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The Mk 14 Submarine-Launched Torpedo:
Four Decades of Service

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NAVAL UNDERSEA WARFARE CENTER DIVISION

Newport, Rhode Island

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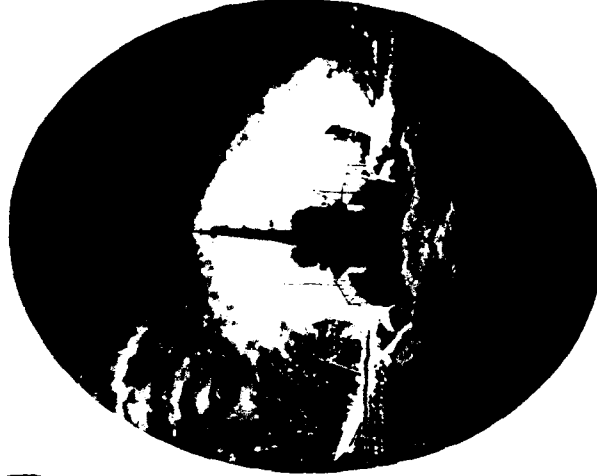


Naval Undersea Warfare Center Division

Newport, Rhode Island

(Successor to the Newport Naval Torpedo Station)

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The Mk 14 Submarine-Launched Torpedo: Four Decades of Service

In the early years of World War II, few would have predicted that the Mk 14 submarine-launched torpedo would play a major role in defeating the Japanese naval and merchant fleets. Initially a problem-plagued and unreliable weapon, the Mk 14 torpedo was the source of much ill will between the Navy's operational forces and weapon developers. But once its problems were corrected, the Newport-developed Mk 14 torpedo redeemed itself and went on to become the single most destructive weapon used by the U.S. Navy during the war.

Introduction

With the clear vision afforded by hindsight, one can readily see that the submarine-launched torpedo has had an unprecedented impact on 20th century naval warfare. During two world wars, it demonstrated itself to be one of the most devastating naval weapons ever employed.

First conceived by engineer Robert Whitehead during the 1860s, the submarine torpedo strongly influenced late 19th century naval thinking and the design of new warships. Whitehead's "automobile" torpedo was a major innovation; it provided a depth-controllable self-propelled underwater projectile that was difficult to detect and that exploded below the waterline,

DAVID WHITEHEAD

The Mk 14 Submarine-Launched Torpedo

dramatically increasing warhead effectiveness because it filled the target with water instead of air. At the turn of the century, when the Whitehead Company installed Ludwig Obry's new gyroscope in its torpedoes, these weapons became what could be considered the first operational guided missiles, because the gyroscope automatically guided them on a preset course.

Although largely ignored by historians and naval writers, these torpedoes wreaked great havoc during two world wars and provided stark evidence of the destructive potential of guided weapons long before the general public even became aware of the torpedo threat. Also, late in World War II, the first acoustic homing torpedoes were operationally employed in combat, the



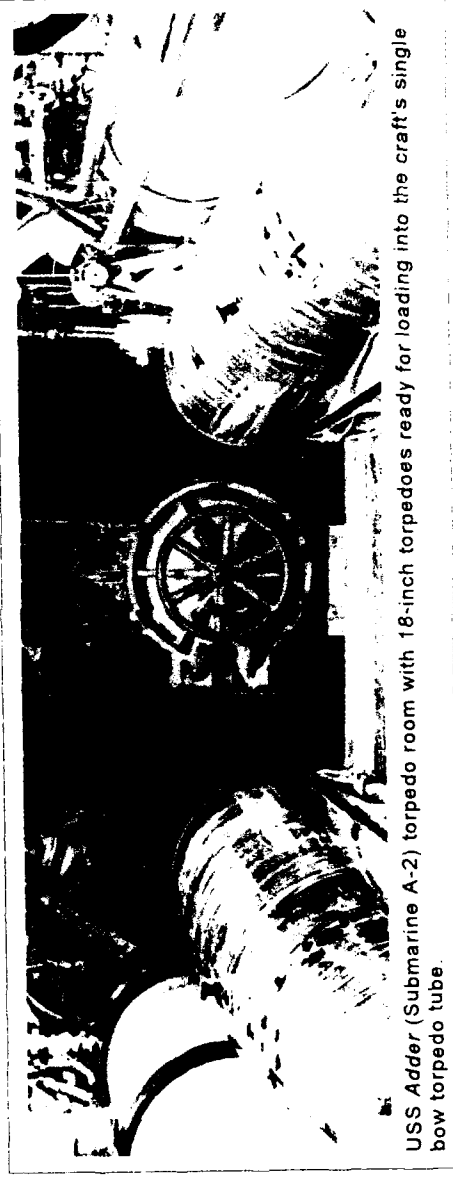
U.S. Navy Whitehead Mk 1 torpedo (1893).

