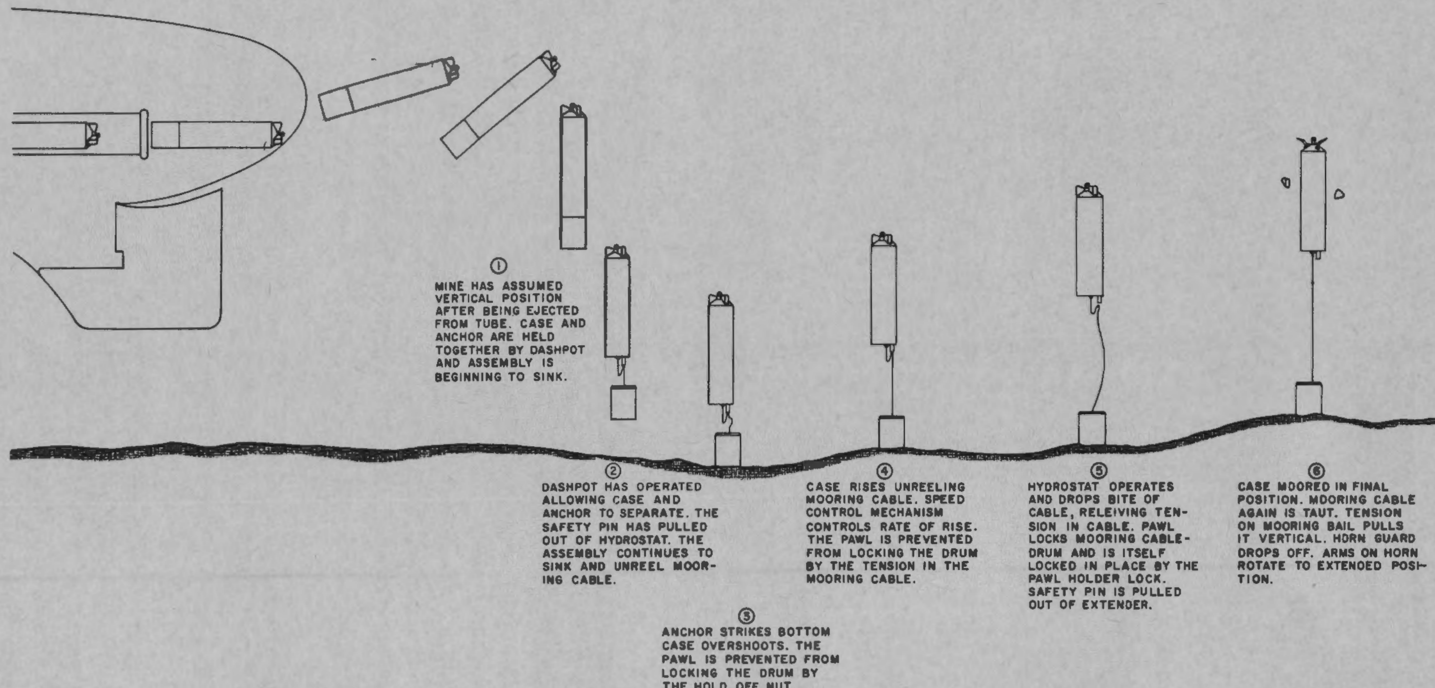



**Figure 33.—Planting sequence of mine Mk 10.**

Since these mines were specifically designed for clandestine laying, the field requirements demanded that the mine case would locate itself at the predetermined depth without ever showing on the surface. The steps in this planting sequence are shown in figure 33. The assembly leaves the torpedo tube in a horizontal position, but soon takes a vertical position due to the weight of the anchor, and since the assembly is not buoyant, it starts sinking. On the way down, the anchor is released from the case, so that if the bottom is muddy, the case will not be pulled into the mud.

The mooring cable is secured to the case at two points, one at the extreme upper end, and the other at a point about 30 inches below the upper end, where the cable is secured to a hydrostat mounted on the bottom of the case. Inside the anchor a locking pawl is held in an open position by the tension on the cable, but when at a predetermined depth, the hydrostat drops the loop, thus releasing the cable momentarily, the locking pawl falls into the cable locking position. The case is therefore anchored without ever showing on the surface.

The mine firing device consists of three Hertz horns described in chapter 7, which have been modified by adding folding levers to the upper end of each. These levers are held down by covers which fall off when the case is finally moored. These levers extend out beyond the contour of the cases and thus increase the sensitivity.

Approximately 1,000 of these were built and this type of mine together with several modifications of it were used with considerable success during World War II.

At one time drifting mines for tactical use were considered highly desirable and the Naval Ordnance Laboratory was directed to design one, using, as far as possible, excess Mk 6 material (since that didn't cost anything). The Mk 7 drifting mine was the result. This used a modified Mk 6 case riding on a low truck whose wheels fitted on the regular tracks of a minelayer. When laid, the truck fell away a few seconds after the assembly struck the water. An antenna-type firing mechanism was used, the antenna being supported by two floats, one of 35-pound buoyancy remaining about 10 feet below the surface, and the other a very small, only 4-pound buoyance, remaining on the surface.

The case and float assembly were purposely given a few pounds negative buoyancy, and therefore sank slowly. A hydrostatically controlled calibrating mechanism mounted on the side of the case dropped small weights as the case moved to deeper depths. When sufficient weights were dropped to give the assembly slight positive buoyancy, it rose to the surface, allowing only a small part of the small float to show on the surface. The planting sequence is shown in figure 34.

The design operated quite satisfactorily, but during certain test war games it was discovered that the fleet might find it necessary to traverse the same area two or three times in a given battle. None of these mines were used during World War II.

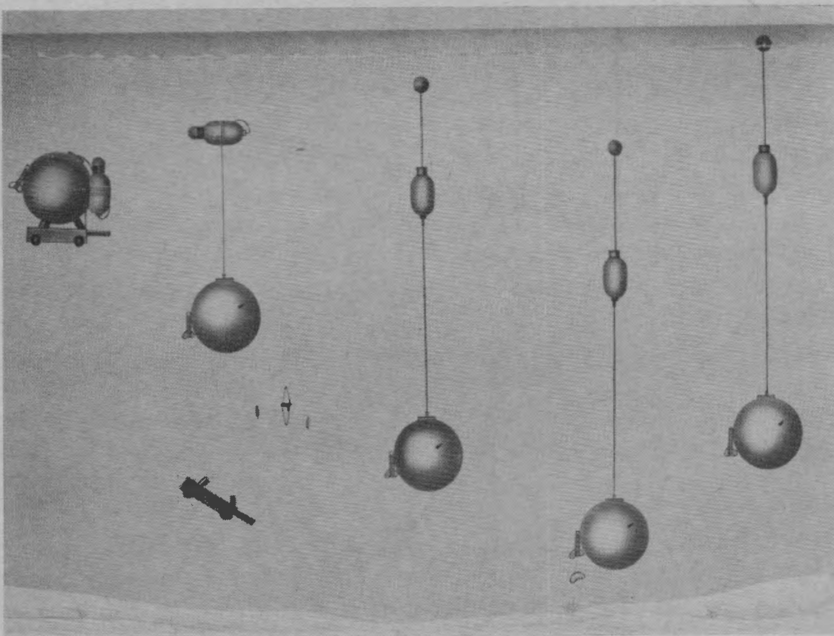


**Figure 34.—Mine Mk 7 planting sequence.**

The first antenna firing device used for World War I was called the K–1 device. An improved design was later used and was known as the K–2 device. Some 20,000 to 25,000 of these were left in stock at the close of the war. The K–3, referred to previously, was a major modification of the K–1 and the K–2. Mine building engineers suggested that the K–2 could be modified incorporating most of the improvements embodied in the K–3 at very much less expense than the manufacture of additional K–3's. This was done by an outside contractor, but the Mine Building served in an advisory and testing activity. The modified device was known as the K–2, Mod 1.

During this 20-year period, 1919 to 1939, the administrative trouble of the mine development organization should be given some consideration. The Bureau of Ordnance located the laboratory in the Naval Gun Factory in order to keep it in very close contact with the Bureau. At the same time the Bureau specified by letter that, while the Gun Factory was to furnish general maintenance and personnel, it was to have little or nothing to say about what took place within the laboratory since mines, as was customary, were placed in very high security. The whole arrangement was bad. The Gun Factory is a large production plant. Its management was naturally interested primarily in its responsibility to maintain efficient manufacturing operations. Funds were always scarce, so in the purchase of tools or in the employment of scientific and engineering talent the bias of the Naval Gun Factory management was naturally toward the Factory. Moreover, since Naval Gun Factory management, even at the higher levels, were not cleared for Naval Ordnance Laboratory problems, they could not become familiar with the Laboratory's needs.

The Senior Inspector, actually the Superintendent of the Gun Factory, was usually of a Captain's rank, whereas the Naval Ordnance Laboratory was small and usually justified only a Lieutenant as its administrator, so those familiar with the military protocol can understand the conditions. The particular officer at the Bureau interested in the work being done at the Naval Ordnance Laboratory was familiar with its needs, but the Chief of the Bureau often objected to taking action unless the request was received from the Superintendent of the Gun Factory to whom had been assigned the responsibility of personnel and equipment, but the Superintendent often had other needs both for material and for personnel in the production plant which he considered of higher priority.

In fact it was generally understood that the Gun Factory would like to eliminate the Laboratory as a separate entity. Because of the secrecy of its projects, the Laboratory was largely a complete unit in itself. It had its own drafting room, its own fairly complete model shop and its own laboratories. The Gun Factory drafting room officer often appeared a little jealous of the fact that the Naval Ordnance Laboratory drafting room, though small, had responsibilities on the same level as his own. This led to humorous results now and then. At one time an ex-Naval Gun Factory drafting officer stated at a Bureau of Ordnance conference that a mine case which had failed in a test would not have failed had it been designed by the engineering experts of the Gun Factory drafting room. He was very embarrassed when he was informed in the conference that this case had been designed by that drafting room before mine design responsibility had been detailed to the Naval Ordnance Laboratory, and that he, himself, had signed the drawing.

At another time, in 1929, the Senior Inspector of the Gun Factory recommended to the Chief, Bureau of Ordnance, that a board be appointed to study the Laboratory's work and to recommend how it could be carried on by other sections of the Gun Factory. The Board was formed with the Senior Inspector as Chairman, and one Naval Gun Factory officer and a Bureau officer as members. It held meetings from 8 to 10 days, obtaining data not only from the Laboratory's personnel but also from those in the Naval Gun Factory who might take over the Laboratory's work. The final report was entirely contrary to the Senior Inspector's ideas. The Board recommended that the name of the activity be changed from Mine Building to Naval Ordnance Laboratory, that it be authorized to work on any ordnance development or research problem assigned to it, and that its staff be increased as required. The Chief of the Bureau of Ordnance approved the recommendations of the Committee except that there was to be no increase in the staff. Technically this was the official beginning of the "Naval Ordnance Laboratory."

Economy was another of the Naval Ordnance Laboratory's serious troubles in these days. Promotion of personnel was almost unheard of, new employees were out of the question, machine tools were largely those discarded by other shops in the Yard and purchases of experimental equipment were nil. Experimental work on all projects was strictly limited. At one time the work on depth charges was limited to $25 per month, which meant that one machinist could work 2 days per month on a depth charge problem. All purchases above $10 had to be submitted as formal requisitions on which bids could be requested and then the article purchased from the lowest bidder. One very urgent job required a small d.c. motor that could be bought from any motor manufacturer for from $15 to $20. In order to save time the laboratory obtained one day a purchase order of less than $10 for the motor frame, and the next day an order, also for less than $10 for the motor armature. The supplier was told that the Laboratory would accept the two parts assembled.

However, during the latter part of the thirties, more interest in mines began to develop in the Navy. Mining was made a special subject for study in the Ordnance Post Graduate Course and each year two or three young officers were assigned to this subject. These men spent a few months at the Bureau of Ordnance Mine Desk, the Naval Mine Depot at Yorktown, and the Naval Ordnance Laboratory. During World War II most of these men held valuable posts in the mining program.

When World War II broke out, it was evident that the United States had fallen far behind Germany and England in mine design. This was partly due to the fact that Congress had curtailed naval appropriations a great deal, but the Navy Command itself can not be entirely excused. For 5 or 6 years after the close of World War I, the Bureau of Ordnance had a "Research Fund" which was allocated mostly to mines and experimental ammunition, but at its own request this fund was added to its general appropriation and from that time on the funds for mine development were extremely short. Congress might have continued to approve funds specifically allocated to military research and development.

It appeared that the Navy high command was interested in standard Navy weapons: battleships, cruisers, big guns, airplanes, bombs, projectiles, etc., but that mines which had performed a great naval function in World War I were uninteresting and not worth great development efforts. Most all of the enthusiastic mining officers of World War I had either retired or had been promoted to high-level jobs. Younger officers assigned to mine work knew little about mines, and in a tour of approximately 2 years at the Naval Ordnance Laboratory could not be expected to learn much or to develop worthwhile enthusiasm.

The author knows of but one naval officer who continued his interest in mining during this period. He commanded mine-laying destroyers and twice occupied the mine desk at the Bureau of Ordnance, and finally became the Commander of the Naval Ordnance Laboratory just before World War

II. It was largely through his efforts that the mine development staff did show some little increase during this period.

During this peace time period up to 1938, this country could get very little information concerning the mine activity of Great Britain or Germany. However, after the war started, it was learned that both Great Britain and Germany had carried out major mine development. The British had improved their standard moored mine, had studied magnetic needle type and magnetic inductive mines, and had considered methods by which ship's magnetic fields could be reduced. They had also produced types of mines which could be planted from submarines and aircraft. Germany's biggest development, of course, was her magnetic mine firing device and the development of mines which could be planted from submarines and from aircraft. Fortunately for the British, Germany was also ignorant of British efforts and assumed that the British would be helpless against her magnetic mine for at least a year or two.

CHAPTER XII

# GROWTH OF THE MINE WARFARE CONTROL ORGANIZATION

The introduction of a new weapon into active use in the country's defense is a problem much greater than that of the design and the production of the weapons themselves. Those in charge of production must know what the users want; in fact they may not be provided with the essential funds for production until the users see some use of the weapon, while on the other hand, the user cannot be sure of how effectively he can use the weapon until he has had the opportunity of trying it out. In the Navy, the service fleets are expected to study the use of weapons and furnish the Navy Department with criticisms or with suggestions for modifications or improvements. This serves very well for weapons being used repeatedly in target practices, but it failed completely as far as the offensive use of mines was concerned.

The defensive mine was not a new weapon. It had been used very effectively in World War I. The United States had a good supply of them and arrangements for their use to defend the major ports of the United States were in existence and in fact many mines of this type were laid prior to Japan's attack on Pearl Harbor.

The aircraft offensive mine was a new weapon as far as the United States was concerned, while the submarine offensive mine was almost new as far as the Navy's service fleet was concerned. It would appear that the logical process in the introduction and use of new weapons would be for the Office of the Chief of Naval Operations to initiate the move and to direct the problems to be assigned to the various naval bureaus. However, the Navy's organizational arrangement did not, at the beginning of World War II, provide for this type of development program. The control group in the Office of the Chief of Naval Operations had to "grow up" as problems were forced upon it.

Up until 1939 the use of mines for offensive purposes had received very little attention by the service fleets. A small mine squadron consisting of destroyers provided with mine tracks was attached to the fleet. It could only lay standard Mk 6 mines and would usually be used for laying defensive fields, although it could dash into enemy controlled areas and lay an offensive field and hope to get away before the enemy could attack it. The more modern submarines were designed to lay mines from their torpedo tubes and a small number of mines were available for this purpose, but very little if any training practices had been carried out. The submarines' commanding officers had grown up with the idea that the torpedo was the submarine's weapon and that mines were merely an undesirable nuisance. Immediately after the Pearl Harbor attack all available submarines could be used firing torpedoes, so War Management control and to a large measure the submarines' commanding officers, could see no reason for assigning these craft to experiment with offensive mines.

The Germans had proved in 1939 the tremendous value of the influence-fired mine as an offensive weapon, especially when laid by aircraft, because they could replenish older fields without danger to themselves. In the United States neither Navy nor Army aircraft pilots had had any experience or training in dropping mines; nor, in fact, had the value of aircraft-planted minefields been in any way impressed on them. Moreover, they had had no aircraft mines to lay.

The situation in the Navy Department was but little better for the effective introduction of offensive mine warfare. The Department consists of a number of Bureaus, each responsible for certain items. The Bureau of Ordnance was responsible for furnishing the fleet with ordnance, the Bureau of Ships with the furnishing and the maintaining of ships, the Bureau of Aeronautics for furnishing and maintaining planes, the Bureau of Personnel for the furnishing and training of personnel, etc. All of these Bureaus would be concerned with mine warfare, but not one of them had the authority to direct it to be undertaken.

Also in the office of the Navy's "boss," the Chief of Naval Operations, there was no section which could pick up the mining warfare problem and carry it through. Here the Navy had a Division of War Plans, one for Fleet Training, one for Fleet Maintenance and one for Naval Districts. Again, each Division would be concerned with some phase of mine use but not one of them was wholly responsible for the directing or the coordinating of a new field of warfare. Offensive mine warfare certainly needed a corps of missionaries to present its possibilities to the Navy and to the Air Force.

As in World War I, it was the Bureau of Ordnance who took the first step. Just as soon as it was announced that Hitler was dropping magnetic mines from aircraft, this Bureau requested its mine development laboratory, the Naval Ordnance Laboratory, to spare no effort in studying the influence fields of ships, the designing of mines to be fired by these influence fields and the developing of methods of neutralizing the fields. Representatives were immediately sent to Great Britain to study the problem more closely. Within a few months considerable progress had been made, especially in the measurement of and the development of methods of neutralizing the magnetic fields of ships.

The Bureau of Ships was concerned with the sweeping of these influnce mines and like the Bureau of Ordnance, it sent representatives to Britain to study their sweeping techniques. Meanwhile in the CNO, the Naval Districts

Division was forced to study the use of mines because each Naval District was responsible for planting defense fields and for sweeping enemy mines that might be laid in that District. Therefore, this office also sent its representative to England.

Another effective step in the education of the Navy on mine warfare stemmed from a small group at the Naval Ordnance Laboratory who met, usually in the evening, and played a "mine-warfare game." A given harbor would be chosen and one group would plant mines there while another group would attempt to neutralize them or find some way to use the harbor. This group developed into a Mine Operational Warfare Research Group so effective that it was later moved to the Bureau of Ordnance and finally to the Office of the Chief of Naval Operations.

All of those who went to England to study the use of mines by Germany against Great Britain, and by Great Britain against Germany returned fully convinced that the United States should make full use of this weapon, and should develop as rapidly as possible a squadron of mine-laying aircraft and a supply of aircraft dropped influence mines. Also those scientists working at the Naval Ordnance Laboratory soon realized the theoretical possibility of an aircraft mine offense program. Thus several groups of mine missionaries developed and they vigorously preached the offensive mine warfare doctrine to everybody who would listen.

One of the important problems which forced mine thinking into the consideration of the Office of the Chief of Naval Operations, was the settlement of mine cognizance questions. Such problems are always likely to arise in an organization with a number of bureaus because of the necessary overlapping of each bureau's functions. The first of these was the question as to which Bureau should be responsible for "degaussing," that is the neutralization of the major part of the ships' magnetic fields. BuShips believed that in its responsibility of ship construction and ship maintenance, it should have cognizance of the neutralizing of ships' magnetic fields, but by the time the question was raised, the Bureau of Ordnance had already developed apparatus and techniques for measuring the fields and had a group of scientists studying how to use electric currents to neutralize them. Moreover, the Chief of the Bureau of Ordnance claimed that that Bureau was responsible for both offensive and defensive ordnance and that "degaussing" was defensive ordnance just as ship's armor was. In addition, this Bureau had to measure the fields in order to intelligently design firing devices, and the measuring techniques and apparatus could be equally well applied to experimentally checking the fields after degaussing coils had been installed.

The matter was presented by both Bureaus to the Navy's Research Council who recommended that the Bureau of Ordnance measure the fields and that the Bureau of Ships design the degaussing coils. To this the Bureau of Ordnance strenuously objected and the whole matter was finally referred to the Secretary of the Navy, who decided, on the recommendation of the Chief of Naval Operations, that the Bureau of Ordnance would design the degaussing coils and that the Bureau of Ships would install them and furnish the power to operate them. He was largely governed by the fact that the Bureau of Ordnance had already made much progress in the problem and that "a change of cognizance in the middle of a project would only result in duplication of effort."

Another cognizance problem closely allied with degaussing concerned the sweeping or destruction of the enemy's influence-fired mines. With moored mines, sweeping had been a strictly mechanical seamanship problem and very appropriately had been assigned to the Bureau of Construction and Repair which later formed part of the Bureau of Ships. With influence mines, the sweeping problem was quite different. In general, it consisted of artificially producing the same influence fields which a ship would produce, and thus exploding the mines with no ship within damage radius. The Naval Ordnance Laboratory scientists and engineers were continually trying to develop a firing device which would be immune to existing sweeping techniques, since it was assumed that the enemy had at least as good sweeping gear as we had. This group might have been able to develop new sweeping techniques to apply to new firing devices being considered, but if the mine sweeping group was detached from the mine design group, the design of a new sweeping gear would be greatly delayed. The Bureau of Ordnance recommended that the design of influence mine sweeping gear be assigned to it in connection with its mine firing design problems. However, the Bureau of Ships demanded that all sweeping remain under its cognizance, and after much discussion and many conferences the Chief of Naval Operations allowed it so to remain.

Since the U.S. general policy was opposed to using a mine unless the United States could sweep it, the initial use of several mines was delayed to give the Bureau of Ships the opportunity to develop satisfactory sweeping techniques. Finally this policy was dropped and, at the end of the war, there were some mines planted in Japanese ports which even the United States could not sweep or destroy.

Another cognizance problem arose concerning the development and use of "controlled mines." Controlled mining was in charge of the Army, because the Army had begun the study of mining immediately after the Civil War and had developed a system of shore-controlled defense mines. Some time later the Navy had become interested in mining and had developed automatic types of mines. In the harbor defense field, the Army and Navy had worked together and the Army's controlled mines had been assigned to areas where friendly ship traffic was likely to occur. On the other hand all sweeping was being done by the Navy, and in many harbors considerable confusion existed concerning overall mine responsibility. In Great Britain the cognizance of all mining was under the control of one group and the U.S. Naval Attache in Britain recommended to the U.S. Chief of Naval Operations that the same arrangement be installed in the United States. The Naval Districts Division considered this proposition and admitted that it was a very logical move, but finally the CNO, on the recommendations of the Naval Districts Division, decided that "regardless of the merit or demerits of the question—it is believed inexpedient" to make the change. However, at lower levels the Navy's Naval Ordnance Laboratory and the Army's Mine Laboratory at Fort Monroe worked very closely together. All of the Navy's magnetic techniques were wholly turned over to the Army's laboratory use, and before the end of the war the Army's technical personnel were housed in the Naval Ordnance Laboratory. Since the war, the cognizance of all mine design and production has been given to the Navy's Bureau of Ordnance.

During 1940, the Naval Districts Division of CNO began to take on additional responsibilities in mine warfare. It became the representative of the Chief of Naval Operations in new mine developments, in directing the mine sweeping programs, in the coordination of degaussing testing and in the maintenance of proper standards by the degaussing stations. It also began to direct the use of the Navy's Mk 6 mine for defensive uses in the various Naval Districts and in broader types of defensive mining along the eastern coast of the country. Further, it contacted Naval War Commanders and Air Force officers, pointing out the very effective use of aircraft planted mines in British and German waters.

In January 1941, the Naval Districts Division was reorganized and its function in mining was recognized by the establishment of an "Underwater Defense" group within the Division and in September 1941, a "Mine Warfare Desk" was created. The functions of the desk were not well defined, but luckily the officer-in-charge of the desk was a mine enthusiast. He had graduated from the mine warfare school and spent several weeks in England studying their mine warfare organization. Two years after Germany had dropped her first magnetic mine, the Navy's mine consciousness had reached the stage that offensive mine warfare was recognized by the establishment of a section in the Office of the Chief of Naval Operations which was to be wholly employed on mine-warfare problems.