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Germans used them against destroyer escorts, and the U.S. Navy used them against U-boats.

Because the technical base (servovalves, depth-control system designs, body dynamics and stability, etc.) to scientifically design an underwater missile did not exist

in the 1860s, Whitehead's torpedo was a triumph of trial-and-error development. The secret depth-control system Whitehead developed for his torpedo was a classic example of tenacious artisan genius, and the depth-control mechanisms of all the major torpedoes employed up through World War II were based on the original Whitehead



USS Adder (Submarine A-2) torpedo room with 18-inch torpedoes ready for loading into the craft's single bow torpedo tube.

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concept. The many torpedoes (e.g., German, British, U.S.) employing these primitive depth mechanisms all experienced depth-control problems, but they sank more than 40 million tons of shipping during two world wars. In the 1950s as dynamic control system theory and simulators

became available, the root cause of these depth problems was identified. Whitehead's original experimental design concept was found to be only marginally stable and extremely sensitive to small changes in torpedo trim, speed, and weight.

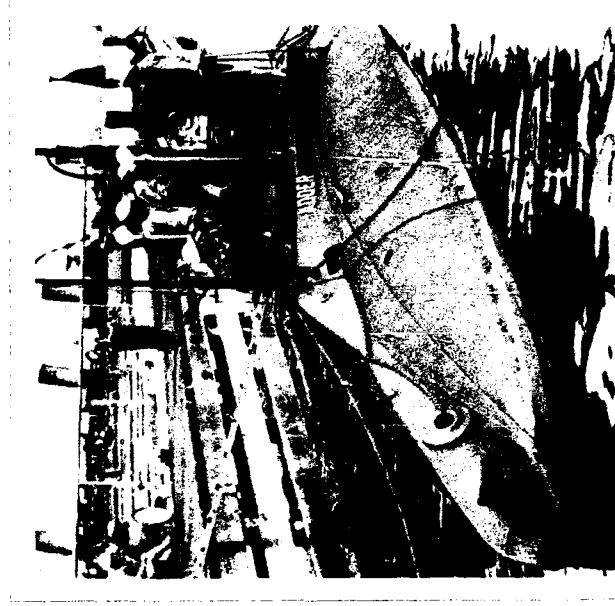


The *Holland* submarine torpedo boat in Newport (RI) Harbor (Naval Torpedo Station is in the background). In 1901 this submarine, manned by a crew from NTS Newport, participated in training exercises while carrying three Whitehead Mk 2 torpedoes

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Undersea Warships

When the submarine became a reality at the turn of the century, the torpedo was the obvious weapon with which to arm the new ships to create a true underwater weapons system. The U.S. Navy purchased its first submarine, the *Holland*, in 1900; it was taken to the Naval Torpedo Station (NTS) in Newport, RI, where a volunteer crew manned the submarine and conducted torpedo firings. Beginning with the *Adder*-class submarines, all U.S. Navy submarines prior to World War I were equipped with 18-inch torpedo tubes. Initially, cold running Whitehead torpedoes (Mks 1, 2, and 3) were used on these early submarines. Later, when the hot-gas, turbine-powered Bliss-Leavitt torpedoes (Mks 4, 6, and 7) were developed, they and the hot-gas Mk 5 Whitehead torpedo (manufactured under



Crewmen aboard USS *Adder* (Submarine A-2) in Newport Harbor

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license at NTS Newport) became part of the standard submarine weapon load.