Mine education was also proceeding rapidly in the Navy and also among Army aircraft pilots. At the request of the Naval Districts Division of the Office of the Chief of Naval Operations, the Bureau of Personnel established a Mine School at the Naval Mine Base at Yorktown, Va. Samples, assembly drawings, electrical circuits and instruction pamphlets of all existing mines became the standard textbooks for students, while as each new mine was proposed it was fully discussed with the classes. Courses in aerial mine warfare were also included in the curriculum. The school was open to both officers and enlisted men of both the Army and the Navy.

Also, through the efforts of the Mine Warfare Section, courses in mine warfare both in its technical and operational phases were established in the Naval Training Stations at Jacksonville and at Orlando and at some of the other air training fields. These courses made no attempt to completely cover the problems, but they did serve to spread the general knowledge of what might be expected from a consistent use of offensive mining. The schools were open to both Army and Navy pilots.

The Bureau of Ordnance continued to send picked officers from its post graduate students for a few months' duty at the Mine Depots, at the Naval Ordnance Laboratory and at the Mine Desks of the Bureau of Ordnance. The Naval Ordnance Laboratory had hundreds of scientists and engineers studying ship's influence fields, degaussing, and how to apply the influence fields to mine firing devices. They were also studying the basic problems of magnetic, acoustic and pressure mines, together with the practical problems of how such mines could be safely handled and laid. The Bureau of Ordnance experts were being ordered out to important mine warfare positions, while many of the Naval Ordnance Laboratory experts were either commissioned for mine warfare jobs or sent out as technical experts to establish degaussing stations and to direct their operations.

The Bureau of Ordnance had expanded its mine group. A general reorganization of the Bureau on a horizontal basis had been established, in which there was a Research, a Production and a Distribution Department. The Naval Ordnance Laboratory reported to the Research Department, and theoretically all laboratory design and design recommendations had to be approved by Research before Production could proceed. This flow was logical but when production was highly urgent, the Production Department often called on the Laboratory's engineers direct, thus causing some confusion, but the rough spots were usually smoothed out promptly.

The Bureau of Ships had established a Mine Sweeping Desk in 1939. It had largely adopted British sweeping gear and techniques. Much of the equipment was being purchased and installed on minesweepers. The Bureau of Ships also established a research group on sweeping and a sweeping test station at Solomon's Island in Chesapeake Bay.

Most of the developments referred to above actually occurred before the attack on Pearl Harbor. However, the user of offensive mines, that is, the War Commanders, had yet to be educated before offensive mines could be effectively used. A commander is given a job to do. It is his responsibility to pick the weapons and decide how, when, and where they should be used.

Immediately after the Pearl Harbor attack, the Naval Commanders found themselves working under very serious shortages. Even the surface mine force had to be used for important services other than mining, while submarines found many targets for their torpedoes. The shortage of aircraft in both the Army and Navy prevented any thought of their use in mining, which was quite appropriate since at that time there were very few aircraft mines to be used. However, again through the Chief of Naval Operations' Mine Warfare Office, several liaison staff officers with both a technical and an operational knowledge of mine warfare were sent out to each of the senior Naval Commanders. These men were well chosen. While each was enthusiastic about the use of mines, they were careful not to recommend their use if it was evident that other methods of attack were better. They were welcomed by the Commanders, were kept informed of the war plans and often advised the planting of tactical offensive fields either by submarines or aircraft, which in a number of cases were highly effective. These liaison officers were also very valuable in keeping the Navy Department familiar with mine opportunities and with the requirements which mines must meet. Fortunately the Australian Army Air Force, which now reported to a U.S. Commander, had served in Britain and were mine-conscious, so that they served as an introductory group in air force mining in the southwest Pacific.

Within a year after this country had entered the war, the Chief of Naval Operations and his Staff became convinced that mine-warfare must be fully utilized, and in January 1943 he signed a directive giving the Mine Warfare Division, the Plans Division and the Readiness Division definite directive orders concerning mine warfare. The Mine Warfare Division was to coordinate the development, production and supply of mining material, to establish the quantities needed and rates of production, to allocate mines to the various areas, to supervise mine schools, to collect and disseminate data on mine warfare and to analyze studies for mining operations, the Plans Division was to carry out joint planning with the Army and to make long range plans for offensive mine warfare, while the Readiness Division was to carry out its appropriate duties as concerned with mining. In many ways these orders merely confirmed, by the order of the Chief of Naval Operations, the duties which had been assumed by these divisions.

It is true that up to this time there had been no opportunity to carry on any large offensive mine laying campaign. During 1942 there had been a number of successful small offensive fields laid by submarines and naval aircraft, but the large bombing aircraft were not available in large numbers. However, the delays resulting from the failure of the Office of the Chief of Naval Operations to recognize the necessity of coordinating mine warfare authority in his office did seriously affect the efficiency of the mining campaign when facilities were available to carry it on. During 1941 and 1942 the desired operating requirements for mines had not been furnished to the Bureau of Ordnance. Some of the requirements issued earlier were found to be incorrect, and certain mine designs were held back for months while modifications were being worked out.

As the War Commanders and submariners and pilots began to show more interest in mining, the mine enthusiasts began to criticize the Bureau of Ordnance for not having more types of mines available for planting. In March 1942 the Bureau of Ordnance was concerned because it had not received specific operational mine requirements, while in September 1942 a BuOrd officer pointed out that the Bureau could not pass quickly from the stage "where nobody wanted aircraft-laid mines" to the stage "where abundant mines of special types are ready to plant from all possible places."

Definite directives were issued to the Bureau of Ordnance by the Vice-Chief of Naval Operations in September 1942, and in November of that year, monthly mine meetings were established between representatives of the Chief of Naval Operations, the Commander-in-Chief, the Bureau of Ordnance, the Bureau of Ships, the Bureau of Aeronautics and the Naval Ordnance Laboratory. These meetings were, in general, for informational purposes and covered all aspects of mine warfare.

During 1943, through the efforts of the Mine Warfare Section, many offensive minefields were planted both by submarines and by aircraft, as more heavy bomb-carrying aircraft became available. Many of these offensive minefields were highly successful, which greatly increased the prestige of offensive mine warfare in the minds of the military command. The overall result was that in 1944 the Army Air Forces were requested to undertake a massive campaign in the inner waters of Japan as soon as their bases in the Mariannas became available for use. Twelve thousand mines were planted in this campaign in 1945.

## CHAPTER XIII

# WORLD WAR II—MINE DESIGN AND PRODUCTION ORGANIZATION

World War II started in September 1939. Events moved rapidly. Hitler had bragged about a "secret weapon" which would win the war promptly. The weapon was probably the airplane-dropped magnetic mine which the Germans began dropping into British harbors in November 1939. Shortly thereafter, British experts opened a mine which fell on shore and discovered that it was fired by a device which was sensitive to small changes in the magnetic field. As has already been pointed out, this country was totally unprepared to use this type of mine or even to defend itself against them.

In the previous chapter we have discussed very briefly the growth of an organization in the Office of the Chief of Naval Operations to guide and direct the various Navy bureaus and the service fleets in a mine warfare program. Had this organization existed prior to 1939, it should have stepped out promptly to guide the Navy's program long before Germany began its very effective use of aircraft-dropped magnetic mines. However, the organization did not exist. It had to "grow up" during the war years.

As has already been pointed out, it was the Bureau of Ordnance which actually took the first step. This Bureau is responsible for the furnishing of weapons to the service fleets and also for the study and research in the development of new weapons or new types of existing weapons. Just as soon as the British experts had reported on their examination of the mine, the Bureau of Ordnance realized the mine's enormous potentialities and called conferences of those familiar with mines and mine warfare and the whole matter was thoroughly discussed. In view of the importance of the program and tragic urgency, the Bureau decided to take very prompt action to get the program started.

In detail, the Bureau's responsibility as far as these mines were concerned, included—

*a.* Research in the study of ships' influence fields,

*b.* Development of methods of reducing the magnetic fields of ships,

*c.* Design of firing devices sensitive to changes in the influence fields,

*d.* Design of mines, especially for aircraft dropping, using their devices,

*e.* The production of the needed stock of such mines, *f*. Their transportation to field stations, and

*g*. Their final assembly before laying.

To accomplish all these responsibilities the Bureau, as of January 1940, had available only a small mine section at the Bureau of Ordnance and a small laboratory, the Naval Ordnance Laboratory, at the Naval Gun Factory in Washington, D.C.

To meet these demands the Bureau would have to very greatly expand its own Mine Section Group and also have the Laboratory expand its housing space, its equipment and its scientific and technical personnel. Of these needs the Laboratory's were much the more urgent since research plans and designs of research equipment and of the weapons themselves were necessary before the Bureau could start its mine manufacturing program.

Therefore, the Bureau immediately provided the Naval Ordnance Laboratory with almost unlimited funds for the purchase of experimental equipment and for the employment of scientists, engineers and other contributing employees. Shortly thereafter the Laboratory was authorized to actually purchase large supplies of mines as the Bureau believed that, until its own contracting group became crystallized, the Laboratory could proceed on these purchases more efficiently than the Bureau could.

Throughout the war the Bureau's policy was to assign the research and design problems to the Laboratory and then to assist the Laboratory in every possible way in solving these problems. This involved not only the furnishing of funds, but also the furnishing and loan of naval vessels, the authority to use equipment and supplies at naval stations, both of this country and also of Great Britain and the others Allies. As test equipment became crystallized, especially for checking ships' neutralized magnetic fields, the Bureau would establish, maintain and man testing stations, but if these stations were primarily for research they were maintained and manned by the Laboratory. The whole arrangement was most flexible and operated very satisfactorily.

When the Bureau took over the purchasing and contracting for mine supplies, other policy problems arose. The Laboratory reported to a research section of the Bureau, and all designs had to be approved by that section before the Bureau's contracting section could proceed. This included, of course, all changes in design made after the contract was in existence. Oftentimes the contractor might request a minor change in design and the Bureau's production section might ask the NOL engineer if such a change would be satisfactory, thus by-passing the Bureau's research section. Or, an NOL engineer might be sent out to a contractor's plant and authorize changes which would by-pass the whole Bureau organization. These changes often increased the cost of manufacture and thus caused accounting difficulties if not properly authorized, but if duly authorized through all the sections concerned, the deliveries would be materially slowed up. To avoid all of this, the Bureau and the Laboratory appointed authoritative committees consisting of an officer from the Bureau's contracting section, one from its research section, and an engineer from the Laboratory who could informally, but with complete authority, modify contracts and allow the paper work to follow rather than precede the modification authority.

The first great need for both the Bureau and the Laboratory was for plenty of scientific and technical personnel. For its own staff the Bureau largely made use of technical personnel who had enlisted in the Navy, but for its outlying stations it usually placed a retired officer in administrative charge with the responsibility for the technical work assigned to civilian physicists and engineers. On the other hand, the laboratory's personnel problem could be most promptly satisfied by the employment of civilian scientists and engineers, some from positions of considerable responsibility.

The Federal appointment system had never been designed for rapid operation. First a new position had to be examined by experts and its grade level fixed and then possible appointees had to be examined by another group of experts and those eligible listed in order of preference. These processes are slow even in normal times, and in this emergency, the examining groups could not take care of the large number of appointments needed. Luckily, the appropriation laws permitted the employment, by personal contract, of specialists. This proviso was adopted and personal contracts were prepared which would allow the appointee to be employed either by the Bureau or by the Laboratory. Representatives were sent to industrial laboratories and to the larger universities and schools to discuss our problems and our personnel needs. Other Federal departments appeared to be waiting for an actual declaration of war before applying full force to war work. The National Defense Research Committee had not been formed and large war development contracts had not been let. The type of people the Laboratory wanted largely believed that this country was sure to be drawn into a war for which it was poorly prepared and were highly anxious to serve the government for patriotic reasons. Once the system got started it continued to grow through the "chain-reaction" system. New personnel were continually being recommended by trusted employees and were employed on these recommendations, except that the Laboratory refused to employ anyone if he had close relatives in any of the occupied countries of Europe. All names were finally submitted to the Office of Naval Intelligence, but this office raised questions about relatively few people. For 2 or 3 years from 15 to 25 new high level scientists and engineers were employed each week. As the war proceeded a great many of these were fed into other departments of the Navy as technically trained officers and civilians familiar with degaussing problems, with mine design and with mine warfare.

All phases of the Laboratory's growth were not so rosy. It was much easier to get physicists and engineers ready to work than it was to get bricks piled up to provide a place to house them or to get equipment for their use. In 1939, the Laboratory consisted of one building of about 14,000 square feet (fig. 28), the lower floor of which was used as a shop and laboratory. It crowded all the personnel it dared to into a large room on the second floor, borrowed a supply of folding chairs from the Naval Gun Factory auditorium, and obtained from the Gun Factory a large supply of wooden slabs and sawhorses to make tables. Employees were sitting so close together that if one man moved, it was almost necessary for all at that side of the table to move uniformly. At times it looked as though some of the men would be forced to stand in corners here and there with a paper pad and pencil working on a design or a theoretical problem. However, the personnel did not complain. They realized the situation and did the best they could under the existing conditions.

Meanwhile, every effort was being made to provide more space. As a first step the building was increased by lengthening it, thus adding 3,500 square feet of floor space. By the time this was ready for occupancy, it was more than filled. Shortly thereafter money was advanced by Congress to build a four story concrete building on a lot adjacent to the Laboratory. This was built rapidly and the Naval Ordnance Laboratory was given two and a half floors for its use. As time progressed and the Laboratory's interest expanded, more space was needed. Certain sections of the Naval Gun Factory were moving into new buildings and the Laboratory took with pleasure what was left. By the time the war was over the Laboratory was occupying about 150,000 square feet of space, or approximately 10 times what it had in 1938.

The enormous amount of special equipment needed by the Laboratory's new staff was purchased for delivery as soon as possible, or borrowed if that were possible. In a few cases the Laboratory ran into trouble with existing regulations. It was informed the government would not purchase used equipment even when nothing else was available, but usually the troubles were overcome by its emergency needs. However, the purchase of urgent equipment was very greatly delayed within the Navy's own confines. The system was poor. The Naval Ordnance Laboratory prepared the requisition in memorandum form. The Naval Gun Factory requisition section prepared several copies of a formal requisition which then had to be approved by the Gun Factory requisition officer before it went to the Supply Department for purchase. Most of the delay occurred in the Naval Gun Factory requisition section. Naval officers there apparently could not understand the Naval Ordnance Laboratory's urgent needs. After a few months of this the Laboratory established special relations with the Supply Department and, except in large orders, it bypassed the Naval Gun Factory delay. However, much of the equipment the Naval Ordnance Laboratory needed was not immediately available, so the new staff never had all the equipment it needed during the war.

The administration of the Laboratory with new problems being assigned almost daily and with many new employees able, but totally inexperienced as far as mine problems were concerned, reporting every week, posed many problems. It was impossible for Laboratory management to assign each employee to the problem for which he was most fitted to attack or to properly fix his supervisory level. Employees were shifted from one problem to another as new problems appeared or as an employee's experience and interest became more definitely known. Some of those placed in supervisory rates wanted their groups to attack every problem that interested them even though it had been assigned to another group. However, the multiplicity of problems served well to keep most everybody on jobs in which they were interested and in a few months the apparent chaos of the first few weeks began to develop into a fairly smooth working organization.

Prior to 1939, the Laboratory with its four to five physicists and engineers had two sections, one working on experimental ammunition and the other on mines. The growth of the experimental ammunition section was more normal and, of course, its growth is not concerned with mine development history. The mine section of the Laboratory, however, was broken down into three sections: one on old mines which were being laid, or being made completely ready for laying; one on new mines; and one on the study of ship's magnetic fields and on methods of neutralizing them. Every effort was made to keep this section fully manned as its work was the most urgent of any of the problems assigned to the Laboratory. Within a couple of years degaussing techniques became more or less routine, but other research-type problems developed and were assigned to this group.

Other needs developed as the Laboratory's work progressed. A great deal of fieldwork and tests were needed. Each of the technical sections attempted to arrange for this themselves although oftentimes the facilities arranged for could be used for the work of other Laboratory groups. In the meantime, the Laboratory had acquired considerable auxiliary test facilities in addition to its prewar supply. These consisted of ships, special test locations scattered all over the United States, and special test apparatus developed and built by the Laboratory. In 1944 the Laboratory established a Test Section which would have charge of all of the test facilities. Its responsibility was first of all a service one. That is, it was to maintain all Laboratory Test Facilities and to furnish test people from its own staff to make tests required by development engineers, or to furnish the facilities to the development engineers themselves. For facilities outside the Laboratory the test group usually maintained continuously a small staff to make tests and to assist the development engineers in their tests.

Two of the more important test areas deserve special mention. The Laboratory needed an area where it could examine the acoustic and magnetic fields of many types of ships and where it could test various types of influence mine firing devices. It therefore established an area just off Fortress Monroe in the Chesapeake Bay, and planted there an experimental minefield and experimental sets of acoustic and magnetic measuring devices. The Army mine design group cooperated very closely with the Laboratory. It permitted the Laboratory to assemble its experimental mines on its dock and to use its office for setting up its ranging instruments. Photographs of these installations are shown in figure 35.

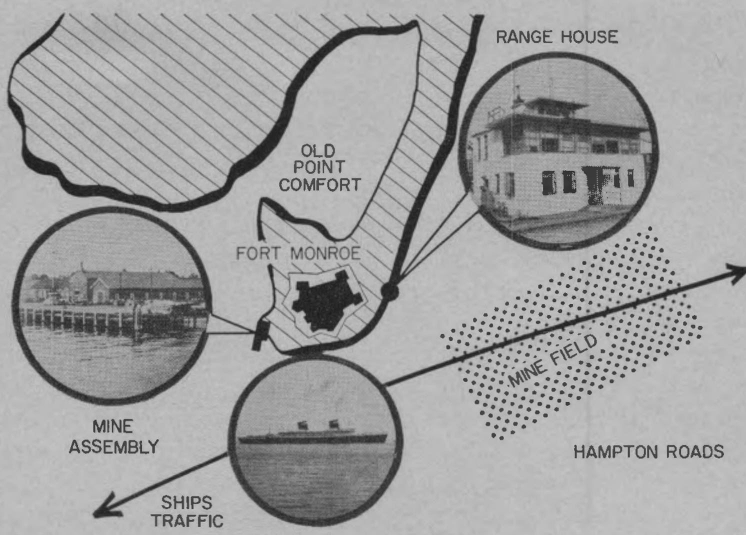



**Figure 35.—Fort Monroe test area.**

The Laboratory also needed an area in which aircraft laid mines could be examined without being molested after being dropped. Drops had been made in the Chesapeake Bay near the mouth of the Patuxent River, but it was always difficult to locate the mine after it had been laid, and there was always a danger that the conditions of the mine might be changed by the picking-up operation. However, at Minas Basin in Nova Scotia there was an area where 40-foot tides existed. Working through Canada, the Bureau of Ordnance was able to get the use of this area turned over to the Laboratory during the war years. Then mines could be dropped from planes at high tide, and at low tide a truck could drive out to the mine and observers could examine it just as it would be lying if dropped in a service minefield. Photographs of this station at low and high tide are shown in figure 36. You may note in the low tide picture the large area which is covered with water at high tide.

Other test areas were established, including one at Solomon's Island, and other points in the Chesapeake Bay, in New York Harbor, just off Provincetown in Cape Cod, off the coast of Florida, two on the West Coast and one in Alaska and one in Greenland. These all had to do with the measurement of acoustic or magnetic fields, the behavior of proposed firing mechanisms, and the operation of mines or mining devices, except the ones in Alaska and Greenland at which the variations in the earth's magnetic field were studied.

In addition to this, the Laboratory specified that before it submitted any design for quantity production to the Bureau of Ordnance the test group must be given the opportunity to thoroughly test the device without any advice or assistance from its developers. The test group could then report that the device did meet all staff requirements or at least met them except

LOW TIDE

HIGH TIDE

**Figure 36.—Mine station test area, Minas Basin, Nova Scotia, Canada.**

for certain definite exceptions. These exceptions might be of such a nature that the device itself could be put to acceptable use by the Navy or it might be that it would have to go back to the developers for further work. The Laboratory had found that the "father" of a gadget is somewhat biased in favor of the gadget's capabilities, and the test group was essential to furnish the Navy with suitable data to provide a basis for an objective decision.

Other service groups also became essential; such as personnel recruiting and hiring, requisitioning material, photography, drafting, report and instruction pamphlet writing, preparation of patent requests, transportation, travel, etc. Most of these groups started originally with just an employee or two working full-, or perhaps part-time only, in each Technical Section, but as the Laboratory grew, management established laboratory-wide service sections to serve the Laboratory as a whole.

During World War II, activities of the Naval Ordnance Laboratory reached a climax probably a year ahead of those of the Gun Factory itself. The Laboratory's extremely large purchases of furniture and equipment and its wide uses of hiring by personal services contract, instead of the customary civil service hiring procedure, appeared to irritate Gun Factory management. The Gun Factory continually asked why each scientist and engineer was considered an "expert," so that he could be included in the contract-hiring process, and why did the Laboratory need these many high-priced pieces of equipment?

As the Laboratory's projects grew and as its activities outside of the Naval Gun Factory multiplied, the annoyances resulting from the upper management group of the Factory not sympathetically interested in the Laboratory's work became more and more bothersome, so in 1942 the Bureau of Ordnance made the Laboratory a Navy Yard department equal to that of the Gun Factory. The Laboratory reported for administrative purposes to the Commandant, but was entirely independent of the Gun Factory itself.

This involved further reorganization of the Laboratory's organization. Its personnel office, file section, requisition section, etc., had up to this time been "unofficial," so far as the Gun Factory had been concerned. They all now became official sections of the new Department of the Navy Yard, reporting wholly to the Laboratory's Commander. This greatly expedited operations and reduced confusion.

Naturally the Laboratory had personnel problems to solve. Some were serious, others just objectionable nuisances. Some involved only one or two people while others involved numbers of the staff. However, it is believed that during the 6 years of the war work, not more than a half dozen staff members left the Laboratory primarily because of personnel dissatisfaction. The fact that so few left is an indication that the big majority of the staff felt that the work they were doing was of special importance in the winning of the war and that they were loyal to the Laboratory management and realized that it was doing all it could to smooth out the rough spots and make the road as smooth and as straight as could be done under existing conditions.

The Laboratory staff had been gathered together very urgently from all over the United States. Some were from universities, others from small colleges, some from research laboratories, some from industrial plants, but in every case they came not because of a desire to increase salaries, but because they felt that the country needed them. Only a very few had ever worked for the government. Most of them were perturbed over the government's plan of working on a definite time schedule, of awarding purchases only to the lowest bidder, of allowing only supply officers to make financial commitments, etc. All of these restrictions delayed procurement of needed material which seemed to them unforgivable when in a war. To these complaints the Navy in fact, added a few more. To go to a cafeteria and find a dining room to which only the officers and their guests were allowed to eat, or for a full university professor, or a head of research of a large industrial laboratory to be challenged at the gate for the contents of a brief case or handbag while a 22-year old ensign aroused no questioning at all—stirred up great complaint among the staff people. However, the above were in most cases of the annoying nuisance class. Explanations of general naval policy smoothed over the complaints even though they failed to explain.

Another personnel problem involved the handling of the Laboratory's young men by the Selective Service. The Government relied on those in charge of Selective Service to raise a large Army, Navy and Air Force. The law prescribed that young ministers and young doctors would not be called, but said nothing specifically about young engineers and scientists. Moreover, the Government did not want to use its authority for making deferments more liberal for Government employees than for non-Government ones. Government laboratories were therefore urged not to make deferment requests a routine matter.

On the other hand, many of the employees were a bit unhappy because they were not out in the military service risking their lives for their country as soldiers were, and were somewhat ashamed of being seen on the streets in civilian clothes. One young man was chided by a group of marines on the street one day as a shirker. Selective Service management itself realized that scientists and engineers at home were essential to give the troops the weapons they needed, but such service was not specifically recognized in the Selective Service legislation.

After much argument and confusion the Selective Service finally decided that drafted personnel would be returned to the laboratories, after being inducted, to continue their scientific work. This only partially solved the problem. Early in the war only the younger men were taken and usually came back to the laboratory as ensigns, and in due season were promoted to junior lieutenants. As the war progressed, the older men, supervisors of those selected earlier, were drawn in and, like the earlier ones, came back to the laboratory as ensigns, while the earlier selectees had become lieutenants. Very frequently the laboratory had ensigns supervising lieutenants. This condition certainly did not improve the morale of the supervising ensigns.