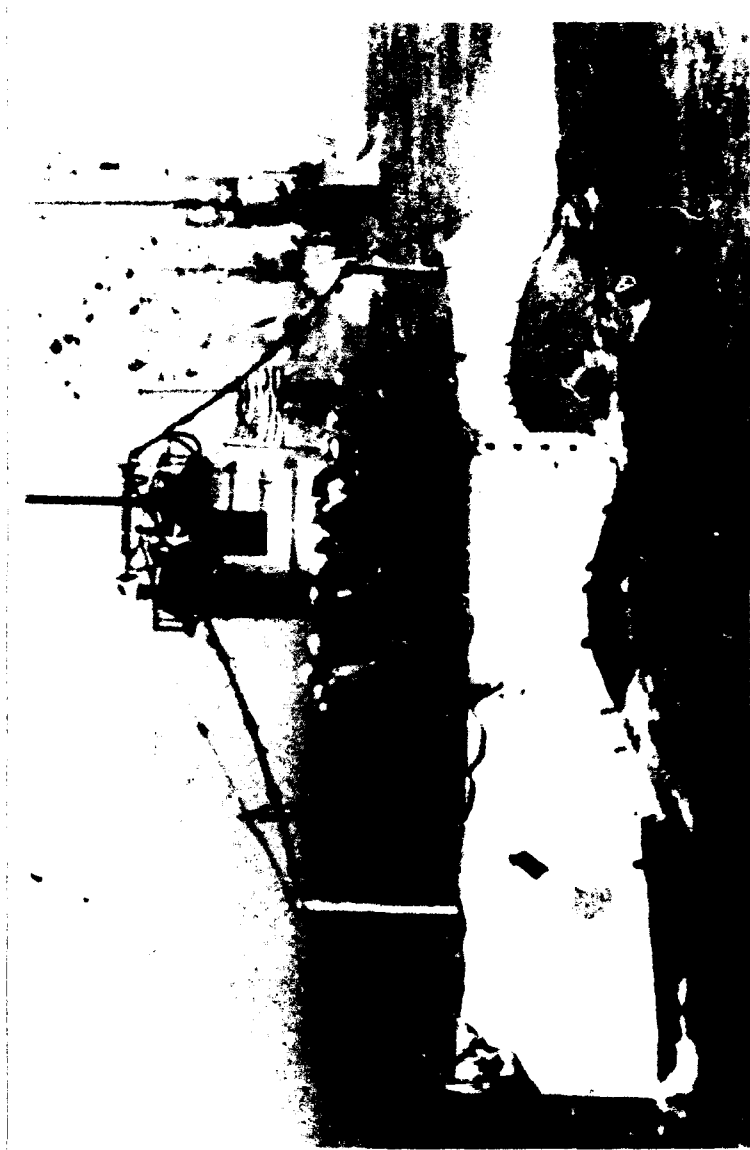
During the World War I era, the U.S. Navy embarked on a major torpedo upgrade program to develop a new family of larger 21-inch-diameter torpedoes including the Mk 8 for destroyer use, the Mk 9 for battleship use, and the Mk 10 for submarine use. The Mk 10 torpedo, the Navy's first torpedo with a 500-pound warhead (497 pounds of TNT), was used on the new R- and S-class submarines that were just entering the fleet when the war ended.

U.S. Navy submarines did not have an opportunity to play an active role in World War I. However, the Germans elevated *guerre de course* warfare to an unprecedented level when they employed their U-boats to conduct an unrestricted

submarine warfare campaign to sever Great Britain's maritime life lines. The U-boats sank more than 5700 ships (totaling some 11 million tons) or one-quarter of the world's tonnage, and came close to achieving a strategic victory by cutting off the flow of raw materials needed by the Allies to conduct the war. To counter the threat posed by the German U-boats employed during the war, a massive commitment of resources was required; more than 300 destroyers, 35 submarines, 550 aircraft, 75 airships, and 4000 auxiliary vessels, manned by 14,000 men and supported by another 500,000 men, were involved in this naval response.

The hard statistics clearly indicated that the submarine, armed with torpedoes, was a lethal weapon system that challenged the classic concepts of sea control because it

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S-class submarines of the World War I era

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provided a means for a minor naval power to inflict immense damage by severing sea lines of communication. Naval professionals, however, abhorred this form of unconventional warfare because it challenged the status quo. Consequently, this problem was addressed by attempting a naive political agreement that outlawed unrestricted submarine warfare.