In many military laboratories serious objections were raised by civilian technical personnel because young officers without technical training attempted to make technical or administrative decisions affecting technical work, over the heads of qualified civilians. From this the Naval Ordnance Laboratory was, the author believes, almost 100 percent free, due very largely to the attitude of the Commanding Officer. There were never any officer-civilian distinctions in the Laboratory.

The Commanding Officers highly respected the civilian staff. They realized the many conditions which might cause dissatisfaction and loss of morale. Many of these were beyond their control but they made it clear that within the Laboratory an employee's experience and ability were the important factors to be considered in guiding and directing the work regardless of the kind of clothes he wore. In return they were highly respected by the civilian staff and due to this relationship the rough spots, caused largely by civilians working in a military atmosphere, were largely overlooked.

All in all, the Laboratory was quite proud of the overall behavior of its hurriedly obtained wartime staff. In general, it was a happier group than existed in many other similar laboratories. Their accomplishments were highly satisfactory and where comparisons could be made, it appears that they worked more efficiently than some other groups. Many of the staff remained with the Laboratory after the war and most of those who left appear to look back with pleasure on their wartime experience.

However, the responsibilities of the Bureau of Ordnance extended far beyond the completion of the Laboratory's design. Its contracting section was responsible for placing contracts for the manufacture of the mine cases, the parachutes for aircraft laid mines, the anchors for moored mines, the firing devices and all of the other relatively small, but nevertheless essential, items required to make complete mines. The delivery of all of these items had to be coordinated so that the assembly plant, sometimes in this country and sometimes in islands in the Pacific Ocean, would have all parts necessary to complete the mines needed. The whole situation was complicated by the fact that design was continually progressing and desirable changes in design often developed during the progress of the contract.

Moreover, all cases, booster and other explosive parts had to be loaded. Most of this was accomplished at the large Mine Depot at Yorktown, Va., and the Naval Ammunition Depot at Hawthorne, Nev., and many of the mines were assembled or partially assembled at these stations. Ordinarily, the mechanical and electrical items were not assembled in the loaded cases until the minelayer was ready to receive the assemblies. Most of the assembly of mines for aircraft-laying in the Pacific was accomplished by mine technicians working at assembly depots on islands in the Pacific. These crews consisted of naval officers and enlisted men but with civilian experts from the Naval Ordnance Laboratory to advise on special problems in mine assembly.

All in all, it was the Bureau of Ordnance which carried the final responsibility for having mines ready for laying when mine-laying vessels or mine-laying aircraft were directed to lay them.

## CHAPTER XIV

# WORLD WAR II MINE PROBLEMS AND DEVELOPMENTS

It has already been pointed out that up to 1939 the efforts of the U.S. Navy had been wholly devoted to maintenance and modifications of existing mine material and the development and design of the two mines for planting from submarines. With the advent of the German airplane-dropped magnetic mine, a whole flood of new and very urgent mine problems were suddenly forced onto the consideration of the Bureau of Ordnance. The aircraft planted mine opened up an enormous opportunity for the offensive use of mines. The basic principle of the old magnetically operated mine proposed during World War I had been proven practical. Could the magnetic fields of ships be neutralized? Magnetic and other influence fired mines should be investigated.

All of these problems were immediately referred to the Navy's mine development organization, the Naval Ordnance Laboratory, which was directed in very general specifications to:—

*a.* Study the influence fields of ships.

*b.* Determine how to neutralize ships' magnetic fields.

*c.* Develop and design a series of influence-fired mines.

These directions were as positive and as detailed as the knowledge of these subjects in the United States would permit. The Navy had no organization available to study the operational needs in these fields. It expected the Naval Ordnance Laboratory to establish a staff of high level engineers and scientists to study the situation and guide naval decisions. The Bureau directive gave the Laboratory authority to spend such funds and to employ such additional personnel as might be needed. Conditions in Europe were such that the study of magnetic fields of ships and methods of neutralizing them was by far the most urgent of the problems. However, beyond this it was known that other psysical force fields did exist, such as acoustic, pressure, gravitational and possibly others. A study of these would indicate whether or not they could be used to operate influence-fired mines and how sensitive the mine-firing mechanisms should be.

The directive to develop and design a series of influence-fired mines was a wide open one. The Germans had proved that magnetic-fired mines were feasible weapons, and that they could be dropped from aircraft as well as laid from submarines and surface craft. Just how feasible other influence-fired mines were, was yet to be determined. No organization in the United States could advise on the most desirable sizes or the operational needs to be met. In general, mines in this country were a Navy weapon. Should they be designed only for Navy planes? No operational studies had been made as to the best way of using mines in an attack on Japan. It was a year or two before the operating personnel of the Army, the Navy and of Great Britain reached the stage where they could make the operational requirements more definite.

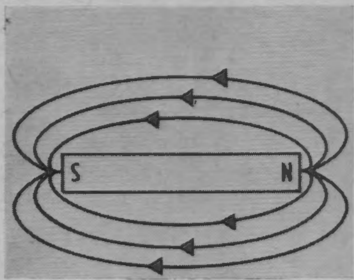
However, the staff of the Laboratory did propose, within a few months, a series of influence-fired mines which was approved on a general basis by the Bureau of Ordnance, and which gave the Laboratory staff some general requirements at which to aim. Most of the early work was developing methods and devices sensitive to the influences emanating from a ship and in building "breadboard" models, which could then be modified to fit into a specific mine, and the original list prepared by the Laboratory comprehended in general the actual mines which were finally developed and used. At no time was there any lack of useful, important jobs for the group of engineers and scientists brought together to the Laboratory.

As mentioned above, the most urgent problem was the development of a method to neutralize, as far as possible, the magnetic fields of ships, since U.S. ships were daily passing through the areas in which German magnetic mines had been laid. The design of new mines was also highly urgent, but not so "frantic." The United States was not yet at war, but both the design of magnetic mines and the neutralization of ships' magnetic fields demanded that more knowledge concerning these fields be very promptly obtained. However, due to the aid of the British, the U.S. Navy was able to proceed immediately on the work of neutralizing the magnetic fields of ships.

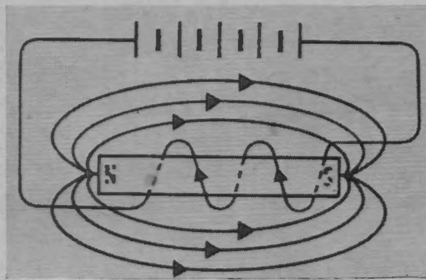
## I. Degaussing

Magnetically a ship is an enormous piece of iron which, of course, is inductively magnetized by the earth's field. After remaining in a fixed location for a considerable length of time, for example during the building process, the ship becomes a semipermanent magnet as well, so there are two fields to be considered. Now as the ship is moved to a location where the earth's field is different, or if it turned into a different direction in the same location, the ship's inductive magnetization will change immediately, but its semipermanent magnetization will change but slowly.

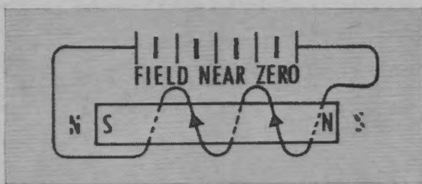
The magnetic field of a ship can be neutralized to a large extent. Sketch 1 in figure 37 shows the magnetic field around an iron bar magnet, while sketch 2 shows the magnetic field around an unmagnetized iron bar with




IRON BAR MAGNET



UNMAGNETIZED IRON BAR
(DC CURRENT)




IRON MAGNET WITH DIRECT CURRENT

**Figure 37.—Neutralizing a magnet's magnetic field.**

direct current flowing through a coil around it. The fields are sensibly the same in form, but the direction of the flow of the direct current has been chosen to make the fields opposite in direction. In sketch 3 the current is flowing around the magnet. No field is shown. It does approach zero. The same system can be applied to a ship, but it becomes considerably complicated because of the irregularity of the ship's iron and steel structure, and because both the horizontal and vertical fields must be considered. Of course, all sorts of combinations of coils may be applied, and by properly placing the coils and properly controlling the current in each coil the field could theoretically be reduced to a very low value, although it might require a large number of coils and of course a new problem would arise as soon as the ship was moved to a different location or position.

By 1940 the British had made considerable progress. Their coils were, in general, horizontal coils wrapped around the ship, or parts thereof. They had named the operation "degaussing" since the gauss is the standard unit of magnetic fields. They kindly furnished the Bureau of Ordnance with the formula giving the amount of current in the degaussing coils which they had found satisfactory in the British Isle area. However, since U.S. ships might strike magnetic mines in areas well scattered over the world, the Navy believed that U.S. ships should have a more flexible degaussing system which could be controlled by the ship's Captain to meet the demands of the specific field in which his ship was located. Therefore U.S. designs provided for a total current about 25 percent greater than that given by the British formula, to be furnished by several coils: one to give about 50 percent, one 25 percent, two 10 percent, and one 5 percent of the total. By using various combinations a very wide variety of degaussing fields could be created. Almost all of the degaussing of U.S. naval and merchant ships was done in accordance with designs prepared on this basis, much of it before much data on ship's fields from U.S. field studies had been obtained.

There were other methods applicable to smaller vessels for partial neutralization of their magnetic fields; one, used usually on smaller ships, consisted of wrapping huge temporary coils around the ship, and then subjecting it to very large fields first in one direction and then in the other, gradually decreasing the strength, similar to the usual technique of demagnetizing a watch. The system, of course, merely reduced the total field existing at the time of the operation and would not affect the inductive field which would develop as the vessel was moved to another location.

The data obtained by the Navy from its ranges and its experimental work with magnetic models was studied particularly to perfect the degaussing technique over that given by the British formula. Additional coils could be placed here and there through the ship to neutralize peaks in the field where necessary. By 1942, the degaussing technique had become so perfected that the degree of degaussing given to a ship was fixed by economic considerations, rather than scientific knowledge. The number of ships being lost to magnetic mines was so low that it did not pay to use the manpower and the copper required to make ships as completely degaussed as it was possible to do. Minesweepers and other ships which might have to operate consistently in shallow water where magnetic mines might have been planted were, however, degaussed to the maximum.

Since degaussing coils did this work in a very unspectacular way, commanding officers were inclined to ignore their existence. However, the particular Commanding Officer who brought his ship into port, and had it blown up as he shut off the degaussing currents, required no further proof that the degaussing system was valuable.

During the war, nearly 13,000 ships were fitted with degaussing equipment in the United States at a cost of approximately $300 million.

## II. Measurement of Ships' Fields

### A. Magnetic Fields

Although the Laboratory gave special stress to the degaussing problem, because of its very high practical urgency, it started groups of scientists and engineers on each of the three problems listed on page 107, and proceeded to make all significant data obtained by one group available to the others.

Within a month or two after the problems had been assigned, the Naval Ordnance Laboratory had designed and built what is probably the first automatic, self-recording, ship's magnetic field measuring unit built in the United States. It consisted of a mirror-bearing magnet mounted to rotate on a horizontal axis; the mirror focusing a point of light on a moving film. The whole device was mounted in a watertight nonmagnetic container which was placed on the bottom while the ship to be tested passed over it. It was used to measure the ships' fields in February 1940 and gave accurate results. However, it was an inconvenient instrument to use for getting the enormous amount of data which had to be collected.

Meanwhile, the Laboratory had sought assistance on its magnetic problems from the Department of Terrestrial Magnetism of the Carnegie Institution. The Laboratory was given every encouragement by both the Director of the Institution and by the Director of the Department, and their scientists were authorized to assist the Laboratory at least on a part time basis. These men were asked particularly to study the design of coils of wire which could be laid on the bottom and which could record on a surface instrument the inductive currents generated in the coil as a ship passes over. However, before this study was completed the British had forwarded to the Bureau of Ordnance a description of their method of measuring and recording the magnetic fields of ships. These consisted of having a ship pass over a number of horizontal coils of wire lying along a line at right angles to the motion of the ship and each recording on instruments above the surface the currents generated in the coils by the motion of the ship. Coils of this design were immediately ordered while Carnegie scientists worked out modifications of a commercial fluxmeter to use as a recording instrument. However, the coils were not entirely satisfactory. It was hard to keep them positively fixed in position and completely watertight. A much smaller coil in which the wire was wrapped on permalloy, or a similar magnetic material, was found more satisfactory. This could be mounted in a copper pipe which was driven into the bottom of the range area; in fact, two such coils could be mounted in the same pipe so that field changes at two depths beneath the ship could be determined simultaneously.

Using these coils, of one type or the other, and fluxmeters, 50 or 60 degaussing ranges were established, mostly in harbors along the continental and island possessions of the United States and in the Allied harbors of the Pacific with a few in South America and in northeast Africa. Each range usually consisted of six to eight coils placed 25 feet apart on the bottom, in a line at right angles to the path of the ship, as shown in figure 38. A further advancement in ship magnetic field measuring techniques was later developed in which the coils were replaced with actual magnetometers each designed to record at a surface recording station the magnetic field at the magnetometers' location. Using these devices a whole magnetometer garden could be planted permanently, as shown in figure 39, which would measure the field at possibly hundreds of places beneath the ship while it was anchored

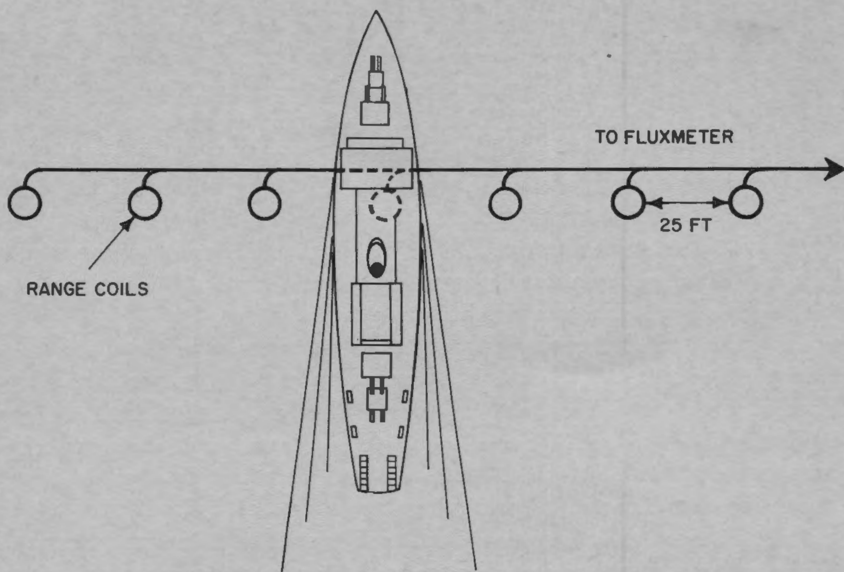



**Figure 38.—Range layout.**

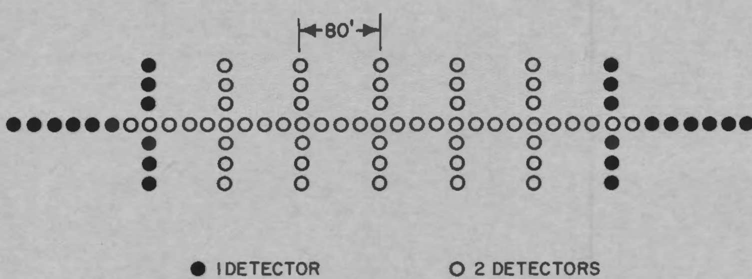



**Figure 39.—Magnetometer garden.**

over the garden. Fifteen or twenty such gardens, usually referred to as Magnetic Proving Grounds, were installed. The total cost of the technical material required for the ranges, proving grounds, deperming stations, etc., amounted to more than $4 million.

Ships, both United States and Allied naval and commercial, were directed to submit themselves for magnetic measurements whenever they were in the neighborhood of ranges or of a proving ground. Thus an enormous amount of data on ships' magnetic fields was collected for analysis, and in addition the degaussed ships were tested and their degaussing equipment calibrated. (Figure 40 gives a record of the magnetic field of a ship before and after degaussing.)

The Laboratory also found that the magnetic fields of a given ship could be estimated from a laboratory study of a magnetic model of the ship. The

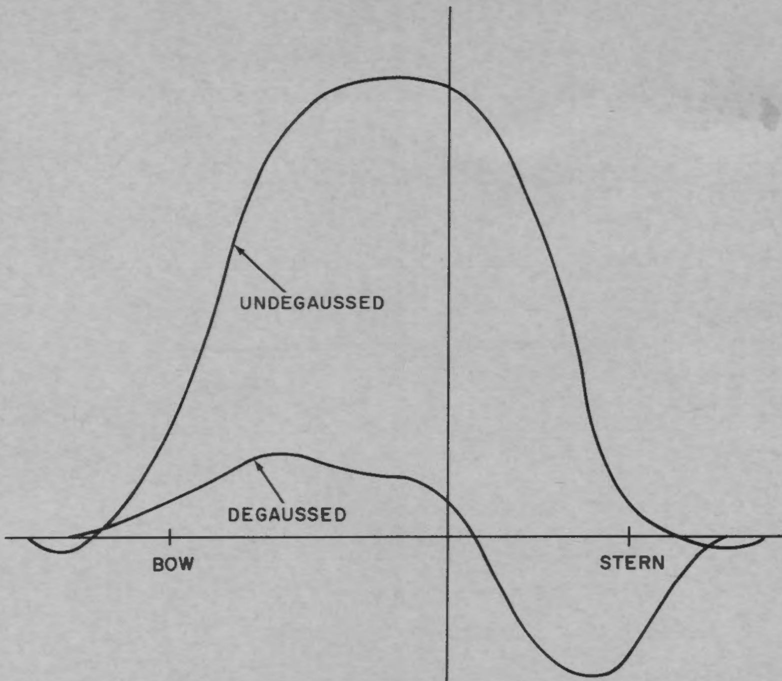


**Figure 40.—Typical magnetic signatures.**

models themselves were expensive to construct, but the total cost of getting the data for a ship was very small compared to what a field test would cost. Also this study made possible the designing of degaussing coils for ships being constructed. Model coils could be put into the model and their effect studied in the laboratory.

Another valuable mechanism was developed and built for the Laboratory. In it the ship was represented by a block of 40 vertical electromagnets. By setting the current in each coil to represent the vertical field of the ship at the point represented by that coil, the total field beneath the ship at deeper depths could be made comparable to the field actually measured by a range at that depth.

By all of these means the Bureau of Ordnance and the Laboratory collected an enormous fund of information about ships' magnetic fields in all latitudes and how these fields varied depending on the position of the ship with respect to the direction of the existing earth's field. This information was analyzed and was used by physicists, mathematicians and engineers in the design of firing devices for magnetic mines, for magnetic depth charges and for magnetic torpedoes. It not only furnished information as to the sensitivity required, but also on the behavior of the firing device as its relative distance from the ship varied, due to the motion of the ship or of the weapon.

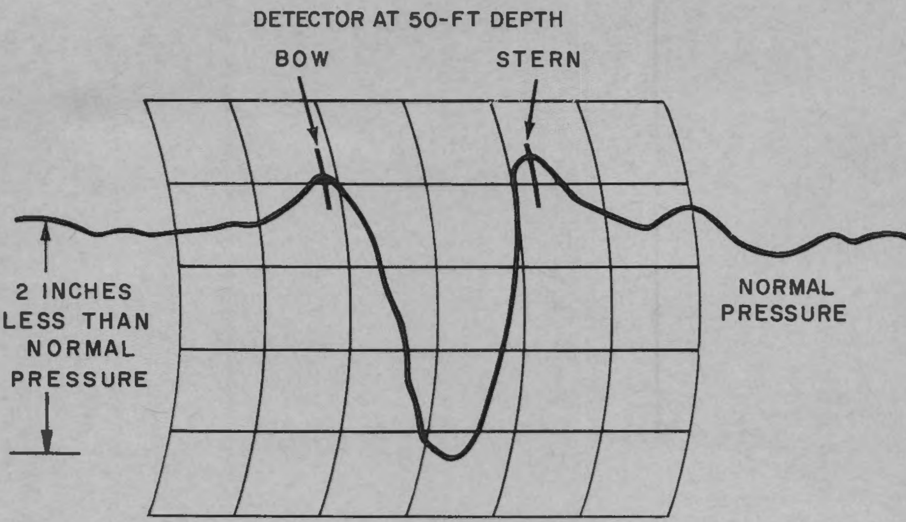



Figure 41.—Typical pressure signature.

## B. Hydrodynamic Fields

The Navy was also interested in all of the other possible influence fields, which might emanate from a ship, to determine which ones might be available for firing underwater weapons such as mines, torpedoes and depth charges. The hydrodynamic, or acoustic fields, those fields which react to produce changes of pressure in the water, were studied in considerable detail. The frequency of the pressure changes in these fields varies from practically zero frequency up to frequencies of hundreds of thousands of vibrations per second.

The so-called "zero" field is a special case and is usually referred to as the ship's "pressure" field, but it is one of the hydrodynamic results of a ship passing over a given area. Normally the hydrostatic pressure at a point in the ocean is fixed by its depth beneath the surface. Now if a ship passes over it, its hydrostatic pressure rises a little as the bow passes over, then drops below normal, but rises above normal again as the stern passes over, the amount of variation depending on the size of the ship, its speed, the depth of the point below the surface, the depth of the water, and to some extent upon the form of the ship's hull. An example of an actual pressure record is given in figure 41. Wave action and tides also affect the hydrostatic pressure.

With frequencies above this zero frequency field, there are hydrodynamic fields of apparently unlimited frequencies emanating from a moving ship. These are usually referred to as "acoustic" fields although some frequencies are below and some are above those which can be heard by the human ear. The propellors make a low thumping noise, especially if they are near the

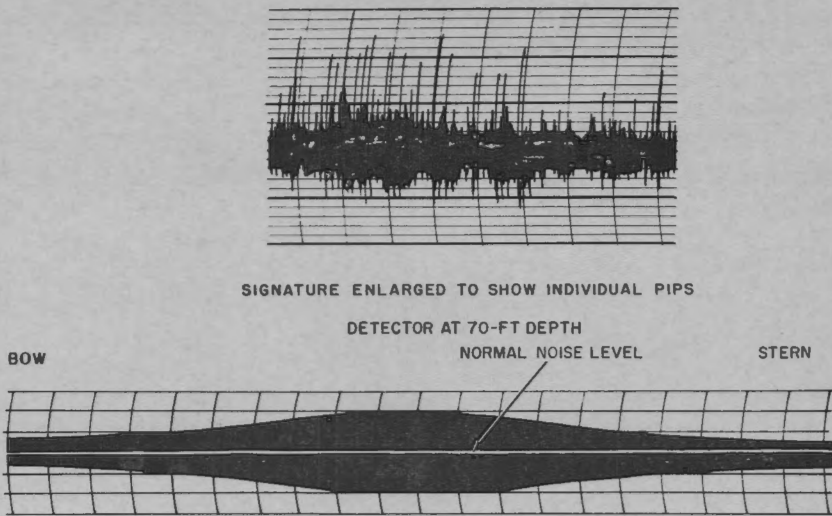



**Figure 42.—Typical acoustic signature.**

surface, while the shell of the ship serves as a very effective sounding board to transmit to the water the vibrations produced by the many moving mechanisms inside the ship. Figure 42 shows an envelope of a record produced by a ship. The small section shown above the envelope, gives some idea of the actual vibrations.

The recording and the analysis of these fields are very much more complicated than those of the magnetic fields. These acoustic fields are affected by the speed of the ship, the depth of the water, and by reflections from the surface and the bottom, which differ depending on the kind of bottom and the kind of surface. By all of these items the magnetic field is to all intents and purposes unaffected. In addition the acoustic field exists in all possible frequencies for which measuring devices have been designed.

There are many other sources of vibrations of this type in the ocean. Wave action, and especially wave action along coastlines, fish, underwater explosions, all produce hydrodynamic fields which in many cases are quite similar to those produced by ships. Each of these had to be studied so that firing mechanisms could be designed, if possible, to be insensitive to sounds from these sources.

The project involved the development of measuring devices which could be placed underwater and record at surface stations. Both the measuring devices and the recorders are in general sensitive only to certain ranges of frequencies, so that a number of systems were required to cover the field. For the lower frequencies a moving diaphragm in the measuring device might cause relative motion between a magnet and a coil, thus generating current which could be recorded at a distant recording station, or the diaphragm might change the capacitance, or inductance, of an electrical device, whose changes could affect an electrical bridge. For high frequencies crystal microphones were usually used.

Several systems were developed and all in all they covered the frequencies fairly completely from 0 up to 5,000 kc. per second. Many acoustic ranges were established and a great mass of measurements was taken to cover almost every type of ship on the seas, and also to study fish noises, acoustic backgrounds and vibrations initiated by explosions.

## III. Mine Development

Essentially a sea mine is an explosive charge in a mine case combined with a means for handling it, laying it and in some cases holding it in place, and a means for causing it to explode. By so designing and choosing these means considerable automatic control can be built into the mine. Ordnance designers have always tried to install more and more "intelligence" into ordnance missiles. First projectiles were only iron balls whose damage was caused by their velocity and inertia, then they were loaded with an explosive charge and a time or contact fuze was added. In World War II one fuze would fire the charge if the projectile approached a plane, or the earth. Also torpedoes and bombs were used that would, to some extent, seek their own targets.

Mine designers began to build intelligence into a mine many years ago. Even Bushnell's kegs had contact fuzes. The British designed a moored mine anchor that was intelligent enough to anchor the case at a fixed depth, regardless of the depth of the water (as long as it was within certain limits). It made it unnecessary to measure the depth and cut the cable accordingly. Early mines also used the solubility of salt washers to delay the arming and the buoyancy of the case to force the firing detonator into its active position. Modern mines demand a relatively high "IQ." Once a mine unit is completely assembled, it is very rarely touched again by human hands. Its operation from this time on throughout the laying process, the arming program and up to the final firing, possibly months or maybe years later, is controlled by the "intelligence" which the designer built into it.

Up until World War II mines were mainly used as moored mines in defensive fields and were usually laid in areas which the mine laying country expected to control. Very little effort was therefore expended to design mines which would defend themselves against enemy attack. Destroying a field was usually accomplished by dragging a heavy steel cable across the field. To make this more difficult the British laid some fields with buoyed inverted grapnels anchored in the field, and also inserted in the mooring

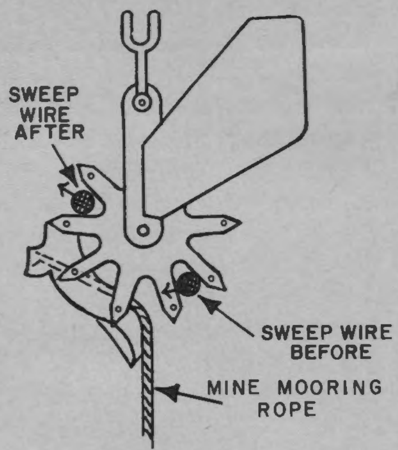



**Figure 43.—Sprocket-wheel sweep evader.**

cables a tooth wheel (fig. 43) which was designed to allow the sweeping cable to pass through without cutting the mine mooring cable. These devices were never used by this country.

In World War II mines were used in great numbers as offensive weapons, and were planted in areas which the laying country did not control. Therefore, it was desirable to increase the "intelligence" built into the mine so that it would defend itself as far as possible against enemy sweeping attack. With influence firing devices the mines could be laid on the bottom. They did not need anchors or mooring cables and they could not be destroyed by cable sweeping. Instead the enemy tried to produce at the mine, from a distance beyond the mines damage area, an influence field, as nearly as possible the same as a ship would produce, which would explode the mine. The mine designers therefore needed to develop automatic devices which would nullify the enemy's efforts.

At the beginning of World War II, in Europe, the United States, while fairly well supplied with defensive mines, had only a meager supply of the offensive-type and had none designed for aircraft planting or to be fired by influence-type firing devices. To develop and design such mines involved such problems as: (a) the design of new cases suitable for aircraft laying, (b) the design of parachutes which could be stowed in a minimum amount of space on the end of an assembled mine; which would automatically open shortly after the mine left the plane, and whose lanyards would be completely released as the mine struck the water, and (c) the design of firing devices and other control mechanisms to direct the operation of the mine after planting. These were new fields and formed a tremendous challenge which was placed before the staff of new physicists and engineers of the Naval Ordnance Laboratory.

The firing device of a mine, the mechanism which senses the presence of a ship and which signals the mine to explode, should not initiate the explosion until the ship is close enough so that the explosive blow is lethal, or if the ship is small it may be desirable not to explode the mine at all. Other controlling devices may enable the mine to count ships and allow a number of ships to pass by unmolested, or they may delay the arming of the mine for hours or days or weeks, or they may control the mine's operation in many other ways. In other words, once the mine is laid the firing device and its controls are the "brain" of the mine and the development of these devices was a most interesting problem for NOL's scientific staff to attack.

In the first place the scientists attempted to determine what physical influences, which exist in the area around the ship, have characteristics which make them desirable and practical for the operation of a firing device. The Germans had proved that the change in the magnetic field was a practical mine firing influence. The hull of a ship furnishes a sounding board through which the noises developing inside the ship are transmitted to the water, so acoustically fired mines appeared desirable and practical. As a ship passes through the water the hydrostatic pressure around the ship changes and laboratory measurements found that this effect was sufficiently great to be of interest.

Other possible fields were also considered. The earth's gravitational field would be somewhat affected by the presence of a ship. The amount of light reaching the mine would be reduced under a ship. A ship exposes various metals, especially steel, zinc, and copper to the sea water, which is a conducting electrolyte, and therefore electric currents in the ocean are existent. These three were considered but it was decided that, for the present, all efforts would be devoted to developing and perfecting the magnetic, acoustic and pressure-firing mechanisms.

## A. Magnetic Firing Devices

The United States had developed a magnetic firing device (M 1) during World War I, but it was a toylike device, operating on the strength of the magnetic field but without any automatic adjustment for the earth's field in which it was laid. This made it very impractical, for if it were assembled for laying at a specific latitude and with the desired sensitivity it would fire on arming if laid 100 or 150 miles north or south of that given position. Considerable thought had been given to correcting its faults in the period between World War I and World War II but no satisfactory solution appeared feasible.

In 1940, the British sent the Laboratory samples of two types of German magnetic firing mechanisms (a photo of one of these is shown in fig. 44). In each type the mechanisms consisted of a magnet, or a group of magnets mounted as a single unit on a horizontal knife edge, with spring controls which were adjusted automatically after planting to hold the magnet system in a horizontal position in the ambient field in which the mine was laid. The whole mechanism was supported in gimbals so that it would always remain in the proper position regardless of the position of the mine case,

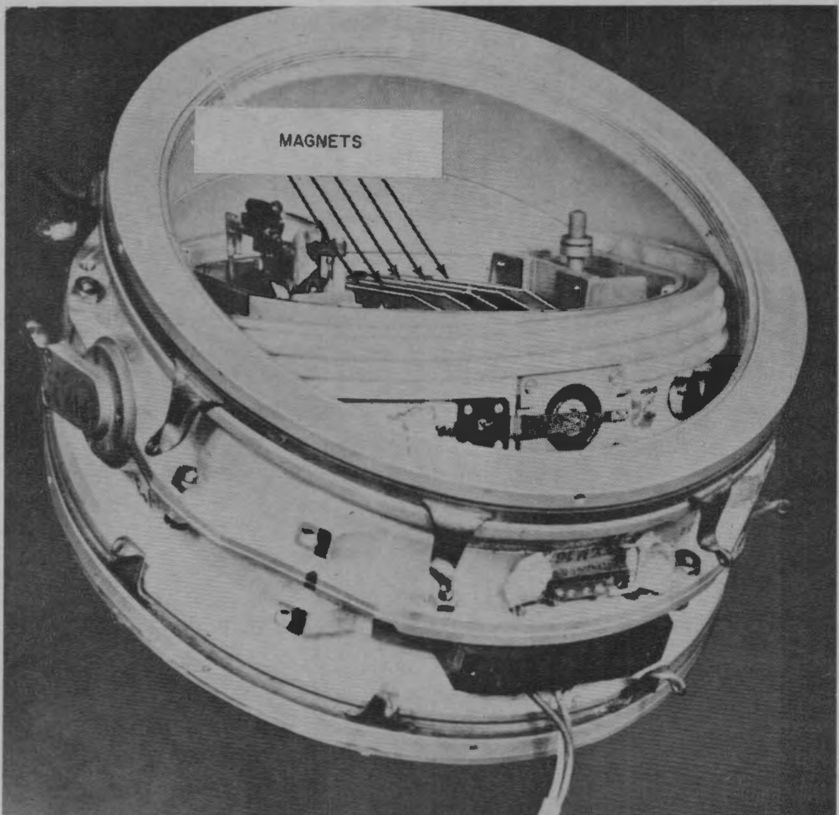



**Figure 44.—Early German magnetic mine firing device.**

while the gimbal support was protected by an elaborate set of springs to prevent any mechanism damage during the laying process. Another automatic control supported the magnet unit during the handling and laying of the case and then gently laid it on the knife edge. The Germans used an aluminum case. (A nonmagnetic case was required by the needle-type device.) The case was designed for laying from a torpedo tube or from aircraft, when equipped with a parachute.

Mechanically the mechanism was beautifully constructed, but its manufacture did demand a relatively large amount of very accurate shop work. However, at the time it was received, the Laboratory had made but very little progress on its own design. (As pointed out above, it was stressing the degaussing problem very urgently up to that time.) Here were mechanisms which had operated satisfactorily so the Laboratory decided to make its first World War II magnetic mine firing device (the M 3) an American copy of one of the German ones. This did involve some redesign and the preparation of a complete set of specifications and drawings. Some delays were experienced in finding American manufacturers who were willing to

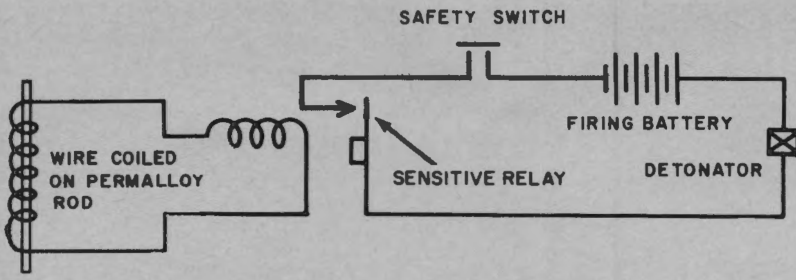



**Figure 45.—Functional diagram of induction-type magnetic mines.**

tackle the job of making some of the parts and then in giving them the time to learn how to proceed satisfactorily in quantity production. The manufacture of the magnets and the aluminum cases were both difficult problems for the companies that accepted the manufacturing contracts. Beyond this the American models had to be thoroughly tested before quantity production could be authorized. However, before December 7, 1941, a supply of these mines was furnished to the Hawaiian Islands and to the Phillipine Islands. In fact, while the Japanese attack was being made, mine experts from NOL were actually in aircraft over the Pacific on their way to Pearl Harbor and Cavite for the purpose of instucting local personnel in the assembly and use of these mines.

Another type of magnetic firing device was also feasible making use of the electromotive force inductively produced in a coil of wire by the change in the magnetic field due to the passage of a ship. Coils of this type were already in use in the measurement of ships' magnetic fields (see p. 160). A simple form of the circuit of this firing device is shown in figure 45. It consists of a rod of permalloy, or a similar magnetic material, on which is wound a coil of many turns of wire, the terminals of which are connected to a sensitive operating mechanism. This may be a sensitive relay, as shown in the figure, or the initial terminals of an amplifier.

The device is operated by the rate of change in the magnetic field. No adjustment is necessary to accomodate it to the ambient field in which it is planted. Moreover, it operates on changes in the field along the axis of the rod be it horizontal, vertical or at any other angle, and the changes in the field from an irregularly degaussed ship may be as effective in causing it to operate as the changes in the field of an undegaussed ship. It can be used in a steel case. It is therefore much more versatile in its application than the needle type.

The device also lends itself to the building into it of a considerable amount of intelligence. An examination of figure 40 shows two sharp changes in the magnetic field as a ship passes over, an increase followed by a decrease, or vice versa. The simplest type of induction firing device will operate on the first change. However, the device can be designed to require two or even three changes, and one of these may be required to be the reverse of the first one. Also the time interval between these may be set to fall between certain limits. These provisions may be used to insure that the mine will be reasonably close to the ship before it fires and also to give the mine the ability to distinguish between large ships, which are the most valuable targets and small ships of little value. It was also possible to adjust the sensitivity of these devices below the maximum sensitivity possible with a given coil and operating mechanism. This also helped the device pick out large vessels from small ones.

The requirement feature which could be built into this device to require at least two changes in the magnetic field, one the reverse of the other, and to put some limits on the interval betwen the two changes greatly increased the enemy's difficulty in destroying a minefield by sweeping. He could produce the reversed field change but if his timing was incorrect he blew up no mines, or he might fire a few and leave others with different time interval settings still alive in the field.

A number of magnetic firing devices of this type were put into production. The M 4, M 9 and M 11 were used in various types of mines. Others were used in magnetic depth charges. For highly sensitive devices longer rods were used or the rods were connected to the ends of the mine case. All the mines were for use on the bottom, and most of them were designed for aircraft planting. Some carried 630 pounds of explosive and others 1,100 pounds. One was designed to be planted from surface craft. The induction type device was not applicable to moored mines, because the motion of the mine in wave action often produced sufficient changes in the magnetic field in the coil rod to fire the mine.

## B. Acoustic Firing Devices

Also in 1940, the British sent a captured German acoustic mine to the Laboratory. The initiating element consisting of a carbon type microphone very similar to that used in the telephone transmitter. It was known that the device was not particularly satisfactory although a mine so armed was of considerable nuisance value and had forced the British to develop and use artificial noisemakers on their sweepers in addition to the artificial field creator. The device appeared to be a good starting point in an acoustic development. The Laboratory's physicists together with some of the sound experts of the Naval Research Laboratory had been considering several possible designs but none had passed beyond the early experimental design. Several pilot models using the German type microphone as a starting point were made, but none were used by this country.

In the meantime the Laboratory's degaussing group was studying ships' acoustic fields. They found that piezoelectric microphones were quite satisfactory as measuring devices and could therefore be used as initiating elements for mine firing devices. The tiny electromotive forces developed by the crystal by the variations in sea water pressure produced by sound waves could be amplified, filtered and controlled in many ways with amplifiers, resistances and condensers. Such controls could limit to a considerable extent the type of frequencies which would operate a firing device and thus make the sensitivity of the mechanism more selective. This would, in general, increase the difficulties of the enemy's sweeping program. Controls could also be installed to neutralize the mechanism against very sudden noise increases as would be produced by mine explosions. However, the devices were still vulnerable to noises produced by waves, by breakers, and by distant explosions, and the position at which they would fire with respect to the position of the ship, could not be satisfactorily controlled. However, one of these, known as the A–3 device (A for acoustic) was manufactured in quantity and was used successfully in the final mine attack on Japan.

Another acoustic firing device, the A–5, sensitive only to very low frequencies, that is from 5 to 30 vibrations per second, was designed. Sounds in this frequency range were not being produced by existing artificial noisemakers, so that the mine was considered unsweepable. However, while internally protected against sudden increases in noise produced by nearby underwater explosions it was found to be vulnerable to the rumbling noises produced by distant explosions. Of course, it could be made temporarily neutral either to sweepers or to ships, by additional devices which could be installed in the firing circuit. Mines armed with this device were used successfully in the final attack on Japan. The Japanese, however, learned how to sweep it, but oftentimes had no sweepers available in the areas in which these mines were laid.

## C. Pressure Firing Device

The variation of the hydrostatic pressure in the volume of water around a moving ship has already been discussed. To make use of this influence, a pressure firing device was developed which in its most simple form consisted of a sensitive pressure gage electrically connected so that a decrease in pressure would close a detonator firing circuit. Operating pressures were balanced so that it could be used in water at any depth up to approximately 100 feet, and slow changes of pressure as produced by tides would not affect it. However, it was sensitive to pressure changes produced by wave action or submarine explosions. It was therefore combined with a magnetic device so that it would ignore pressure changes unless they were accompanied by a magnetic field change. This produced a mechanism which was practically sweep-proof. No satisfactory method of producing the changes in the pressure field except by ship movement was developed during World War II. The use of this device was not permitted until very late in the war, because it was feared that the enemy might learn its secrets and make use of it against the United States and Great Britain. It developed later that the Germans had a similar device, but probably for similar reasons had withheld it from use until the Allies attacked Europe in 1944. There were two models of this device, the A–6 and the A–8, designed for use in different mines. These were used in large quantities in the final mine attack on Japan.

## D. Mine Accessories

As has already been pointed out, much of the intelligence which is built into a mine assembly is through the use of devices which control the mine's overall operation. Some of the more important of these are discussed below.

**1. Parachutes.** Practically all aircraft laid mines used in World War II used a parachute to lessen the blow on the mine case and its contents as the mine struck the water. During handling and stowage in the aircraft the parachute must be secured in a very compact space on the end of the case, and must remain in this position relative to the mine until the assembly is a short distance away from the plane, and in fact, if dropped from extremely high altitudes it may be necessary to keep the parachute in this housing until the mine reaches a point a few thousand feet from the ground. In general, this is handled by a pull-pin in the parachute housing which is pulled out by a pullout wire attached to the plane. If the parachute is to open at this point a spring controlled mechanism will release it. If it is to remain with the assembly during a part of the fall, this pin will merely release an aerostatic device which will in turn release the parachute as the assembly passes a level where the atmospheric pressure is sufficient to operate the aerostatic release. The mine case, however, must be free from the parachute, after the mine strikes the water, so another mechanism, usually operated by inertia, is attached which releases the parachute completely at that time.

**2. Safety and Delay Mechanisms.** The U.S. Navy insists that every mine have at least two safety devices to keep it from firing prematurely during handling and planting and for a few minutes after being laid. One of these is usually the extender, which is a mechanism, operated by water pressure, which pushes the detonator into an active position. The other is usually a switch in the firing circuit, which is held open by a washer of a compressed salt which will dissolve in the water. For longer delays the switch may be held open by a clock whose operation is initiated by water pressure.

Clock delays may also be used for other purposes. Electrically driven clocks may keep the mine inactive for days or weeks so that the enemy sweepers will believe that the area is completely free of mines, only to have some of them become active.

**3. Ship Selectors.** Another bit of intelligence which may be built into a mine, is by means of a device which will count ships, or sweeps. This device operates each time a ship passes or a sweep is made, but after a certain number of operations, fixed by the mine command, be it 5 or 10, or even more up to the upper limit of the device, it connects the mine firing detonator into the circuit, so that the next ship, or the next sweep, will cause the mine to explode. The enemy therefore may sweep and resweep until he is sure that all mines have exploded, only to set the ship eliminator for the next ship.

**4. Sterilizers.** An advancing command may expect to want to use a harbor at a given time. To allow for this a "Mine Sterilizer" was developed which will open the firing circuit, or blow a hole in the mine after a certain number of days have elapsed. The timing element in this device is usually the electrolysis of a metal element which, upon breaking, will allow a spring controlled switch to open. Usually two of these mechanisms were placed in parallel in each mine to be sure that there would be no chance that the mine would remain active beyond the proposed date.

## E. Army Designs

Besides the group at the Naval Ordnance Laboratory, whose mine developments we have been discussing, there was a much smaller group working at the Army Development Laboratory at Fortress Monroe in Virginia, on a new controlled mine. The contact-type controlled mine which had been laid in defense areas were troublesome in that the ships' propellers often fouled the mine mooring cables. The Army wanted to replace the mines already laid with mines equipped with magnetic detectors. This group worked very closely with the Naval Ordnance Laboratory's staff and developed a controlled mine with a magnetic detector which could either signal to the control station that a ship was present, or could fire the mine. All power, of course, was supplied from shore.

## F. Summary

At the beginning of the war the United States Navy's mine mark numbers ran from Mark 1 to Mark 11, inclusive. Of these Marks, 1 to 4 were obsolete, while Mark 8 and Mark 9 had never been completed. In 1945 the Naval Ordnance Laboratory was working on Mine Mark 45. This means only that Marks 12 to 45, inclusive, had been considered of sufficient interest to have Mark numbers assigned to them. Some of these were still under development, while the work on others had been discontinued. On the other hand, there were other mines on which some work had been done, but which had been given only experimental code markings.

The mines actually released for field use during the war are listed below. Most of these were used in several modifications, depending on the accessories used.

Mark 6—An antenna type mine developed during World War I, figure 18.

Mark 10—A cylindrical mine laid by a submarine's torpedo tubes, figure 33.

Mark 12—A cylindrical aluminum-case mine laid by submarine torpedo tubes or by aircraft.

Mark 13—Aircraft laid magnetic mine, figure 46.

Mark 16—An antenna type mine using a case larger than the Mark 6.

Mark 18—A highly sensitive magnetic bottom mine laid by surface craft, figure 47.

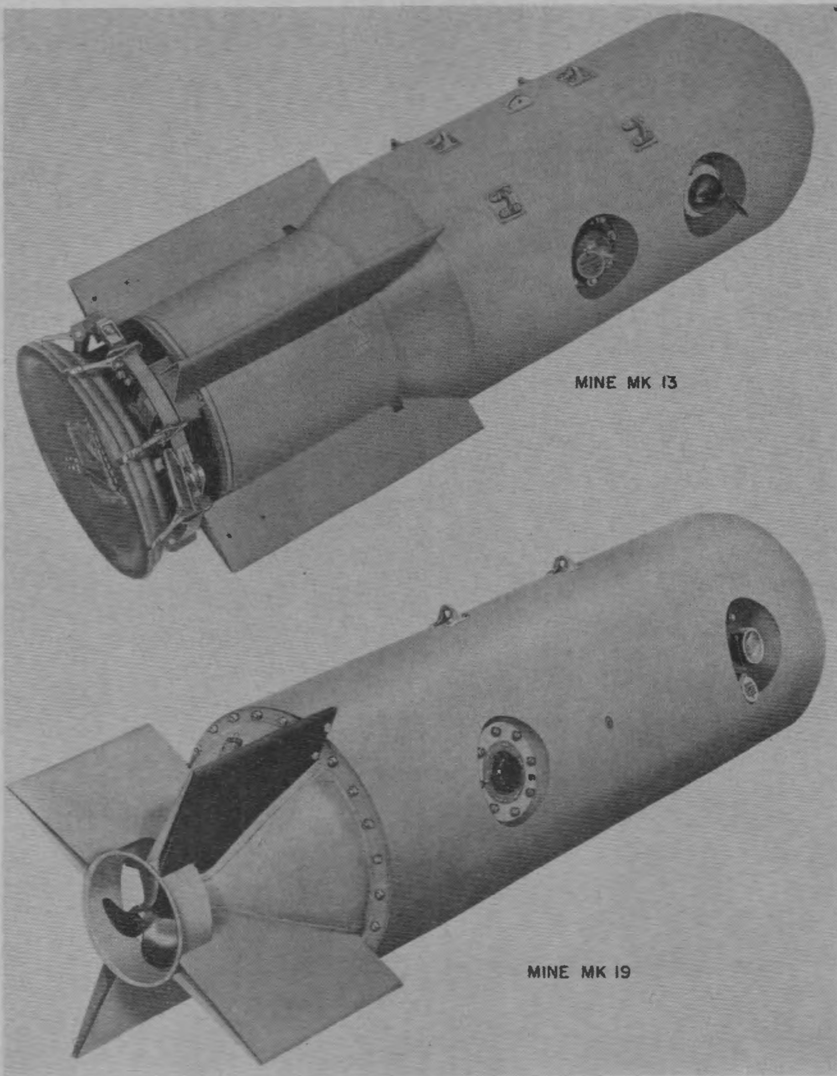



**Figure 46.—Mines Mk 13 and 19.**

Mark 19—An aircraft laid drifting mine, figure 46.

Mark 25—A large aircraft laid bottom mine, figure 48.