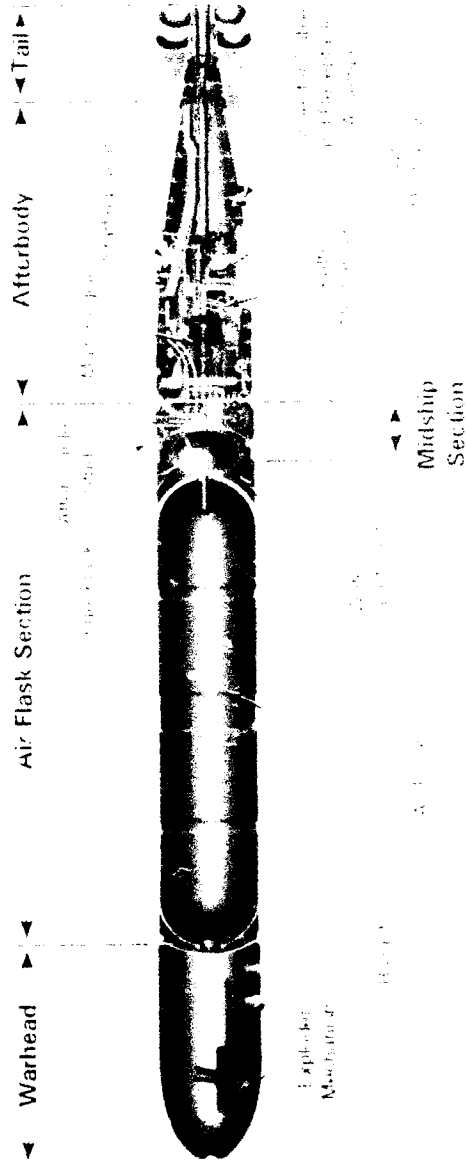
multispeed Mk 11 and Mk 12 destroyer torpedoes, which were produced in limited numbers by NTS Newport.

By the end of the decade, as the need for new submarine and aircraft torpedoes grew, the Navy directed NTS to simultaneously develop three new torpedoes: the Mk 13 for aircraft use, the Mk 14 for submarine use, and the Mk 15 for destroyer use. During this austere period, with annual research and development budgets averaging \$50,000, limited resources dictated a high degree of subsystem commonality in the development of the three new torpedoes. The three-speed Mk 12 destroyer torpedo, which was just entering production, incorporated the latest subsystems, and its technology provided the basis for developing the Mk 13, Mk 14, and Mk 15 torpedoes. To simplify their development cycle, all three

Post-World War I Torpedo Development

In the post-World War I period, submarine warfare was given a low priority. The limited resources available for torpedo development were again applied to develop bigger and better destroyer-launched torpedoes that could be used to sink battleships. In the United States, the only torpedoes developed during the 1920s were the

The Mk 14 Submarine-Launched Torpedo



Mk 14 Torpedo (Longitudinal Section)

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torpedoes used turbine power plants, a compressed air and alcohol combustion system, a common depth and course control system, and similar exploders. When World War 'I began, it soon became apparent that all three torpedoes had serious problems involving the depth and exploder subsystems they shared.

project. The initial Mk 14 torpedo development models, built in the early 1930s, were three-speed torpedoes. The final design selected for volume production was simplified to make it a two-speed torpedo.

Mk 14 Torpedo Development

The Mk 14 submarine torpedo, developed to replace the World War I vintage Mk 10 torpedo, maintained the same 21-inch diameter, but its length was increased by approximately 50 inches to allow increases in speed, range, and warhead size. It was also to be designed to employ a then-secret influence exploder that was being developed under a separate, highly classified