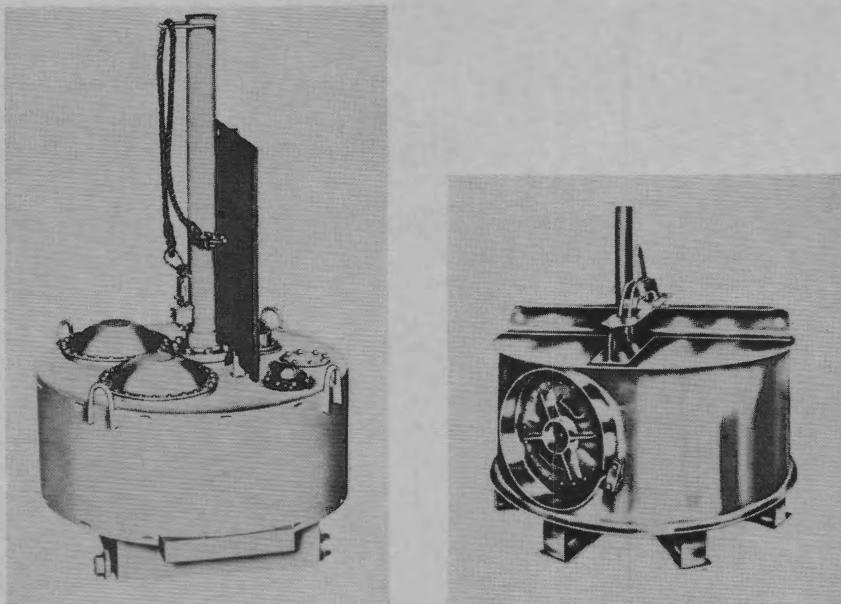
Mark 26—A small aircraft laid bottom mine, figure 48.

Mark 36—A small aircraft laid bottom mine similar in appearance to the Mark 26, figure 48.

The Army's contact type of controlled mine.

The Army's magnetic controlled mine, figure 47.

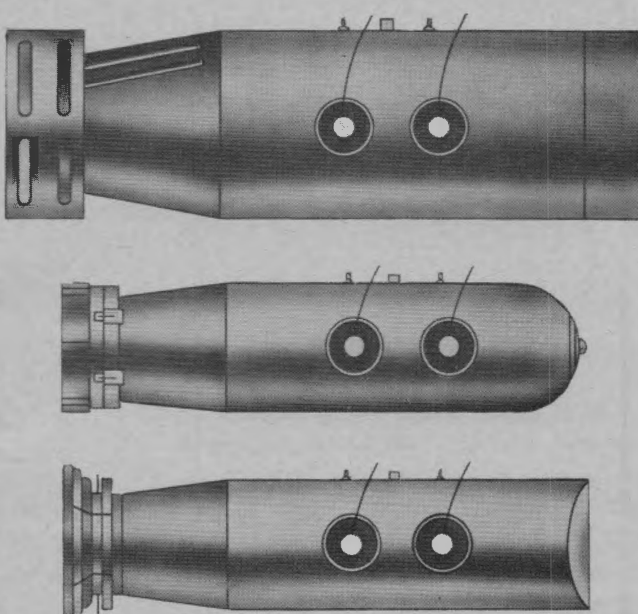
It takes considerable time, a few years usually, to design a new mine, thoroughly test it and have a usable supply manufactured. During that interval the progress of the war may change the field requirements, so that



MINE MK 18

ARMY'S MAGNETIC CONTROLLED MINE

**Figure 47.—Mine Mk 18 and a controlled mine.**



MINE MK 25

MINE MK 26

MINE MK 36

**Figure 48.—Mines Mk 25, 26, and 36.**

the specific mine is not needed. For example, the Mark 13 was rushed through to meet a specific use in the Mediterranean. No parachute was called for. By the time it was available, the area for which it was desired was so well defended that it was suicidal for aircraft to fly low enough to lay it. Fortunately it was later equipped with a parachute and was used widely in the Pacific.

The Mine Mark 22 was requested by the Marines to help defend islands which were being attacked by the Japanese. The Laboratory spent a great deal of effort in designing an extremely sensitive magnetic firing device for this mine. By the time the mine was ready for production, the war had progressed to the point where the Marines were chasing the Japanese, so the mine was not needed. Had the Laboratory been willing to adopt a simple contact-type mine, it might have been able to get them to the Pacific in time for the Marines to use. In this particular case the "desire for perfection may have killed the use of the good."

In another case, the Bureau of Ordnance, apparently with the idea that the most effective mines should all be equipped with magnetic firing devices, directed the Laboratory to design a magnetic firing device for a moored mine, the Mark 16. The Laboratory scientists questioned whether such a device was feasible, but did not want to say it could not be done. A large amount of effort was spent on the project. A magnetic firing device of desirable sensitivity would be operated by wave action. Attempts were made to invent an automatic desensitizing device which would reduce the sensitivity as wave action increased, but these attempts were not successful. The design of the Mk 16 mine was never completed. Cases which had been contracted for were later used with an antenna-type firing device. The mine was known as the Mark 16 Mod 1.

The expenditure of effort on devices which were never used must be accepted as one of the misfortunes of war. Luckily for the United States, many of these devices were not needed because of the successful war program being carried out by the U.S. War Command. On the other hand, it is true that effort was expended on many mine items at a time when the War Command was not particularly interested in the weapon, but which were used very effectively in 1944 and 1945. Work was started by the Laboratory at the direction of the Bureau of Ordnance on Mine Marks 19, 25, 26 and 36 in 1941 and 1942 and they began to be delivered in quantity in 1944 and 1945, at which time the War Command was ready and anxious to make use of them. The Marks 25, 26 and 36 armed with either magnetic, acoustic, or pressure firing devices were the ones which practically starved the Japanese economy in 1945.

## CHAPTER XV

# HOW THE MINES WERE USED

The United States entered World War II much better equipped than it had been in World War I. The Army had, near each area assigned to it for defensive minefields, a supply of controlled mines and mining equipment. Minelayers were also available with officers and crews specially trained for mine laying. The Navy also had in store in each Naval District the mines, mine equipment, minelayers and mining crews needed for laying its local defense fields.

The total supply of mines in stock in the United States on 7 December 1941 was approximately as follows:

| | |
|---|---|
| Army Controlled Mine—Moored | 5,000 |
| Navy Mk 5—Moored—Hertz Horn | 2,000 |
| Navy Mk 6—Moored—Antenna | 59,000 |
| Navy Mk 10—Moored—Hertz Horn (planted from 21-inch tube) | 1,200 |
| Navy Mk 11—Moored—Antenna (planted from 40-inch tube) | 200 |
| Navy Mk 12—Ground—Magnetic (planted from 21-inch tube) | 600 |
| Navy Mk 12—Ground—Magnetic (planted by aircraft) | 200 |

Early defensive mining projects were started even before the attack on Pearl Harbor. The Navy had planted a minefield of Mk 6 mines near Cavite and the Army had planted several fields of controlled mines.

At that time some offensive mine types were available. The Mk 6 could be planted by fast destroyer minelayers in offensive fields, the Mk 10 and the Mk 12 were available for offensive use by submarines. However, the large destruction of fleet units accomplished by the Japanese at Pearl Harbor demanded considerable rearrangement of duties, and the mine planting surface craft found themselves assigned to more urgent matters than the planting of offensive minefields. Moreover, the western Pacific was teeming with Japanese naval and commercial vessels, and submarine commanders believed that they could accomplish more rapid destruction of the enemy by directing their energies to torpedoes. Neither aircraft mines nor mine laying aircraft were sufficiently available to encourage aircraft mining. The Navy's aircraft were needed in actual naval battles and the Army Air Force had given little thought to mining problems. The overall result was that there was a period of approximately 8 months before any offensive fields were planted. Later as the Japanese were driven back into their own empire, mining became largely an aircraft project since by that time there were so few enemy ships in the areas in which submarines and surface craft could operate with reasonable regard for safety.

The first offensive fields laid were by destroyer minelayers in August of 1942. Submarines laid their first field in October while aircraft (British) laid the first U.S. aircraft mines in December in the Mediterranean Sea. American aircraft laid their first mines (British make) in February 1943, and the first U.S. aircraft mines used in the Pacific were laid by U.S. aircraft in March 1943. In general, the time concentration of offensive mining continued to increase throughout the war; approximately 350 offensive mines were laid in 1942; 3,300 in 1943; 3,900 in 1944 and 16,000 in 7 months of 1945. The above includes the so-called "Starvation Campaign" waged against Japan using aircraft planted mines during the last 4 months of the war. Twelve thousand mines were planted in this campaign alone.

In the following pages the World War II U.S. mining campaigns are discussed briefly, pointing out in a number of sample cases the interesting and valuable results of specific minefields and outlining in a general way the total results and the total costs in ships and planes.

## I. Defensive Fields

The Army laid the first U.S. mines in World War II. As early as February 1941 it laid defense fields near Balboa and Cristobal where a surprise attack might have been very serious. By December 7, 1941, 1,200 of the Army's controlled mines had been laid to defend important U.S. areas. Immediately after Japan's attack, planting in all of the other mine areas assigned to the Army was started and all fields were completed early in 1942. Altogether the Army laid 3,569 mines in areas around the United States and its outlying possessions. The location of the fields along North American shores is shown in figure 49.

The laying of these controlled mines is quite a different matter than that of laying the Navy's automatic mines which can be pushed off the deck as the vessel steams along its course. With the controlled mine each one must be laid separately, with a waterproof electric cable passed through a stuffing box into each case, and cast iron anchors are often used which means that the mooring rope must be cut in accordance with the depth of the water. In addition, each of the electric cables is connected to a transfer box, also submerged, and then a cable leads from that box to control equipment on shore. In general a mine laying flotilla cannot lay more than one group of


**Figure 49.—The Army's defensive minefields.**

19 mines per day. The general arrangement is much like that shown in figures 11 and 12 in chapter VI.

At each local mine depot the control equipment had been established and had been kept in a satisfactory maintenance condition, and there was sufficient mining equipment to lay out the prescribed fields and keep them in good shape for at least 1 year. The mine laying personnel were experienced, as since 1939 each group had been required to lay out and keep in continual maintenance two complete groups of inert mines.

All of this first lot of mines were moored mines carrying charges of from 100 to 500 pounds of TNT, and were anchored approximately 15 feet beneath the surface. These were not fired by contact, but contact was necessary in order to notify the control station that a ship was there. It was therefore necessary to restrict friendly traffic to unmined channels, but this was not always possible and numerous accidents occurred when ships' propellers became fouled with mine mooring lines.

By 1943 the magnetic firing device housed in a ground mine was available and all of the fields were replanted using the magnetic mines except the Manila field which at that time was under the control of the Japanese. The number of mines planted in many fields was increased so that 3,751 mines were used. With this new firing device, signals were furnished to the control panel whenever any steel ship of 1,000 tons or over passed over the line of mines. Friendly traffic was in no way limited.

There is no record that any of these fields sank or damaged enemy craft, nor is there any record of any enemy craft passing through the fields.

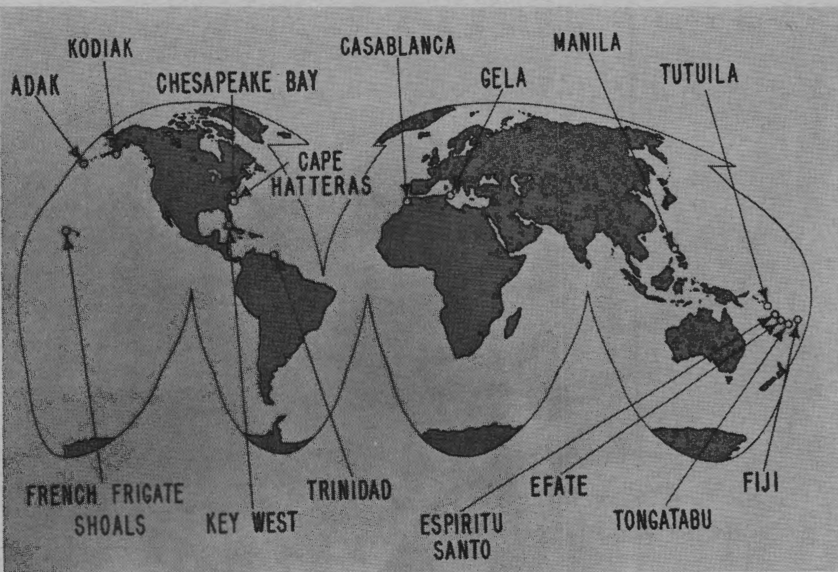



**Figure 50.—The Navy's defensive minefields.**

The officer in charge of the Manila field has stated that about the middle of January 1942 they had three strikes on mines one night and one another night. Searchlights did not show any ship on the surface. The contacted mines were fired by the control station, but there was no positive evidence that ships had been sunk or damaged. However, some weeks later the mining crew tried to replace some unserviceable mines in one of these groups and found that all of the electric cables were securely held down at a point very close to where one of the fired mines was located. After the Japanese got control of this area, they asked some very specific questions as to whether any mines had been fired against real targets, but they carefully avoided giving any reason for the question. The American officer hopes, but has no proof, that the field might have sunk some Japanese submarines.

The Navy laid 700 mines in Manila Bay prior to December 1941. During 1942 the Navy laid some 18,000 Mk 6 moored mines in defensive fields, followed by another 500 or so in 1943 and 1944. Fields were planted just outside of the Chesapeake Bay to protect the bay against submarines. Thousands were planted near Cape Hatteras and around Key West to create areas where commercial traffic could take refuge at night from German submarines. Large fields were laid around Trinidad, another off North Africa and another near Sicily in the Mediterranean. In the Pacific the layers ranged all the way from Alaska to the Fiji Islands and the New Hebrides, laying defensive fields as called for by the War Command. The individual fields are shown in figure 50.

A percentage varying from 2 to 3 percent up to 15 to 20 percent of these mines were not effective. Some destroyed themselves by prematures, while others floated. These faults were particularly serious in fields planted in areas where water currents were very large. Probably the largest percentage of failures occurred in the field planted around Trinidad where tidal rips up to 3 or 4 knots existed. However, a number of the fields were experimentally proved effective because several American ships that accidentally passed over the fields were seriously damaged.

There is no record of any of the enemy's ships being sunk or damaged in the Navy's defensive fields, nor is there any record of enemy ships passing through the fields. There is no known record that any enemy ship tried to pass through these areas. Possibly the knowledge that the fields existed prevented any attempts being made. To quote from Captain Cowie's book: ". . . over 185,000 British mines were laid for protective purposes—the effectiveness of these minefields must be judged chiefly by the degree of protection afforded to shipping and this in many cases (was) the sole reward for many months of slogging and unspectacular effort of the minelayers."

## II. Offensive Fields by Surface Craft and Submarines (Fig. 51)

**A. Surface Craft.** For about 8 months after the Pearl Harbor attack no offensive mine planting was attempted. There was an ample supply of Mk 6, Mk 10 and Mk 12 type mines available, and there still existed a Mine Craft Force and mine planting submarines which could plant these mines. However, the war situation in general was such that the Navy command saw many other duties which they believed were much more important than the laying of offensive minefields.

Surface craft offensive mining finally started August 9, 1942 when a mine laying destroyer laid 84 Mk 6 mines in Maramasike, Malaita. Six months later a squadron of these ships laid a field of 255 Mk 6's off Guadalcanal. During 1942, 43, and 44 these mine laying destroyers laid 13 fields in the southwest Pacific while a few of the Mk 13 type were laid by gunboats around southwest Bougainville in the summer of 1944. All told, 1,829 mines were laid by these surface craft. Of the total only 16 failed to operate perfectly as far as the minelayers could tell. No layers were lost.

It is most difficult to evaluate the enemy's losses due to these fields. In May 1943, fields were planted to break up the "Tokyo Express" by which

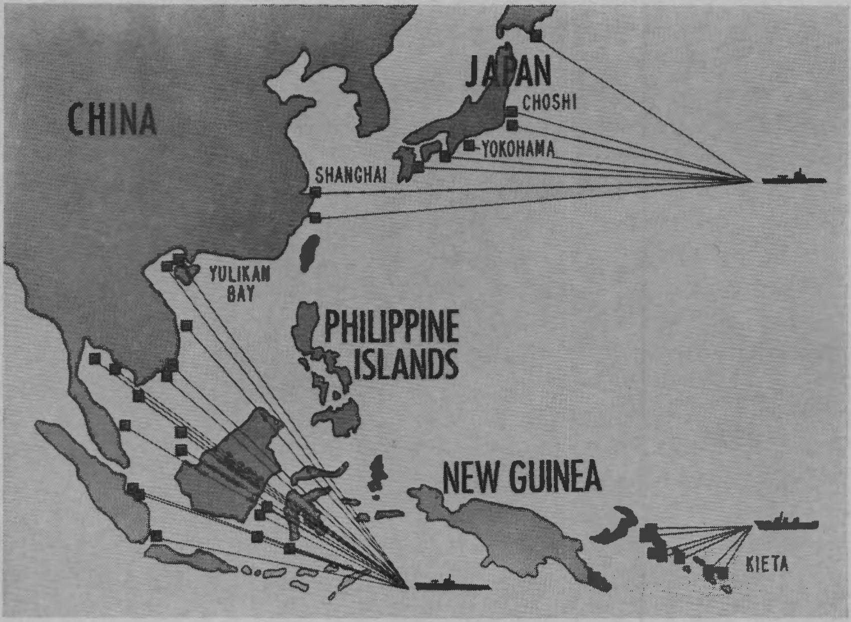



**Figure 51.—The Navy's offensive minefields.**

Japanese garrisons in the Solomon Islands were being supplied. A few hours after the field was laid three destroyers were sunk in the field. Another field sank a destroyer the night after it was planted. Eight to ten other vessels were sunk or damaged in these Mk 6 fields. Apparently the Japanese tried to avoid the mines rather than sweep them for many of the fields were still in existance when the United States reconquered these areas.

**B. Submarine Mine Laying.** The U.S.S. *Argonaut* (see figure 32) was the only U.S. submarine which had been specifically designed for mine laying. She could carry and lay from 65 to 70 Mk 11 mines (an antenna-type moored mine carrying a 500-lb. charge). However, possibly because of the Pearl Harbor disaster, she was redesigned early in the war as a submarine supply ship and her mine planting equipment was removed. She was later sunk by the Japanese.

All of the later submarines were equipped to carry and lay the Mk 10 and the Mk 12, and at the beginning of the war the Navy had an available supply of each of these types. However, the torpedo was the primary weapon of these boats, at least in the minds of most commanding officers, so for most of the war mine laying was undertaken usually for only very specific tactical purposes. In 1943 the submarines of the Seventh Fleet, developed a new scheme of loading mines and torpedoes, so that by giving up space for three torpedoes, eleven mines could be carried, and from then on this group of submarines usually went out on their excursions with combination loads.

The first submarine fields were laid by these submarines operating out of Perth, Australia in October and November 1942. Five fields were planted in the approaches of Bangkok and Cape Padaran, at Haiphong, and at Hainan Strait. These threatened the heavily used route around the Indo-China coast to Siam, and the traffic passing through Hainan Straits. A total of 160 Mk 12 mines were laid and they immediately began to produce significant casualties. At least six ships, totaling 22,000 tons were sunk and six, totaling 18,000 tons, were damaged.

About 3 months later the submarines started another series of mine laying excursions. Between March and June 1943, fields totaling 71 mines were planted at Tanjong Aru, Api Passage and Steffen Straits. Information on the results of these fields is incomplete although they did definitely affect Japanese shipping routes. Credit for three sinkings and four damaged ships is given to these fields.

Beginning in October 1943 and continuing through January 1944, using the new loading arrangement, which allowed 11 mines and 21 torpedoes to be carried, eight fields, of 11 mines each, were laid along the coast of French Indo-China, on the Malay Peninsula north of Singapore and along the Borneo and Celebes shores of Makassar Strait. On the basis of incomplete reports, these sank or damaged a heavy tonnage of Japanese ships.

About 7 months later, from August 1944 to May 1945, minefields totaling 136 mines were laid in various passages and along Japanese ship routes around Borneo, Indo-China and Sumatra. Heavy traffic was recorded prior to the planting, but it suddenly dropped to practically nothing, yet no casualties were reported from several of the fields. The known casualties amounted to five sinkings and two damaged ships.

Central Pacific submarines operating from Pearl Harbor laid their first minefields on October 25, 1942 and by the end of the year had planted 91 mines in four fields in the home waters of Japan. These fields interfered very much with traffic down the east coast of Honshu to Tokyo and along the southern coast of Japan to Nagoya or to the entrances to the Inland Sea. Credit for three sinkings and six damaged ships are given to these fields.

The crew of one submarine enjoyed the rare experience of seeing a ship blown up in a field of the Mk 12 type which it had just laid. While laying the Inubo Saki field, the submarine saw a ship approaching. The submarine submerged and moved away from the field. A few minutes later there was a violent explosion. The submarine came to the surface and saw that the back of the Japanese ship had been broken. It sank in a very few minutes.

A few months later, during April and May 1943, Central Pacific submarines planted five more fields, totaling 112 Mk 12 and Mk 10 mines, two along the coasts of Honshu and Hokkaido and three along the coasts of China. Their fields are credited with six sinkings and four damaged ships. The Central Pacific fields covered most of the shallow water frequented by ship traffic in these areas, and since the mines were not equipped with sterilizers, submarines could not safely operate in the same areas again.

Altogether submarine mine layers planted a total of 576 Mk 12 mines and 82 Mk 10 mines in 36 fields. Ship casualties resulting will never be completely known. All fields were planted clandestinely and the Japanese naval authorities have agreed that many of the earlier mine sinkings may have been attributed to torpedoes because the Japanese were unaware that mines had been planted in those areas. Moreover, aircraft fields were planted in several cases very close to the submarine fields and the resulting losses can not be definitely attributed to either group.

However, 421 mines planted in 21 fields sank 27 ships (approximately 63,000 tons) and damaged 27 more (approximately 120,000 tons). In other words, one ship was sunk or damaged for each eight mines planted.

No casualties have been reported from the other 15 fields. Some of these were planted in out-of-the-way areas where sinkings might occur without being seen or in areas near to those where torpedo attacks were frequent, so that mine casualties may not be credited to mines. However, assuming that these fields resulted in no casualties, the total submarine campaign sunk or damaged one ship for every 12 mines planted. In addition, the fields did delay much of the important Japanese sea traffic and forced it to change routes, oftentimes into more dangerous areas. No submarines were lost on mine planting excursions.

## III. Offensive Fields by Aircraft

As far as aircraft mine planting was concerned, the United States was totally unprepared when the first German magnetic mines were dropped in 1939. This country had given no official thought to this type of warfare. There were no mines and practically no planes available for the job.

As has been already pointed out, the U.S. Navy applied all possible pressure to the mine development problem, and by December 7, 1941, there was one aircraft planted mine in very short supply. Two years was not long enough to pass from a zero development stage to one with an ample stockpile of aircraft mines. However, the stockpile did develop, not too slowly, considering all the demands on manpower and manufacturing facilities, but at a rate which appeared terribly unsatisfactory to those of us in the game.

During the same period the number of available planes increased enormously and the Army Air Force's B–29's became active in long range bombing work. Those planes were large enough to carry pay loads of mines over distances of from 1,500 to 2,000 miles.

Mine warfare was officially the Navy's problem. It had the laboratories for designing and testing of mines. It had the administrative staff and the funds to procure, maintain and distribute them. The Mine Warfare Section of the Navy's Chief of Naval Operations, which had become officially the Navy's top mine warfare organization was studying the results accomplished by Great Britain and Germany in the use of mines, especially aircraft planted influence-fired types, and a group had been assigned to study how best to use this type of mine against Japan.

On the other hand, the Navy did not have and could not expect to have aircraft best suited to carry on a sizable aircraft mining campaign. Its aircraft operated mostly from aircraft carriers and in general could carry but one or two mines at a time. For the type of a mining campaign which it was proposed to use against Japan, the Army Air Force had to be "sold" on the use of mines.

Early in 1942 the Head of the Mine Warfare Section discussed with Air Force officers the effectiveness of aircraft mine warfare as it had been demonstrated in Europe. This resulted in the Air Force sending aviators to the Navy's Mine Warfare School at Yorktown, Va., and in the establishment of some mine warfare courses in the Army Air Forces School of Applied Tactics at Orlando, Fla. The Section also sent special mine liaison officers to the Central Pacific, South Pacific and Southwest Pacific Commands. These men were familiar with mine design and mine development problems and had studied the methods by which aircraft planted mines were being used effectively in Europe. Much of the success which later crowned the U.S. mining campaign should be credited to these men who studied each problem on its own merits and although enthusiastic about mines, often recommended that some other weapon appeared desirable. Thus they gained the respect of their commanding officers who gave all of their recommendations full consideration.

Groups of expert mine designers and mine technicians were also established in various Pacific areas. It was their responsibility to finally prepare each mine as a piece of "fixed ammunition" for the planting planes. These groups performed this service both for the Navy and the Army Air Forces. The characteristics of a mine's operation are to a large extent fixed by the accessories used and by their adjustments. Photographs of one of these establishments together with a mine stowage area are shown in figures 52 and 53.

The aircraft mining program, therefore, made four very worthwhile and more or less essential accomplishments, as listed below, during the first 12 to 15 months of the war. These are:

*a.* Initial development and procurement of aircraft mines

*b.* The procurement of aircraft satisfactory for mine planting

*c.* The education of commanding officers and aircraft pilots that mines were effective weapons.

Figure 52.—Living and working quarters in the Pacific.

Figure 53.—Mine stowage area in the Pacific.

*d.* The training of mine designers and mine technicians and the establishment of final mine assembly stations close to the mine operation areas.

## A. The Navy's Aircraft Mining

The Mk 13 mine was the first U.S. mine actually planted by aircraft in World War II. This mine had been particularly designed to meet a need in the Mediterranean Sea, and a few (38 to be exact) were planted on the northern coast of Africa and around Sicily from December 1942 to May

1943 by British planes. The mines were not suitable for the job. Either the designers had received incorrect specifications or the war requirements had changed. The Navy's actual planting of its own aircraft mines was all done in the Central and South Pacific areas. All the fields planted were for specific tactical purposes, and were usually small, but in every case were successful not only tactically, but also in the destruction of some Japanese ships, many of them war vessels.

In its first offensive fields, between March 1943 and February 1944, aircraft laid fields in various harbors and channels around the Solomon Islands to disrupt the flow of Japanese supplies and reinforcements. TBF and PV–1 planes were used, carrying but one mine apiece. Three sorties, one mine each, were carried out by PV–1 planes of the Royal Naval Air Force of New Zealand. These fields, plus those planted by destroyers forced the Japanese to change their shipping routes to those less desirable and in more dangerous areas. Several Japanese war vessels and merchant ships were sunk or damaged.

The next naval mine project was in support of the U.S. attack on Kwajalein and on Eniwetok in the Marshall Island group. During December 1943 and January 1944, 117 Mk 12 and Mk 13 mines were planted in Jaluit, Maleolap, Wotje and Mille, all of which had good anchorage facilities. The object of these fields was to prevent the use of these anchorages during the U.S. attacks. The results were apparently successful as Japanese shipping practically disappeared after the fields were planted. Navy sources credit the fields with the sinking or damage of several large merchant ships and they undoubtedly weakened the Japanese defense effort. The Kwajalein Atoll was not to be mined, but a field of dummy mines was planted there to fool the Japanese. It apparently succeeded in convincing the Japanese that this atoll would not be the U.S. invasion point.

Probably the most spectacular strike of naval aircraft mining was the attack on Palau in March 1944 (see fig. 54). The initial purpose was to mine all outlets from the atoll anchorage and then to attack the ships inside of the atoll with bombs and torpedoes, and to follow this with mines equipped with long arming delays and with antisweep features planted in the entrance channels to keep the anchorage useless for some time as a naval base. On March 30 and 31, 1944, TBF planes from naval aircraft carriers planted 78 Mk 10 and Mk 25 mines in the atoll entrances. Succeeding strikes by aircraft using bombs and torpedoes sank all of the 32 vessels in the harbor. Several days later the Japanese lost three ships trying to enter the harbor and then closed the harbor entirely for 20 days while a frantic sweeping effort was being made. Moreover, the base was abandoned as an operating base for naval vessels. The long arming delayed mines appeared to have been effective.

In April 1944, the Navy continued its mining effort by planting 55 mines in Truk, using PB4Y–1 and PB2Y–3 aircraft from Fleet Air Wing One based on the newly captured Eniwetok. There were no known

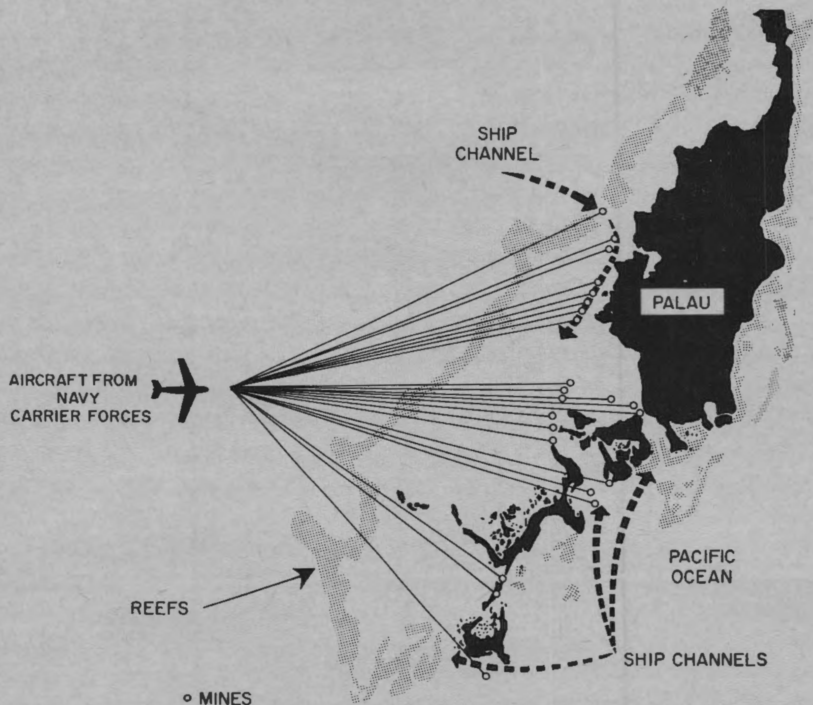



**Figure 54.—Mine attack on Palau.**

casualties, but the harbor was closed to shipping for about 1 month and the Japanese finally had to sweep one of their own defensive fields to get into the anchorage.

The last mine laying project undertaken by Navy planes was the planting of 170 mines of the Mk 25, Mk 26 and Mk 36 types in the channels between the small islands on the extreme southern coast of Korea. The work was done by PBY–2 aircraft of Fleet Air Wing One, based on Okinawa. The minefields sank or damaged 10 to 12 ships and forced the traffic out into the more dangerous open seas. The action might be considered a part of the starvation campaign since it occurred in June 1945 while the 21st Bomber Command AAF was trying to starve the Japanese economy by enormous mine plantings in its inland waters.

This concludes the Navy's mine laying. It had laid defensive fields early in the war and at various times during the war and had laid offensive fields using high speed surface ships, submarines and Navy aircraft. It had learned that mines could be used very effectively as a complement to other methods of attack and that mines could be used to keep a continuous threat on areas whereas bombs and torpedoes could only maintain the threat when the ships or planes were present. As has already been pointed out, naval aircraft were not large enough to handle payloads of mines over long distances. Most of the mines planted by the Navy were carried

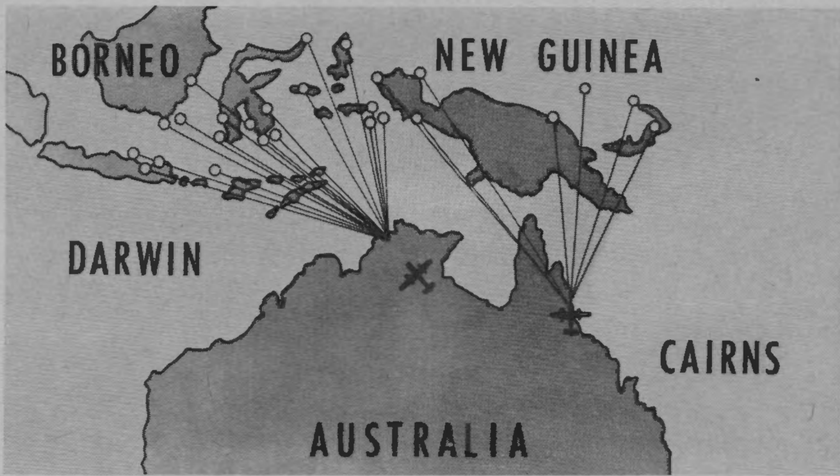


**Figure 55.—RAAF minefields.**

one to a plane. Four hundred and eighty-six successful sorties planted 687 mines.

The Navy's total losses were low. No surface craft or submarines were lost and but 15 aircraft, most of which were lost due to storms and geographical conditions rather than by enemy gunfire. The total Japanese material losses are estimated to be between 90 and 100 ships sunk or badly damaged and in addition shipping was denied either for a short time or for the duration of the war to every mined area.

## B. The Army Aircraft Mining in the Pacific

The Army aircraft mining against the Japanese can be broken down into five groups based on the areas on which the laying planes were based as follows:

1. The Southwest Pacific Theater—Planes based for the most part in Australia but later moving up to the Philippine Islands. With the exception of sorties made by the U.S. 5th Army Air Force, all of the planes were Royal Australian Air Force PBY's.

2. The India-Burma theater—Planes based on fields in India, Burma and Ceylon. The planes were mostly U.S. B–24's, B–25's and B–29's of the 10th Army Air Force and the 20th Bomber Command, and B–24's of the Royal Air Force, India.

3. The China Theater—From fields in China. The planes were U.S. B–24's of the 10th Army Air Force and B–29's from the 20th Bombing Command detailed to the Chinese area for long distance mining sorties.

4. The Central Pacific—From Guam and Saipan. Those were B–24's of the 7th Army Air Force.

**The Southwest Pacific Theater (See Fig. 55).** A very large part of the mining of the earlier part of the war was done by the Royal

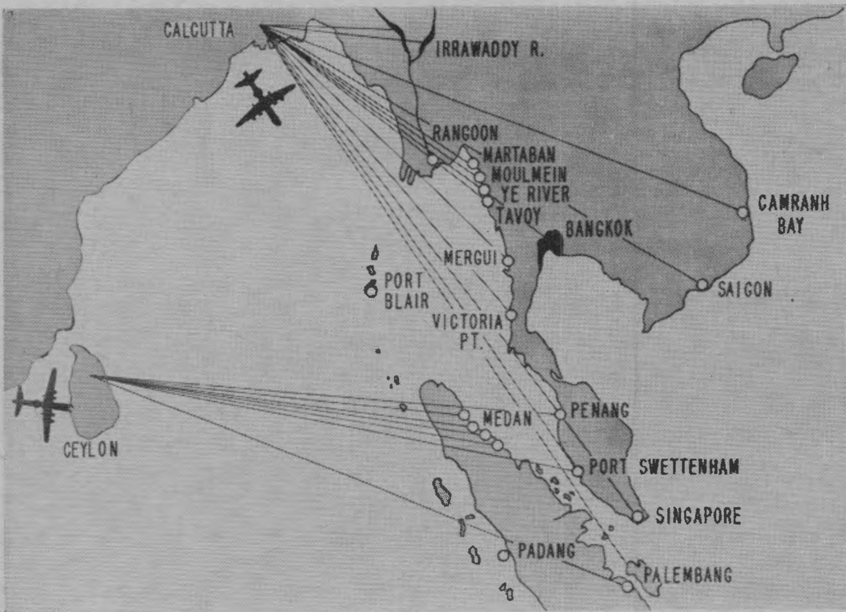



**Figure 56.—Minefields planted from India and Ceylon.**

Australian Air Force from this theater. Many of these pilots had served in England and were more mine conscious than the U.S. aviators or U.S. aviation commanders. By 1943 several U.S. types of mines and some British mines were available and other types were received later. All plantings were made by PBY–5 planes of the RAAF except four sorties by B–24 planes of the 5th Army Air Force based at Port Moresby.

During 1943 minefields were planted in all mineable harbors and shipping routes within range of Australian bases and as the Japanese defeats allowed use of bases outside Australia, minefields were laid in the principal harbors of New Guinea, Halmahera, Celebes, Java, and Borneo. In April 1944 they planted tactical fields in Woleai Atoll in support of the Hollandia invasion, in June against Palau to support Marshall Island landings and in November and December in Balboa Strait and Manila Bay in support of Philippine landings. In March 1945, as Philippine bases became available, the RAAF's changed their targets to China, Formosa and Hainan.

Altogether the Royal Australian Air Force made 1,130 sorties and laid 2,522 mines, 654 of which were of British manufacture. The total Japanese casualties were approximately 90 ships, aggregating around 25,000 tons. In addition, they were forced to practically abandon Kavieng and Surabaya and several other ports and channels were closed to them during the allied attacks on Hollandia and the Philippines.

**The India-Burma Theater (Fig. 56).** Planes based on India and Burma also got into the mine laying game about as soon as mines were available, although they did not devote as full time to it in 1944 as the Australian RAAF. The Royal Air Force, India, and the 10th and the 14th U.S. Army Air Forces all joined in the mining projects carried out in this theater.

The first U.S. Army aircraft minelaying ever performed against an enemy was made by planes of the 10th Army Air Force, which on 22 February 1943 planted 40 British mines in the Rangoon River. The field was laid particularly to prevent the Japanese from using Rangoon as a base in the shipping of supplies and reinforcements to its army fighting the British offensive in Southeast Asia. The result was immediate. Several ships were sunk and traffic fell off to a negligible amount. The Japanese then tried to bring their supplies through Bangkok and by rail to Burma, but mines at Bangkok and in some ferry crossings in Burma made this route difficult and dangerous. These minefields were replenished from time to time.

Another mine victory occurred at Penang on the west coast of Malaya. This port had been developed as a submarine base for Japanese and German submarines. In October 1944 RAF Liberators began to mine the area and continued to do so for several months. The results were successful. The Japanese abandoned submarine operations in this area and the Germans moved their base to Batavia.

In August 1944, B–29's based on Ceylon laid a field of mines in the important approaches to Palembang, Sumatra. This mission was combined with bombing and was probably the longest nonstop mission of its kind ever carried out up to that time. This mining attack is of special importance because it was here that B–29's first proved themselves as satisfactory aircraft minelayers. Operation tactics were modified to take advantage of their precision bombing equipment and their radar bombsights. The successful mission therefore proved that the B–29's would be satisfactory in making plans for the later mining attack on Japan.

In January 1945 India based B–29's laid several hundred magnetic mines in the approaches to Singapore, Saigon and Camranh Bay, and the minefields were replenished in February and March. After March 1945 no enemy convoys attempted to make the hazardous trip from Singapore to Japan, and Camranh Bay was not used by Japanese ships after it was first mined in January.

All in all, these groups of planes laid a total of 4,580 mines of which 3,443 were of U.S. design and 1,137 were British. Again the British planes laid more than U.S. planes (3,235 vs. 1,345). There were 937 sorties and nine planes were lost. While many Japanese ships were sunk or damaged by the India-Burma campaign, the most important result was the stoppage, or delay, of Japanese shipping either with supplies for the armies in the field or with raw materials needed to continue the economy of Japan and to manufacture war munitions.

**The China Theater (Fig. 57).** Mine laying from Chinese bases began with the dropping of three Mk 13 mines in the approaches to Haiphong in October 1943. A few more were planted in November. The results

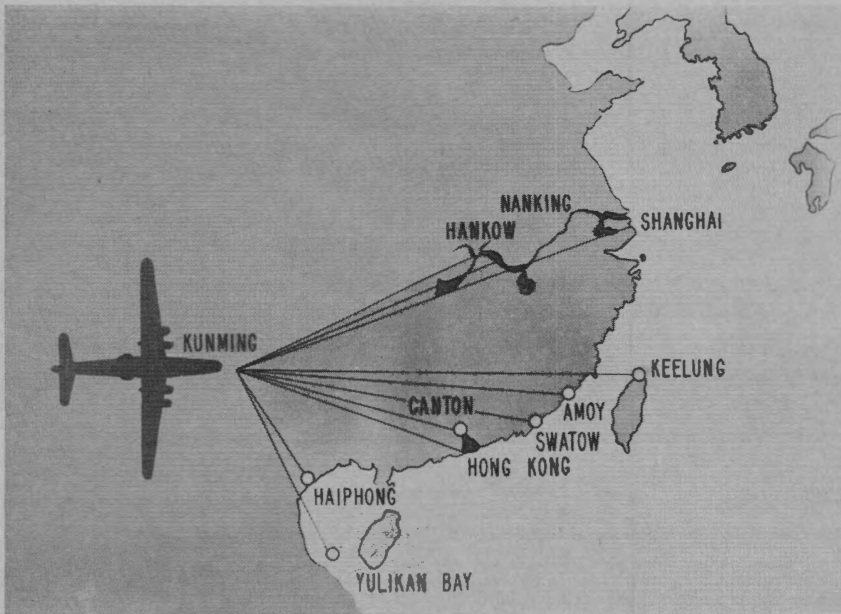


**Figure 57.—Minefields planted from China.**

were encouraging. Several ships were sunk and the Japanese abandoned the port except for very small ships. This encouraged the 14th Army Air Force to continue. They kept Hong Kong, Canton, Takao and Shanghai, and other important ports under more or less continuous attack. The harbors were frequently closed for several days.

Mining was also used to interfere with traffic in the Yangtze River. Between 600 and 700 mines were dropped in this river, over 200 of them being Mk 19's which were designed to float down the river beneath the surface until they made contact. The 14th Army Air Force requested the 20th Bomber Command to make some long distance mining trips to the lower Yangtze. They planted 263 mines in this area. All told 1,239 mines were planted, all U.S. design. The most important results were the disruption of Japanese sea traffic and the resulting failure of supplies and reinforcements to field troops.

A Japanese officer, since the war, has stated that the mining of the Yangtze River greatly affected the Japanese drive into South China, while another said that he believed a great many drifting mines had been planted in this river, because they knew of no planting in certain areas where mine explosions sank or damaged many ships.

**The Central Pacific Theater.** Most of the mining from Central Pacific areas, outside of the Japanese Starvation Campaign, to be discussed below, was carried out by Navy aircraft. However, the Navy's original plan to mine certain harbors in the Bonin Islands had been canceled because of Japanese fleet operations and the mining was finally carried out by B–24's of the 7th Air Force, operating from Guam and Saipan. From November 1944 to February 1945 these planes planted 226 Mk 25's and Mk 36's in these harbors. Several Japanese ships were sunk or damaged and traffic was materially reduced. In fact, Japan was never able to reinforce these Bonin Island bases.

## C. Starvation Campaign

In any concept of a war with Japan, the need of eliminating Japanese shipping traffic between the islands themselves and between the Empire and the mainland of Asia becomes very apparent. This could only be done by aircraft because Japanese mines, nets and shore defenses made such an attempt by submarines or surface craft most difficult, if not impossible. However, by the time the actual war with the United States had started, Japan had secured for herself such a wide expanse of islands that no airplane could effectively reach these areas with payloads of bombs or mines.

As the war progressed, and the Allies began to win back some of the outer islands of the Japanese Empire, mine enthusiasts argued and urged that mines could be made the major weapon of an attack to destroy Japanese economy. Mines had been used rather successfully in relatively minor roles in the attacks on Japanese held islands and the results had been spectacular in comparison to the effort expended and the very minor losses incurred. The B–29 planes had in 1944 proved themselves to be effective minelayers and the Navy had developed and had under manufacture a group of influence-fired aircraft-laid mines. It was pointed out that mines would lie in wait for their victims, that they could be planted from high levels and by radar control, and that high accuracy and clear daylight skies were not demanded.

By late 1944 an enormous percentage of all Japanese shipping passed through Shimonoseki Straits between the Sea of Japan and the Inland Sea and the coasts of Korea and China. During that year Japan had depended on sea traffic to bring in 80 percent of her oil supplies, 88 percent of iron ore and ingots, 24 percent of all coal (90 percent of her coking coal) and 20 percent of her food. Her food situation was such that a material decrease in this 20 percent would actually mean starvation for a considerable part of her population. Inside the islands themselves a very large part, estimated at 75 percent, of transportation was water borne. This distributed over half of the coal used in her great industrial regions.

As of March 1945 the Japanese steel merchant ships of 1,000 or more tons amounted to approximately 1.8 million tons, which would make an effective operable fleet of probably 1.4 million tons, and it was estimated that these were bringing each year from 1 to 1½ million tons of food and raw materials into Japan, mostly from China and Korea. A very large percentage of this moved through the Shimonoseki Straits up to the industrial centers

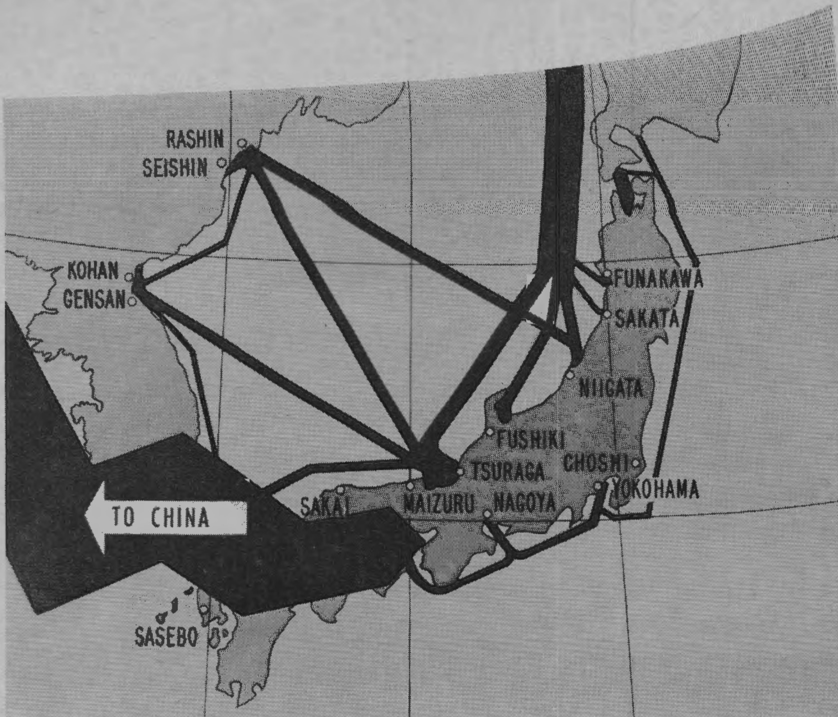



**Figure 58.—Japanese traffic situation, March 1945.**

of Kobe and Osaka. A graphical survey of Japanese shipping in this inner zone is shown in figure 58. The average daily shipping is indicated by the width of the black lines.

Japanese targets of merchant or naval vessels in the area outside the inner zone had almost ceased to exist because of the danger of attack from U.S. bombs, torpedoes or mines. She had withdrawn most of her shipping into an area where she could use it to maintain the economy of the islands themselves.

The Japanese navy, that is what was left of it, was largely stationed at Kure, or at other ports in Japan's Inland Sea. It was still a formidable fleet consisting of three battleships, several aircraft carriers (not of much value because of Japan's shortage of planes), cruisers and destroyers. The battleships included Japan's newest and finest battleship, the *Yamoto.*

**The Object of the Proposed Mining Campaign.** The time, therefore, appeared about ripe for an economy destroying campaign. The Navy had the mines, either available or in production, but no Navy planes could do the job. The Army Air Force had the B–29's just recently available in the Marianas, which were within long range flying distance to Japan, but it had no mines.

In November 1944, the Commander in Charge of the Pacific Fleet proposed to the Commanding General, Army Air Force that it undertake the imposition of a mining blockade on Japan. The suggestion was accepted and the Commanding General, 21st Bomber Command, was directed in December 1944 to initiate planning so the campaign could be started about 1 April 1945. The overall mission was to blockade all Japanese sea commerce and to tie up within the islands what was left of Japan's Navy. This would include:

*a.* The immediate tying up of Japanese naval units. The attack on Okinawa was already planned and it was hoped to prevent the Japanese Navy from assisting in Okinawa's defense.

*b.* To prevent the supply and deployment of raw materials and food into Japan.

*c.* To prevent the supply and deployment of her military forces.

*d.* To disrupt her internal marine transportation within the Inland Sea.