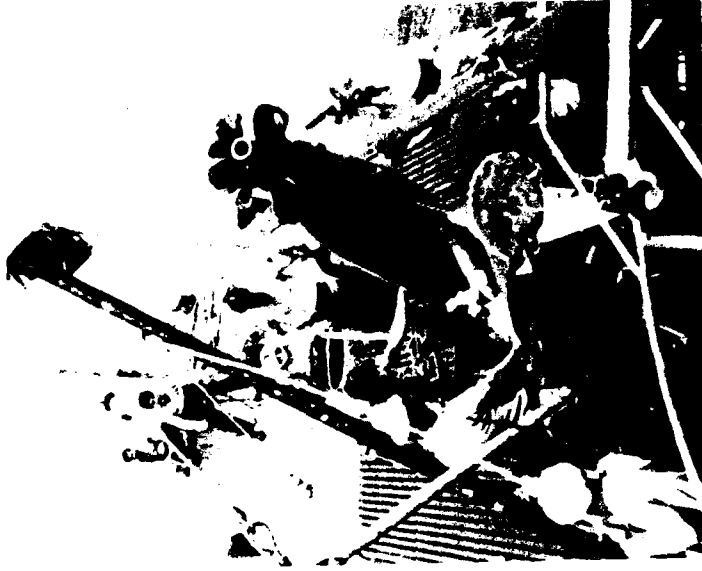
Mk 14 Torpedo Characteristics

<u>Physical</u>		<u>Performance</u>
Length	246 in.	Speed (knots):
Diameter	21 in.	Low -- 31.1
Weight	3200 lb	High -- 46.3
Propulsion	Turbine	Range (yd):
Guidance	Gyro	Low -- 9000
Warhead	643 lb of HBX	High -- 4500

By the mid-1930s prototype production of Mk 14 torpedoes was in progress at NTS Newport, by 1938 limited numbers of

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Mk 14 torpedoes were being evaluated on the long-range fleet submarines (with their longer torpedo tubes), which began to enter the fleet during the 1930s. These included the *Salmon* and *Plunger* classes (mid-1930s) and the *Tambor* and *Cato* classes (late 1930s), the latter two classes having 10 torpedo tubes (6 forward and 4 aft). During the pre-war period, Mk 14 torpedoes were in short supply, and the Navy was reluctant to conduct warshot tests for fear of depleting a limited inventory. Consequently, the majority of test firings was conducted with exercise-configured Mk 14 torpedoes, and serious problems with war-shot-configured Mk 14 torpedoes remained undetected until they were actually used in combat operations when the war began.



Mk 14 being loaded into forward torpedo room of USS *Lungfish* (SS 297).

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The Secret Torpedo Exploder

In 1922 a secret project, designated G-53, was initiated to develop a new magnetic influence exploder that would increase the torpedo's effectiveness by exploding the warhead directly under the target. The exploder would be activated by the changes in the earth's magnetic field caused by a ship's iron hull. The design of a magnetic influence exploder required a detailed knowledge of the earth's magnetic field in all geographic areas where the exploder might be employed and similar detailed knowledge of the signature of the target ships. For example, it was found that the magnetic signature of similar ship designs varied significantly depending on where they were built and operated (northern versus southern latitudes). During the early 1920s the Navy, with the assistance of the

Carnegie Institute, conducted surveys to gather the basic information required to design an influence exploder, and an experimental magnetic influence device was ready for testing by 1926. In May of that year, a submarine hull (ex L-8) was sunk by a torpedo equipped with an influence exploder. Incredibly, this single successful test, which was later shown to be a fluke, provided the Navy with a basis for refusing both additional warshot tests and urgently needed magnetic surveys in distant ocean areas. The extreme secrecy imposed on the project, combined with the lack of basic scientific data required to support the development, created serious problems that hindered the orderly scientific development of the new influence exploder.

By 1934 the effort had progressed to a point where a decision was made to initiate

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production of a new Mk 6 influence exploder for use in the Mk 14 torpedo. As a security measure, a companion Mk 5 contact exploder was developed for use in fleet issue Mk 14 torpedoes; the plan was to substitute the secret Mk 6 influence exploder for the Mk 5 contact exploders in the event of war. Development of the Mk 6 influence exploder had been conducted in a compartmented secret program that hindered peer review and exchange of information, and the fleet was not even informed of the exploder's existence until the eve of World War II. Serious problems were encountered with the Mk 6 influence exploder when later used in combat.

Coincidentally, the Germans and the British undertook similar secret programs to develop influence exploders for their torpedoes. When employed during World War II,

these influence exploders also experienced serious operational deficiencies similar to those of the U.S. Navy's Mk 6

Major Torpedo Problems in World War II

World War II was the first war in which the U.S. Navy expended large numbers of torpedoes, and most of the problems with torpedo performance arose from two root causes:

- subtle but critically important differences between the weight and trim of exercise and warshot torpedoes; and
- a reluctance, based on a false economy, to expend warshot torpedoes in peacetime fleet exercises against real targets.

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If World War II had been fought on the NTS Newport range using exercise torpedoes, there would have been no serious problems; however, the war was fought in the Pacific Ocean with warshot-configured torpedoes. The combination of the difference in weight and trim between warshot and exercise torpedoes (running depth errors), differences in the earth's magnetic fields (northern versus southern latitudes), and the lack of realistic warshot exploder tests (exploder not used in exercise firings) created a series of torpedo crises during the early part of the war.

Warshot Torpedoes Run Too Deep.

Because submarines were expending the largest number of torpedoes, they experienced the most problems. Relations between the submarine force and the ordnance community deteriorated rapidly

when the Mk 14 torpedo failed to live up to expectations. The fleet complained that the *warshot* torpedoes were faulty, but the Bureau of Ordnance (BUORD) and NTS Newport, after conducting extensive tests with *exercise* torpedoes, maintained that the torpedoes were operating properly.

At the start of the war, the World War I vintage Mk 8 (destroyer) and Mk 10 (submarine) torpedoes being used by the older four-stack destroyers and S-boats in the Far East Fleet were running deeper than their preset depth. During World War I, both the British and the Germans had experienced torpedo crises because their heavier (negatively buoyant) warshot torpedoes ran at deeper depths than the lighter exercise configurations, which were trimmed to be positively buoyant at the end of their run to permit recovery.

The Mk 14 Submarine-Launched Torpedo

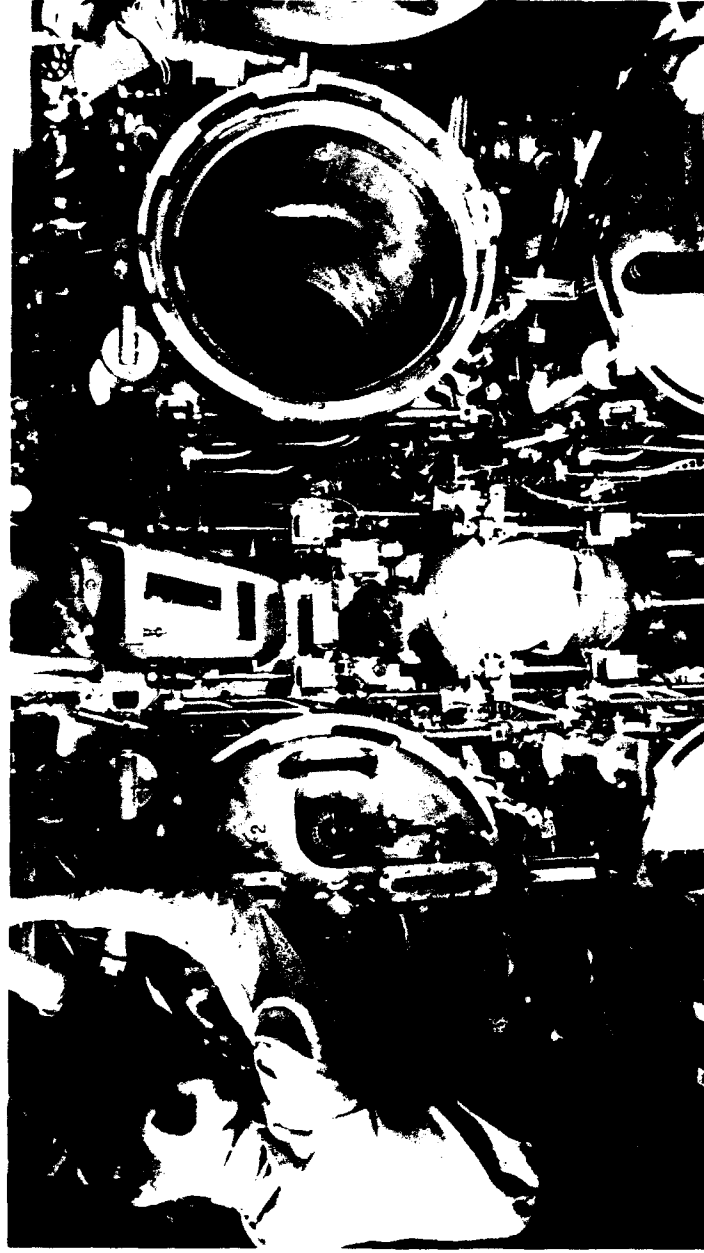
The higher angle of attack required to provide lift for the heavier warshot torpedoes introduced an error in the depth sensor that caused the warshot torpedoes to run deeper than the exercise configurations and caused the warshot torpedoes to run under a target. When the depth mechanisms were calibrated to function with the heavier warshot configurations, the torpedo worked well.