If this could be accomplished, enemy industry would be practically stopped and the whole population would be put into a starving condition. The operation was therefore called "The Starvation Campaign."

**The Overall Situation.**—MINES (NAVY). Loaded mine cases of the Mk 25, 26, and 36 types were available or could be furnished. Five influence-type firing devices were available or were just coming out of production contracts in fairly large numbers. Two of these were magnetic devices, the M 9 and the M 11, two were acoustic, the A–3 and the A–5, while the fifth, the A–6, was the mechanism operated by the change in water pressure resulting from the passage of a ship. The magnetic devices had previously been used against the Japanese, and could probably be swept by the Japanese towed magnet sweep. It was also believed that the A–3 device had been compromised and that the Japanese knew how to fire it by explosive means. The A–5, operating on very low period vibrations, and the A–6 pressure device had not been compromised and the Japanese might find it much more difficult to sweep them. In fact, the A–6 was unsweepable as far as we knew, except by the use of "Guinea pig ships." These two devices were in production but were not available for use until early in May of 1945.

The firing devices were furnished in what was known as "conversion kits," each of which contained all of the parts required to assemble that firing device into a specific type of case. Most of these devices could be modified to some extent by expert mine technicians, and additional gadgets to fool the enemy could be installed in the case during assembly. The dead period on the magnetic devices could be increased so that the existing Japanese sweep would be less effective; the A–3 acoustic could be made less vulnerable to simple explosive sweeps, and the sensitivity of all the mechanisms could be decreased so that, in general, they would attack only the larger vessels. Long delay-period devices, ship counters, and sterilizers were also available and could be installed to modify a mine's operating characteristics.

LAYERS (ARMY). From 80 to 100 B–29's of the 313th Bombing Wing of the 21st Bombing Command were available as mine layers at Tinian, from 1,400 to 1,900 miles from the areas to be mined in Japan. The B–29's had been found quite satisfactory as minelayers in various Pacific minefields. They could carry a big payload of mines over the long flights required.

PERSONNEL (ARMY AND NAVY). The operation was under the direct command of the Commanding General of the 21st Bombing Command, but his mining officer was a Commander of the U.S. Navy and a mine enthusiast. The Commanding General of the Bombing Command and his plane crews, while at first not particularly enthusiastic over the use of mines whose action they could not see compared to the use of bombs whose action they could see, became quite enthusiastic when the reports indicated that a considerable number of ships were being sunk while their own losses in planes were very small.

Fortunately the Navy had established at Oahu a "Mine Modification Unit" headed by a group of mine designers. This unit was moved to Tinian just as soon as facilities to house it were available there. It was an advisory group to determine how the firing devices could be modified to thwart Japanese countermeasures or to make them sensitive only to larger ships and to test various experimental modifications. They could also direct the installation of ship counters, delay mechanisms and sterilizers as might be necessary. Additional experts were furnished as newer mine firing devices or other gadgets became available at Tinian.

In addition the Navy established a mine assembly unit at Tinian. These were men mostly drawn from other depots, but some were sent out directly from Washington so that expert mine technicians were available on every type of mine or mine accessory to be used. This group consisted of 11 officers and from 160 to 175 men and in 5 months they assembled 13,000 mines of many different types. In June 1945, 3,975 mines were assembled. There is no doubt that this group broke all records for assembling aircraft-laid mines.

**Operations.** The whole campaign is undoubtedly by far the largest and most time concentrated aerial mining project ever undertaken. Its success is largely due to the immense amount of preparatory work and the continued pressure drive of the staff assigned, both Army and Navy, and above all, the enthusiastic cooperation of the Army and Navy personnel assigned to the job.

In early 1945, the situation may be summed up as follows:

1. It was desired to drop thousands of mines (about 12,000 were dropped) in Japanese waters as rapidly as possible.

2. The mine planting was assigned to the 313th Bombing Wing (about 80 to 100 B–29's) of the 21st Bombing Command.

3. There was very little experience background in the dropping of mines from B–29's and the B–29's of the 313th Bombing Wing had had no experience.

4. Parachutes were used on all mines to break the final speed. Parachutes seriously affected dropping accuracy, but mines did not need to be placed as accurately as bombs.

5. No detailed planning for mining Japanese waters existed. Should mining be done by day or by night? Should mines be dropped from low levels or high levels? What approach routes should be used?—etc.

6. Relatively few complete mines were actually available. They were in production in the United States and would be sent to Tinian as rapidly as possible during the campaign.

7. The mine would be received unassembled and the final assembly would be completed after they arrived at Tinian.

8. A relatively few types of firing devices would be received, but it would be very desirable to modify them if possible to confuse the Japanese sweepers.

9. Various special accessories, not absolutely essential to mine performance, were available, such as arming delays, ship counters, and sterilizers. These should or should not be used depending on mining conditions.

Immediately upon receiving the order to carry out the mining campaign, the 313th Bombing Wing made a detailed study of the conditions to be met considering the areas to be mined, the operating characteristics of the B–29's and the planting requirements of the mines themselves. Some of the final decisions could not be made until some mining trips had been completed.

The Wing then established elaborate mine laying training flights over an area near the Marianas and each crew carried out numerous mine laying trips over this area using the same types of directions and of mine laying instructions, which were to be used in the service plants. Shortage of mines to spare for training purposes limited this training to some extent.

These studies and tests finally resulted in the following general decisions:

1. To lay heavily concentrated fields in a chosen area and to do no sporadic mining in other areas until conditions were good for laying concentrated fields there. This should cause many immediate losses before sweeping could be done, and would probably bring sweepers into these areas from other areas not yet mined.

2. To lay mines from the lower levels at night using radar for guidance. This would avoid forcing the planes to fly at high altitudes and would therefore increase the accuracy of dropping and would allow each plane to carry about twice the payload. Planes would usually be able to takeoff and land in daylight.

3. To use single aircraft rather than formation flying. This type of flying at night would greatly reduce antiaircraft fire.

After the first few plantings, routine operation developed into the following steps:

1. Each month the mine planers of the 20th Air Force furnished a mining schedule for 30 days. This usually involved some mining sorties every other night and indicated the type of mines to be planted in each area to be mined.

2. The Mining Section of the 313th Bomber Wing then made preliminary plans specifying the areas to be mined on each date, the type of mines to be used and the number of aircraft for each minefield.

3. A mine assembly order was then prepared from these plans for the use of the Mine Assembly Depot. This might involve modified mine firing devices, in which case the Mine Modification Unit would be requested to advise the Assembly Depot. It often specified different mines for different planes, and possibly for different mine locations in the same plane, thus tremendously increasing the details of the preparatory procedure.

4. About 80 hours before a mission's "takeoff" time a conference was held between the Wing Mining Section and the Group Operations, giving the Group the minefields to be laid and the number of aircraft for each field.

5. The Group then planned the routes to be used, and the Wing Mining Section made the final minefield design and prepared final loading plans and navigation charts.

6. The loading plans indicated the code of the mine to be loaded in each mine station while the navigation chart indicated when each mine was to be released.

7. About 48 hours before "takeoff" time, the 313th Wing would inform the 20th Air Force, and other Wings, of the time, routes, number of aircraft and other pertinent data.

8. All mines for each mission were completed 48 hours before "takeoff" time.

9. Thirty-six hours before "takeoff" the mines were hauled from ready storage to plane loading stands.

10. Twelve hours before "takeoff" time the loading of the planes started.

The whole project was executed as a single 4-month continuous campaign. The greatest concentration of Japanese shipping existed in the Inland Sea and through the Shimonoseki Strait, and every effort was made to keep this area continually loaded with mines. One of the early Japanese defenses was to bypass this area where possible and use ports on the northwestern coast of the southern half of Japan, so these ports were mined beginning about the middle of May and continuing through to the end of the campaign. The actual carrying out of the campaign is described briefly below. The information is obtained from a pamphlet, "Starvation," prepared by the 20th Air Force. It divides the campaign into five phases, each increasing the area of attack up to the final "Total Blockade."

During each phase the results were carefully studied. Aerial photographs were taken of the areas mined, which furnished information as to the success of the Japanese sweeping efforts and whether the areas had been closed to ship traffic. Many of the ships which had been sunk were shown in the photographs. The areas to be mined and the characteristics of the mines to be used during the succeeding phase were based on these studies.

*a.* The first phase extended from March 27 to May 3, 1945. Two hundred and forty-six aircraft were airborne and 2,003 mines were laid. Five planes were lost. It was evident that the Shimonoseki Straits area should be attacked first and as much damage as possible brought about before the Japanese sweeping gear could be put to work. In addition, the attack on Okinawa had been planned. It took place 1 April 1945. No doubt the Japanese would attempt to place a naval force in the Okinawa area as soon as possible after the attack, and the Navy had requested that every effort be made to at least delay the attempt which the Japanese navy might make to reach the Okinawa area.

The two requirements were entirely compatible, so on March 27 and March 30 strong minefields were laid in the Shimonoseki Straits and in the harbors of Kure and Sasebo. The enemy reacted with a most vigorous sweeping campaign using many small suicide craft. The use of small suicide craft indicated that the mines should be made less sensitive in order to limit their targets to the larger ships and thus to prevent small ships being used as "guinea pigs." This had been planned but lack of facilities and lack of experienced personnel had prevented doing it in these first fields.

The blockade kept the Straits effectively closed for 10 days or 2 weeks resulting in a cut of traffic to about 25 percent of normal. It was estimated that 35 ships were sunk or damaged, totaling about 100,000 gross tons.

The effort to delay a naval sortie to Okinawa was also successful. It was not until April 6 that the Japanese attempted to get any of their naval vessels out of the Inland Sea. On that day the Yamoto, a cruiser and seven or eight destroyers passed through Bungo Straits and proceeded along the east and south coasts of Kyushu toward Okinawa. On 7 April Navy planes of the 5th Fleet sank the Yamoto, the cruiser and three destroyers, and damaged the remaining units. Evidently the ships avoided Shimonoseki Straits because of minefields and chose a route along the eastern and southern coasts where it was much less protected than along the west coast of Kyushu. Figure 59 shows the Japanese ship traffic after the completion of Phase I. This plate should be compared with figure 58.

*b*. The second phase extended from May 3 to May 13. One hundred and ninety-five craft were airborne, and 1,422 mines were laid. No aircraft were lost.

During this phase it was possible to modify the mechanisms desensitizing them against small craft. This defeated some of the enemy sweeping tactics, especially the use of suicidal small craft. A supply of A–6 pressure mechanisms had been received and were used here for the first time. It was believed that the Japanese would not be able to sweep this mine at all.

The effect on shipping was large. Most of the ships which now passed from the Inland Sea to Asia were small wooden ships. The use of large steel ships was almost eliminated. The good results are believed to be due to the use of the A–6 mechanisms and the M 9 type magnetic device with its timing and sensitivity modified as directed by the Mine Modification Unit. Figure 60 shows the Japanese ship traffic after the completion of Phase II. Information concerning the campaign was released to the press by the

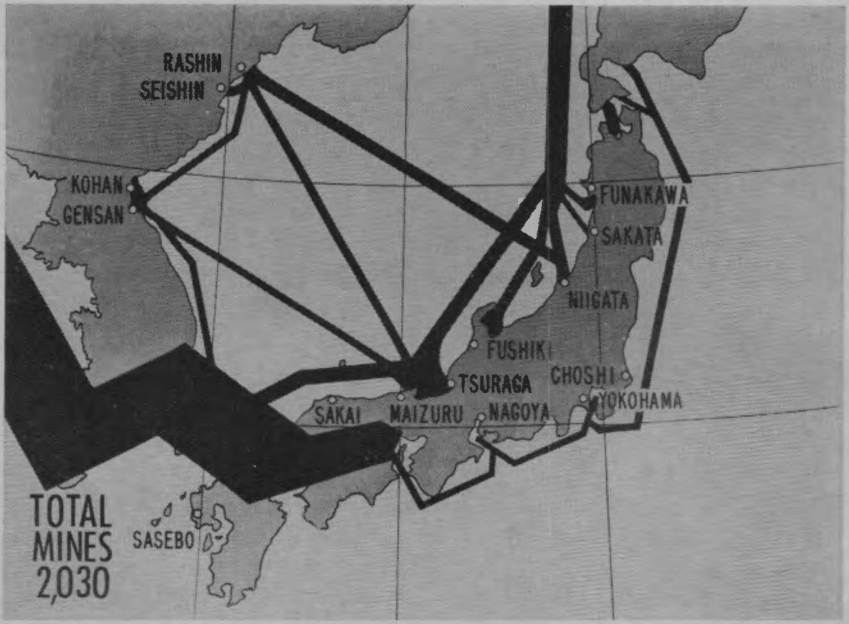



Figure 59.—Japanese traffic situation, after Phase 1.

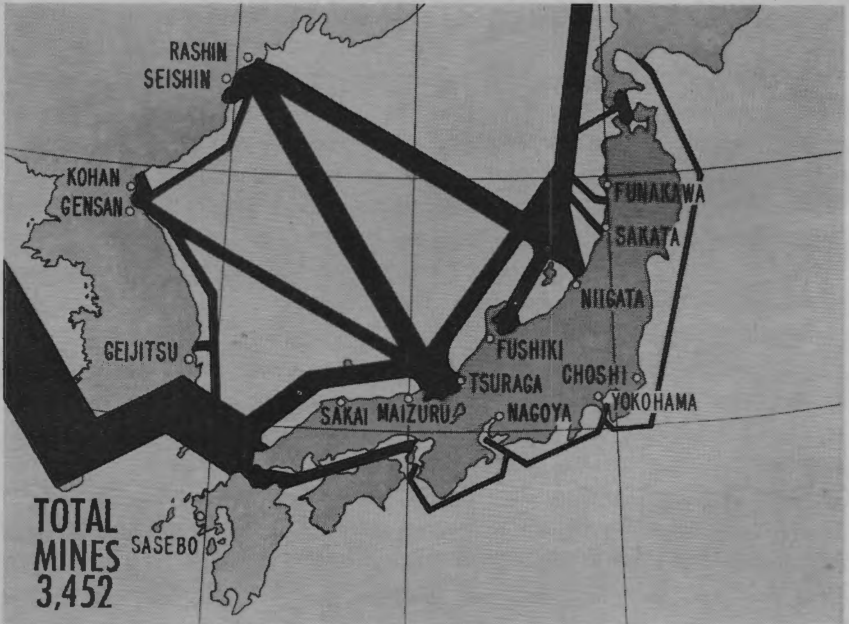



Figure 60.—Japanese traffic situation, after Phase 2.


**Figure 61.—Press clippings.**

Air Force during this phase, and news items appeared in allied newspapers in many cities. Excerpts of these items from Honolulu and from Indian and British papers are shown in figure 61.

*c.* The third phase extended from May 13 to June 6. Two hundred and nine aircraft were airborne and 1,313 mines were laid. Three aircraft were lost.

A study of the technical results of the first two phases of the campaign indicated that, since the number of mines available was limited, frequent remining with a relatively few mines was more effective than large scale mining once or twice per month, and that less sensitive mines were desirable to give greater damage to each ship mined and to decrease the efficiency of enemy sweeps.

The Mine Modification Unit therefore took on increasing importance as it tried to work out methods and instructions for reducing sensitivities and target widths. Much of the shipping was now being diverted to important ports on the Asia side of Japan, so this phase was directed against these ports as well as maintaining the Shimonoseki Straits blockade.

The results were similar to those of the first two phases. Mined ports and mined passages were closed for a few days and then opened again, but apparently the closures were for longer periods than at first, probably because of inadequate sweeping equipment. Sweep bombs were still used against the A–3 firing device, and a new double catenary sweep appeared against the magnetic mine, but it was awkward to use. However, it proved

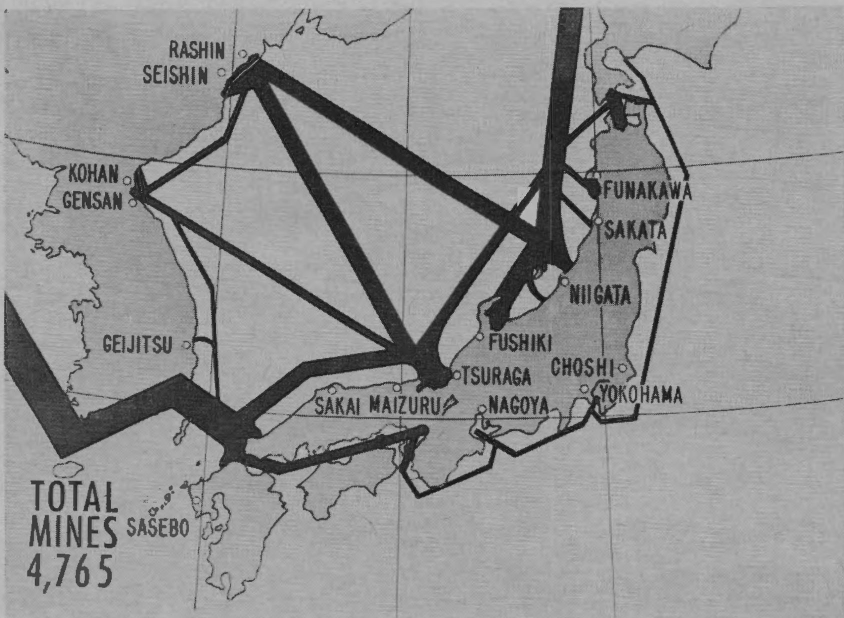



**Figure 62.—Japanese traffic situation, after Phase 3.**

that the enemy was familiar with the time-delay changes made in magnetic mines. No information on the sweeping of the A–5 and A–6 devices was available.

Enemy shipping losses increased rapidly. It was estimated that, during May, 75 to 100 vessels aggregating 300,000 gross tons were sunk or damaged. In the Shimonoseki Straits at the end of May, ship passage had been reduced to 2 to 4 a day, and tonnage reduced to 7,000 tons per day instead of 70,000 tons per day in March. Figure 62 shows the traffic after the completion of Phase III.

*d.* The fourth phase extended from June 7 to July 8. Four hundred and four aircraft were airborne and 3,542 mines were laid. One aircraft was lost. In planning Phase IV it appeared that the remining with a relatively few mines as proposed in Phase III was justified, that target widths should be kept narrow and that mine firing devices should continue to be desensitized to catch only the larger ships. More mines could have been used if available. The enemy's sweeping efforts were not yet too successful, but it appeared that the A–3 was completely sweepable and was of nuisance value only. The A–6 and the magnetic mines appeared to be nearly unsweepable. The A–5 could be swept explosively although there were no definite records of the Japanese doing it. For the more sweepable mines the ship counters and delayed arming were used to confuse the sweeping problem as much as possible.

Closures of ports continued as before, extending up to 2-week periods at times, but the Japanese had developed a new loop-type of sweep which might


**Figure 63.—Japanese traffic situation, after Phase 4.**

fire most of the magnetic mines and had discovered that a slow moving ship could pass over the A–6. It was possible that the very great effects noticed earlier might gradually decrease as Japanese countermeasures improved. The actual shipping loss during June was estimated at 300,000 gross tons.

The shipping situation was still showing considerable change, but it appeared that further mining of Tokyo, Nagoya, Nagasaki, Sasebo and the Inland Sea would no longer be profitable providing the Straits were kept closed. The traffic situation after the completion of Phase IV is shown in figure 63. Note the very tiny stream of traffic passing through the Inland Sea.

*e.* The fifth and last phase extended from July 9 to August 5. Four hundred and seventy-four aircraft were airborne and 3,746 mines were laid. Six aircraft were lost.

As suggested during Phase IV, the effect of Japanese countermeasure improvement was evident. Periods of closure of ports where the enemy was well prepared were shorter than previously. In the case of Fushiki, there was apparently no closure at all. However, in Korea, where the Japanese were unprepared, the periods of closure were of the usual period of 10 days or 2 weeks.

Ports in Korea were attacked heavily during this phase as it was noted that Japan was increasing its shipping from Korean ports. The results were successful. They were able only to partially clear their shipping lanes, and had to accept abnormally high losses in order to get some shipping through.

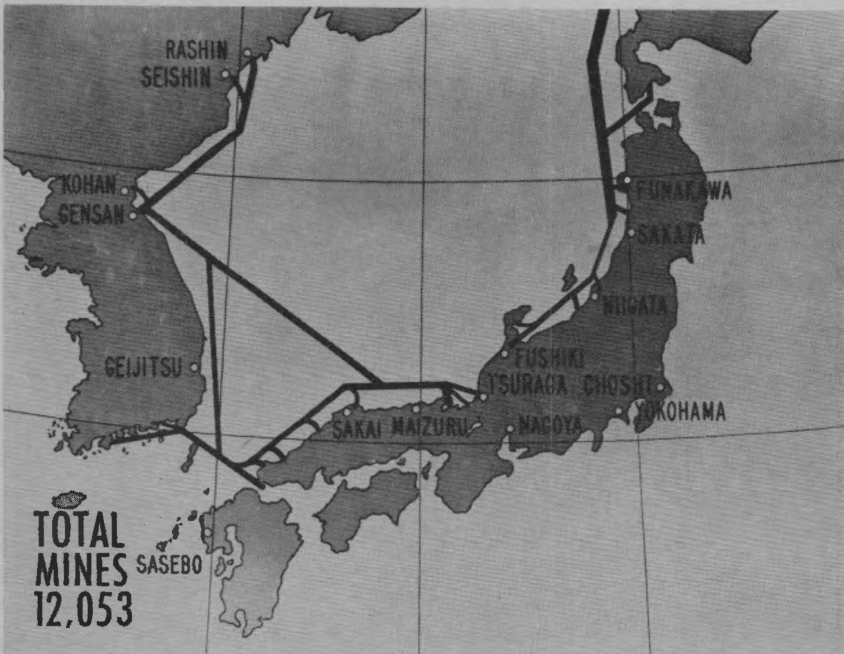



**Figure 64.—Japanese traffic situation, after Phase 5.**

Shipping losses during this phase were estimated at 300,000 gross tons. The total losses during the later phases of the campaign are, of course, smaller because the total amount of shipping available to the Japanese had been so greatly reduced. The final traffic situation at the close of the campaign is shown in figure 64.

**Results.** During this 4½ month campaign, the 313th Bombing Wing of the 21st Bomber Command, consisting of from 80 to 100 planes, planted 12,135 mines on shipping lanes in and around Japan and in many Japanese and a few Korean ports. Aircraft made 1,424 trips over the mining targets. Each aircraft carried on the average of 8½ mines (a B–29 can carry twelve 1,000-lb. (500 lb. charge), or seven 2,000-lb. (1,000 lb. charge) mines) and the longest distance flown without refueling was 3,110 nautical miles. The mines were dropped by radar sights from 5,000 to 8,000 foot levels. Approximately 4,900 mines were magnetic, 3,500 acoustic, 2,900 pressure and 700 low frequency-acoustic, while about half of them were 1,000-pound mines and the other half 2,000-pound mines.

Records kept by the Japanese show that 670 ships, including 65 warships, were sunk or severely damaged; 294 were sunk, 137 damaged beyond repair and 239 damaged and repaired. In tonnage the total was approximately 1.4 million tons, or about three-fourths of the shipping available in March. Relatively little food and raw material were coming into Japan from Asia, and the traffic in the Inland Sea and along Japanese shores was only a trifle of that required to distribute materials effectively. Leading industrialists pointed out that industry could not continue to produce, and estimated that 7 million Japanese would starve within the year.

The shipping charts referred to were prepared by the 20th Air Command, with the width of the line proportional to the average tons of shipping per day. A comparison of these charts will indicate how the Japanese shifted their shipping to the less mined ports early in the campaign, and also how the total amount of shipping was reduced as each phase of the project was completed.

A few of the comments expressed by Japanese officers and industrialists after the war are of interest here.

(1) "The result of B–29 mining was so effective against the shipping that it eventually starved the country. I think you probably could have shortened the war by beginning earlier."

(2) "—the minelaying B–29's with their great carrying capacity were a peerless weapon which hastened the last hour of the war."

(3) "—in the war's last months the proportion of shipping sunk were 1 by submarines, 6 by bombs, 12 by mines." (These data are not proved by actual statistics, but the statement does indicate the Japanese opinion.)

(4) "Around June and July this year (1945) conditions were so bad that regardless of losses we pushed the ships through."

(5) "The aerial sinking of Japanese vessels and the B–29 aerial mining of Japanese harbors were equally effective in the closing stages of the war as the B–29 attacks on Japanese industry." (The Air Force has stated that the Inner Zone Mining Campaign represented but 5.7 percent of the 21st Bomber Command's total effort.)

The success of the project was due very largely to the 100 percent cooperation of the Army and Navy forces involved. This can not be stressed too strongly. Each group repeatedly referred to the other group's continued cooperation. Fleet Adm. C. W. Nimitz, USN, has said, "The planning, operational and technical execution of the Air Force aircraft mining on a scale never before attained, has accomplished phenomenal results and is a credit to all concerned." General LeMay, Commanding General, 21st Bomber Command, congratulated the Navy's Mine Laboratory for the effective mine designs.

## B. Mining Summary

**Summary of U.S. Command Mining Campaign in World War II.** All of the mining campaigns discussed in this chapter, except for the very few U.S. mines dropped in the Mediterranean, were accomplished under the U.S. Command, although nearly 6,000 mines, both of United States and British manufacture, were planted by the RAF, RAAF, and RNAF, while operating under the U.S. Command.

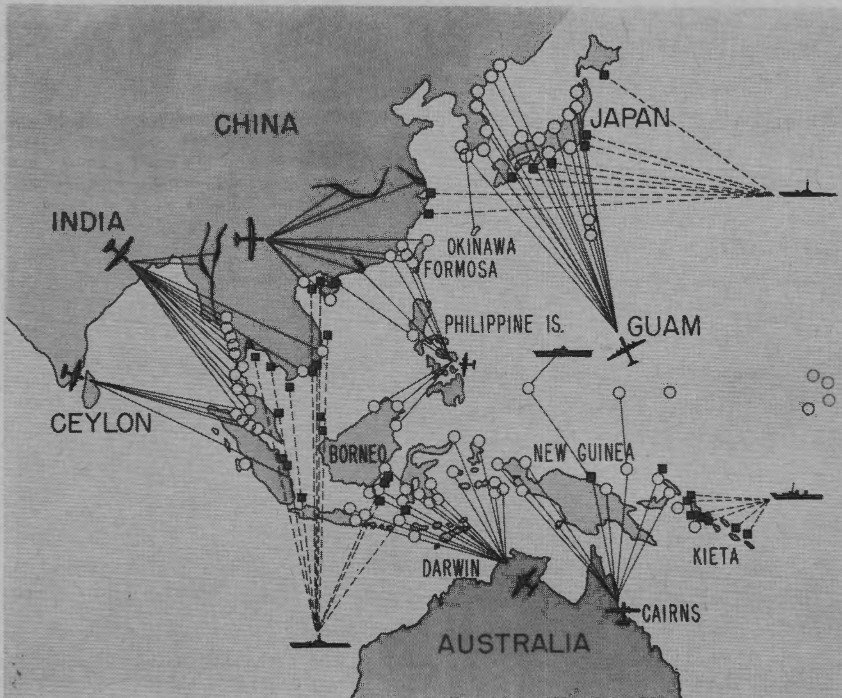



**Figure 65.—Total mine campaign against Japan.**

Nearly 31,000 mines were laid in the Pacific Ocean, Indian Ocean, and in waters of Asia and Japan, primarily against the Japanese. Nearly 8,000 of these were in defensive fields where they served their purpose in preventing hostile craft from operation in that area, but so far as is known, sank no ships. The 23,000 offensive mines resulted in the sinking or serious damaging of 1,075 Japanese ships, both naval and commercial, with a total shipping tonnage of approximately 2,289,000 tons. The total offensive campaign is graphically shown in figure 65.

Overall, the Japanese lost one ship to every 23 mines planted offensively. Breaking this down more in detail, the Japanese recorded losses are:

Aircraft—1 ship for every 21 mines.
Submarines—1 ship for every 12 mines.
Surface (offensive)—1 ship for every 250 mines.

The losses of the U.S. Command were almost inconsequential. It lost no surface craft, no submarines and but 57 aircraft. The low cost is phenomenal—1 aircraft for every 20 enemy ships lost. It merely proves again the efficacy of mine warfare in which mines can largely be planted when the enemy is not there.

While the Japanese losses listed above were staggering to the Japanese navy and merchant fleet, the loss of the use of ports and passages, the tying up of ships in areas where they were useless or could be destroyed at leisure, the failure to support outlying armies and the final starvation of the Japanese economy played a much larger part in the losing of the war than the sinking and damaging of the ships themselves. Note the following comments of Japanese officers:

*a.* "It was not only the bombing of factories that defeated us; it was the blockade which deprived us of essential raw materials, aluminum and coal."

*b.* "The allied sea mining campaign greatly harassed the operation of the Japanese army in Burma."

*c.* "Aircraft mining almost severed the Japanese line of communication with Rangoon."

*d.* "The headquarters of the Japanese China Sea Fleet found American mines extremely effective and disastrous. Mines carried by a single American plane could close a port for a long period of time."

*e.* "The military situation was greatly affected by the mines, especially the Japanese drive into South China. The Japanese were unable to send troops and equipment up or down the Yangtze."

*f.* "The practical application of methods of long term delayed action, detonation control, detonation by repetitive influence and the principle of compound detonation is exceedingly successful."

A summary of all mines planted by the U.S. Command is shown in the table on page 160.

**Mining Campaign Summary—World War II.** During World War II the United States and Great Britain together laid over 300,000 mines. The British laid 185,000 defensive and 76,000 offensive—over 260,000, and the United States laid nearly 50,000. In Europe all of this mining was done by British craft except for some defensive fields, totaling about 3,600 mines, laid off the coasts of North Africa and Sicily by U.S. minelayers. The United States laid defensive fields totaling almost 23,000 mines around the shores of the Americas and in Pacific and Indian Ocean ports. In the Pacific most of the offensive laying, more than 23,000 mines, was done by the United States, except that many aircraft mines were planted by the RAF, the RAAF and the RNAAF, operating under the U.S. Command. British surface craft planted about 2,000 moored mines around Noumea and New Caledonia, and British mine planting submarines were also operating in this area. In addition, some mines were planted by other Allies, but the author has no record of the number of mines planted or of the results obtained.

The British credit their minelaying campaign with the sinking or seriously damaging 1,590 enemy ships in European waters, so that there was a total loss of nearly 2,700 enemy ships from mining projects in World War II.

*Mines planted by the U.S. Command during World War II*

| Planting craft | Make of mine | | Type of mine | | | | |
|---|---|---|---|---|---|---|---|
| | United States | British | Contact | Magnetic | Acoustic | Pressure Mag. | Total |
| Army, U.S. | 7,320 | ... | 3,569 | 3,751 | ... | ... | 7,320 |
| U.S. Navy, Defensive | 18,884 | ... | 18,884 | ... | ... | ... | 18,884 |
| U.S. Navy, Offensive | 2,871 | ... | 2,859 | ... | 12 | ... | 2,871 |
| Aircraft, Navy | 662 | ... | ... | 575 | 54 | 33 | 662 |
| Aircraft, Army, Outer Zone | 1,665 | 182 | 268 | 1,397 | 182 | ... | 1,847 |
| RAAF | 1,944 | 554 | ... | 2,129 | 369 | ... | 2,498 |
| RAF | 2,228 | 1,007 | ... | 3,235 | ... | ... | 3,235 |
| RNAAF | 3 | ... | ... | 3 | ... | ... | 3 |
| AAF, Inner Zone | 12,135 | ... | ... | 4,921 | 4,255 | 2,959 | 12,135 |
| Total | 47,712 | 1,743 | 25,580 | 16,011 | 4,872 | 2,992 | 49,455 |

## CHAPTER XVI

# LOOKING BACKWARD AND FORWARD

The author has attempted in the preceding chapters to give a factual, objective story of the uses made of sea mines by the United States. In this, the closing chapter, it appears desirable to sum up in a general way the results obtained and the costs expended and to determine to some extent how worthwhile a weapon the minefield has been. These lead to some brief prognostications for the future. In general, the "present" has been purposely omitted. The "past" brings U.S. mine history up to the end of World War II. Whatever has happened since that, we must withhold. If this country, or if any of our Allied friends, is ever attacked, we hope the enemy will learn "the hard way" of the results of some of the "present" items that could be added to this story.

Suffice it to say that the Navy, which now has cognizance over all U.S. mining, is progressing on the policy which it established and followed for 3 or 4 years after World War I, that mine development will be a continuing activity. The Naval Ordnance Laboratory, one of whose major functions is the development of mines, has been made one of the Navy's largest research and development laboratories. It is located on an 800–900 acre tract of land a few miles from Washington and is one of the most modern laboratories of today. It is shown in figure 66. There U.S. mine development proceeds. To such an organization has the country's first mine laboratory (1777), probably an old barn along the Delaware River a few miles above Philadelphia, grown.

The powder-filled flintlock kegs developed at the 1777 laboratory failed to sink any British ships, but from the Revolutionary stories which have come down to us, they did cause a great deal of confusion, and probably did affect the morale of the British sailors. They would be continually worried for fear some more of these "devilish devices" would come floating down the Delaware. However, for the next 140 years the Federal U.S. Government made practically no effort to use the weapon. A few were planted by the Federals in the Civil War, but there is no record of success. None were planted in the Spanish American War, although it would seem that minefields would have been useful in trying to pen Admiral Cervera's fleet up in the harbor at Santiago, Cuba.

The rest of the world, however, took a greater interest in the weapons first used in the "Battle of the Kegs." Around 1850 small minefields planted

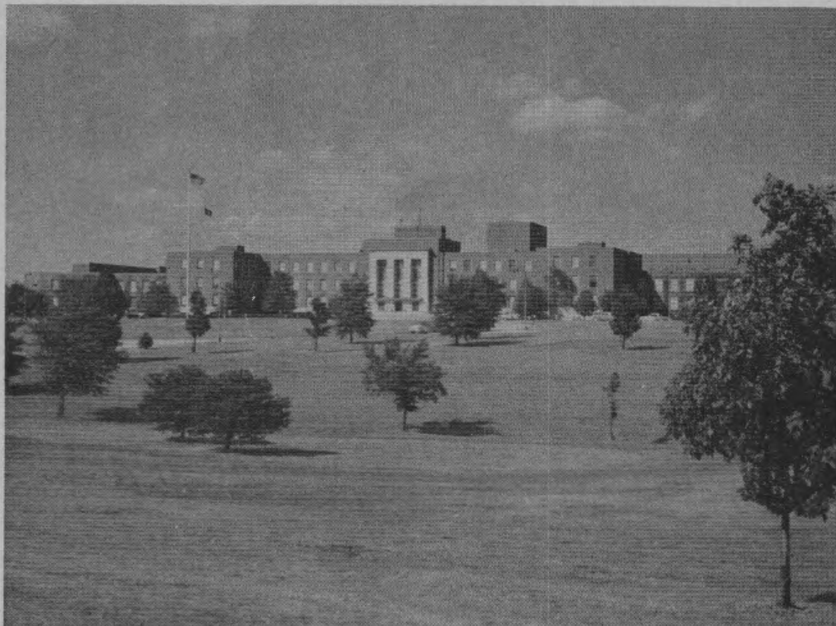


**Figure 66.—U.S. Naval Ordnance Laboratory, White Oak, Md.**

in European harbors possibly won worthwhile victories. The enemy made no attempt to enter these harbors. The financial cost of the victory was negligible and the cost in life and facilities was nothing. Throughout the 19th century many European countries gave considerable thought to mining and made several important steps in the art. However, no notable results occurred during this period.

The next great step in proving the effectiveness of mines again occurred in America when the Confederates sank 27 Federal ships with mines and held the Federal Navy away from several battles where the Confederates defeated the Federal Army. Fifty years later the Russians and the Japanese again proved the effectiveness of mine warfare. The score there was 15 ships (including 3 battleships and 5 cruisers).

By 1914 Germany was well prepared to make full use of mines. Minelayers were on their way to lay proposed minefields before war was actually declared. Mines sank the *Hampshire*, a British cruiser, carrying Lord Kitchener, Britain's Minister of War, and mines clinched the Allied Dardanelles defeat. The British, entering the war without a satisfactory mine, quickly realized the need and manufactured a new type in great haste, while the United States entering the war 3 years later, with no mines, developed a new one and manufactured 100,000 in 15 to 18 months. Altogether, a total of approximately 240,000 mines were planted during the war and over 600 ships were sunk or damaged. The total ship damage from mines was appreciably greater than that by gunfire and torpedoes.

It is interesting to note that Great Britain and Germany both had great fleets, each of which felt itself superior to the other and each of which looked forward to proving its superiority in a great naval battle, but in the 4 years that they were arrayed against each other, never did they get close enough together for a long enough period of time to prove which was superior. Also, the U.S. Navy with a great fleet of warships probably performed its greatest war service in building 100,000 and planting 56,000 mines, upon which no money had been spent prior to the declaration of war.

By the time of World War II, mines had reached a stage where they were twice used in attempts to economically starve island empires. The one against Great Britain failed partly because Germany was not prepared to use her mines in great numbers and partly because the British Navy, with the great help of British scientists, was able to reduce the effect of the attack in a short time to a satisfactory low level. On the other hand, the one against Japan succeeded partly because the United States, profiting from German mistakes, planted mines in great numbers (more could have been used had they been available) and partly because the Japanese were in no way able to nullify the attack.

During the 175 years since mines were first used, the art of mining has taken advantage of the general improvements in science and mechanics. Mine designers have continually applied the progress in other fields which could be applied to their field of work. Originally black powder was used in wooden kegs with a flintlock inertia-type firing device. As electrical science developed, electric firing was applied, but the firing batteries were kept on shore; later, battery development produced batteries that could be installed in the mines, and in several cases the water of the ocean was used as an electrolyte. Various influences emanating from ships, magnetic, acoustic, pressure, etc., have been studied and applied. Electronic processes have been used to amplify tiny impulses or to distinguish between the kinds of noises, or the kinds of magnetic fields, in the hope that only ship-initiated influences will function. Gadgets of many types and forms have been invented to give intelligence to the mine and to fool the enemy. The designers have also taken advantage of explosives developments. The gun powder changed to guncotton, then to TNT, Torpex, and finally HBX, as they became available.

New methods of planting have developed—first, mines were planted individually by hand, then automatic anchors allowed surface ships to plant mines in rows by simply dropping them off the stern, and later by the use of high speed destroyers which made it possible to enter an enemy controlled area, plant a field of mines and get out again before an attack could be launched. In World War I submarines were used as layers, so that a field of mines could spring up almost within your own fleet with no warning. By World War II, aircraft had been added to the list. This enormously increased the field open to mines. Fields could be replaced at will. Old mines in the field could not threaten the layers. Mines could be planted in areas wholly under enemy control, and they became a very powerful offensive weapon. Again we see that mine designers and mine planners proceeded to use all the arts, materials and facilities open to them.

The world philosophy concerning the use of mines has also almost completely reversed itself over what was claimed by certain nations in the early 1800's. No one, not even the United States appears to worry over the civilians that may be aboard a mined ship. The commercial fleet of Japan must have carried many civilian passengers, but no thought is taken of that when the United States claims that so many ships were destroyed. (It is a question just how sincere the British and the French were in the early 1800's, for we note that each encouraged Fulton to blow up some of the enemy's ships.)

There is no question today about the value of the mine as a war weapon. After the First World War Admiral Strauss said, "The mine as a weapon of nautical warfare now presents greater possibilities than ever before. The United States in less than 1 year was able to construct a squadron of minelayers and produce sufficient mines to keep them constantly employed, laying on each excursion in less than 4 hours more mines than the United States had ever possessed prior to her entry into this great war."

While after the Second World War, we have from Fleet Adm. C. W. Nimitz: "The Air Force mining—has accomplished phenomenal results." From Gen. N. F. Twining: "—the B–20 mining campaign—should be given careful consideration and evaluation in future military planning." And from the Operational Research Section of the H.Q. RAAF Command: "When the substantial indirect returns (of mine laying in the Southwest Pacific) are taken into account, these sea-mining operations have been in the order of 100 times as destructive to the enemy as an equal number of bombing missions against land targets."

As war weapons, mines do accomplish certain desirable functions which no other weapon does. They furnish a constant dangerous threat to the enemy without accepting a return threat. Torpedoes and bombs may sink ships, but the attacker is always available to receive an attack against himself.

Mines may win battles passively. The enemy may refuse to make an attack. The Japanese were driven out of various areas in the Pacific because they preferred not to attempt to eliminate the minefields. Or they may win battles a bit more actively, but with no human losses. The Confederates won several battles because the Federal Navy tried to destroy and pass through minefields.

Mines may hold ships in areas where they may be attacked by other means, or they may force them to choose longer and more dangerous routes.

Mines are a continual menace to enemy morale. In World War I a German submariner stated that the German submarine crews were more afraid of mines than of any other weapon. While in World War II a Japanese officer has stated that "the crews—were very much worried and frightened by this mining, but they were under orders and had to work through it."

Mines lie in wait for and attack targets which the controller of manually controlled weapons can not see or hear. Great effort is being expended to learn how to locate a submarine some distance away. As submarines are improved with increase in underwater speed and with the ability to stay submerged for longer periods, the value of the mine as an antisubmarine weapon is relatively increased.

Like other naval weapons, mines do sink and damage ships, and in every case where mines are used their success is usually measured by the number of ships sunk or damaged. This is very often the least valuable result of a minefield, but the more important ones are indirect and difficult to evaluate.

Mines also force the enemy to tie up enormous quantities of his manpower and materials to defeat them. The German magnetic mines caused the Allies to use much of their manpower and billions of dollars to degauss their ships, much more probably than the cost of all of Germany's magnetic mines. The United States forced the Japanese to use all the men they could spare (and that was far from enough) to fight its mining campaign.

Mines are a very economical weapon. As pointed out above, when mines do their attacking the mine laying activities are far away. However, the layers are open to attack during the laying process—but high speed destroyers may be able to finish their jobs before the enemy is ready to attack; submarines can usually pick their time of laying when no enemy is available and aircraft can usually do the same. In the Pacific the total loss of mine laying craft operating under U.S. command was but 57 planes. No submarines or surface craft were lost. However, this record can not be taken as an average one. The British lost a much higher percentage of their minelayers—surface, submarines and aircraft—because their mine planting was carried out in concentrated war areas, and it was hard to find times when the enemy was not looking for minelayers.

In general, offensive war weapons continually find themselves in a state of warfare with their possible countermeasures. Offensive mines are no exception. Countermeasures may be of several different types. With moored mines it usually consists of sweeping the area with heavy steel cable. With ground mines it usually consists of artificialy producing the correct impulses either magnetic, acoustic or pressure, or a combination of them to explode the mine, thus clearing the area. Other types operate on the ship. With antenna-type mines the electric potential of the ship may be changed artificially so that ship-antenna contacts will produce very little current. With magnetic mines degaussing or some other magnetic procedures may reduce the ship's magnetic field. Acoustic mines might be beaten if ship noise could be reduced to practically nothing. (So far as the author knows this has not been accomplished although studies have been made along this line.)

Within the Navy's own confines there should be a continuous friendly competition between the mine designers and the mine sweep designers, which in the United States is a function of the Bureau of Ships. The mine designers should lead the way, always attempting to produce a mine which the sweepers can not sweep. Should they become able to do so then the mine designer should go a step further if possible. In other words, it is up to the designer to propose all the possible gadgets to the sweeper, which a potential enemy might use sometime in the future.

Mine designers must also continue to use, where applicable, new art which may develop in electronics, in batteries, in explosives and in materials. If possible, they must make their mines more sensitive to pick up tiny noises or tiny changes in magnetic field, but at the same time they must be directive and pick out impulses which arise directly above them.

Mine components should also be designed so that the assemblyman, far away from a laboratory or a manufacturing plant, may change the mine's characteristics to nullify the enemy's countermeasures. The British did this to a considerable advantage during the war. At one time they found that enemy submarines or special craft were being brought through minefields by following a heavily constructed, artificially magnetized vessel which was designed to fire magnetic mines a safe distance ahead. The British therefore assembled a few mines so designed that the magnetic ship would merely cock the firing device and the trailing ship would fire the mine. The Germans counteracted by using two magnetic ships, so the British used mines to require two strong magnetic pulses to cock the mine for the third impulse. One began to wonder whether the Germans would run out of magnetic ships or the British of delaying relays first. The U.S. Mine Modification Unit in the Pacific could have made U.S. mines more effective against Japanese sweeping had the firing devices been designed to permit wider changes in operating characteristics in the field.

But the mine designer must not limit himself to designing a "perfect" mine. Such a mine may include so many gadgets that it has no room for explosives; it may demand so much manpower for its manufacture that other essential defense items must be limited; or it may demand so much strategic material that only a small number can be built. The scientist may dream of the perfect mine, but the engineer must be bound by the practical. Someone has said "the perfect is the enemy of the good." Those who design mines must not allow the desire for perfection to limit too much the delivery of the "good." Moreover, the scientist's perfect mine may not be as perfect as he may assume. His perfection may be attained by the addition of complications. High reliability is demanded. Otherwise manpower, material and planting effort are wasted. Mines are necessarily subjected to much rough handling. Every contact, every gasket, every relay, and every other gadget has some possibility of failing, and even though each has a relatively high reliability, the mine's overall reliability may be unsatisfactory.

It is also a great mistake to label a mine as useless or as of nuisance value only as soon as the enemy learns how to sweep it. A simple sweepable mine dropped in concentrated attacks in all the ports and passages of Japan would have exhausted enormous quantities of her manpower and facilities merely establishing and maintaining sweepers in all the mined areas and would have closed ports for many days. Moreover, sweepable mines can be made unsweepable for various periods of time by using various types of gadgets which the mine designers have invented. A single minefield of such mines will keep the sweepers busy for many days and will temporarily kill the use of the port or passage.

For defensive fields the intelligence and the enemy fooling and annoying characteristics are largely unnecessary. The United States will plant these defensive mines in great numbers but in areas which it hopes it will completely control throughout the war. The enemies which those mines must meet individually are those of nature. The mines must be permanently located both in horizontal and vertical positions. Friendly craft will be directed how to bypass the field or possibly pass over it, so the anchors must not slide, and the mine depth must be as planned. The cases must be watertight. The firing devices must not fire prematurely and must not be subject to chain firing. These requirements should be met if possible by the designers, but many of the complications and gadgets highly desirable with offensive mines should be omitted. They take up weight and space, reduce the overall dependability and use manufacturing facilities and manpower unnecessarily.

World War II was often referred to as a "total war," meaning presumably, that the total population and facilities of a country received the attack of the enemy. It is total also in that civilians in general designed and manufactured the weapons which were delivered by the military. This is particularly true of mines. Mine programs are essentially team programs.

The success of the whole U.S. mining program was the result of 100 percent cooperation between able scientists and engineers and the military forces. The development of influence mines demands an intricate study of physical phenomena emanating from ships and to use these required complicated and intricate scientific gadgets. The result is a demand for the most able scientists and engineers. However, these people are not familiar with the operating problems, so naval officers must come into the design end of the program and work hand-in-hand with the scientists. Also, they actually carry out the operations and in doing so must find any faults which should be corrected or improvements which should be made.

In both Great Britain and the United States this cooperation was a very happy one, and the campaigns were highly successful. In Japan, and surprisingly in Germany, we find that this cooperation was much less happy and the results were less successful.

Beyond this in the United States the Navy is responsible for mine development and procurement and usually for defense and tactical offensive planting, but for the carrying out of campaigns such as that carried out in the mine areas of Japan and the rivers of China, the large bombing planes of the Air Force are needed, so that effective team work between the Air Force and the Navy is essential. It was this combination that made the Starvation Campaign a success.

This summary of the use of mines by this country would not be complete if it failed to point out the wonderful cooperation in the mining game between the United States and the British Commonwealth. In World War I the British appeared a bit reluctant to agree to the proposal for the Northern Barrage. They apparently felt that the United States was overly optimistic about the new mine, and they were undoubtedly correct. However, once the proposal was approved by both countries, the British carried through their share of the program.

In World War II, they gave the United States the benefit of their experience in degaussing, they furnished samples of German mines and of their own mines, they welcomed U.S. mining experts to their laboratories and sent their own to this country, and in the war in the Pacific, their planes planted more mines than U.S. planes did up until the beginning of the Starvation Campaign.

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