When World War II began, the U.S. Navy finally confirmed in combat that its World War I vintage warshot torpedoes were also running deep. The problem was easily solved by providing new depth calibrations for warshot-configured torpedoes, but this problem provided a strong indication that the lack of emphasis on realistic fleet testing and evaluation of warshot torpedoes during the peacetime years was a serious

error that would come back to haunt the Navy in wartime.

Exploders Perform Erratically. When the new Mk 13, Mk 14, and Mk 15 torpedoes were used in combat, complaints about warshot failures poured into BUORD from operational commanders. Controlled tests in which warshot-trimmed torpedoes were fired at nets to accurately check their operating depth against the preset depth were conducted on the NTS Newport range; it was confirmed that the new torpedoes, like their World War I counterparts, also ran deeper with the heavier warheads installed. The fleet was provided with data to correct the depth error, but the submarine force continued to complain about the poor performance of the Mk 14 torpedo.

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Forward torpedo room in a World War II submarine. Visible in this photo are four of the six torpedo tubes. The man between the tubes is operating the forward gyro regulator, which set gyro angles on torpedoes in the tubes.

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The new secret Mk 6 influence exploder came under suspicion due to frequent reports that Mk 14 torpedoes equipped with the exploder were detonating prematurely under some conditions, when still 50 feet from the target. Much ill will was generated as the operational forces and the technical community exchanged accusations concerning the poor performance of the Mk 14. During this turbulent period, Admiral Lockwood directed that Pacific Fleet submarines (SUBPAC) deactivate the Mk 6 influence exploder and use the contact exploder for all firings, while Admiral Christie, who had participated in the development of the Mk 6 exploder, directed that Southwest Pacific submarines continue using the Mk 6 influence exploder.

As evidence continued to accumulate and the exploder's erratic performance in the

South Pacific was confirmed, the Mk 6 was taken out of service, and a crash program was initiated to simultaneously correct its problems and develop a new influence exploder. An improvement program was conducted and the Mk 6 exploder's performance was enhanced dramatically; a new backup influence exploder (Mk 10) was also developed. However, the submarine force, disenchanted with the poor performance of the Mk 6, lost all interest in influence exploders and continued to use contact exploders for the duration of the war.

When the use of the influence exploder was discontinued, fleet complaints about "dud shots" using the contact exploder increased markedly. In responding to these complaints, BUORD and NTS Newport suggested that part of the problem might be

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due to marginally trained submarine crews claiming dud shots when they actually failed to even hit the target. This response generated a new round of ill will and bitter exchanges between the fleet and BUORD. The validity of the fleet complaints was dramatically demonstrated on 24 July 1943 when torpedoes fired by the submarine USS *Tinosa* (SS 283) disabled a large Japanese whaling factory ship. The *Tinosa* closed to sure-shot range to finish off the ship and proceeded to fire dud after dud at the stationary target. During this attack, 15 torpedoes were fired and 12 hits were claimed. The *Tinosa* saved its last torpedo and brought it back to Pearl Harbor for examination. Less than a month later, USS *Haddock* (SS 231) disabled a 10,000-ton Japanese tanker and proceeded to fire 11 more torpedoes at the damaged ship without getting a single warhead explosion.

This confirmed poor performance got the attention of SUBPAC, BUORD, and NTS Newport, and extensive testing was initiated in Chesapeake Bay, Pearl Harbor, and Newport, RI. These tests revealed that the contact exploder worked well for glancing or angle hits, but when the torpedo hit the target broadside (at a right angle to the target) at 45 knots, the impact bent the firing pin and the exploder failed to function. Tests conducted both at Pearl Harbor and NTS confirmed that the firing pin was the culprit. To solve the problem, SUBPAC proposed a lighter firing pin, while NTS proposed a heavier spring for the firing pin. BUORD, not wanting to take any chances, opted for a "belt and suspenders" solution by incorporating both a lighter firing pin and a heavier spring to be absolutely sure that the problem was solved.

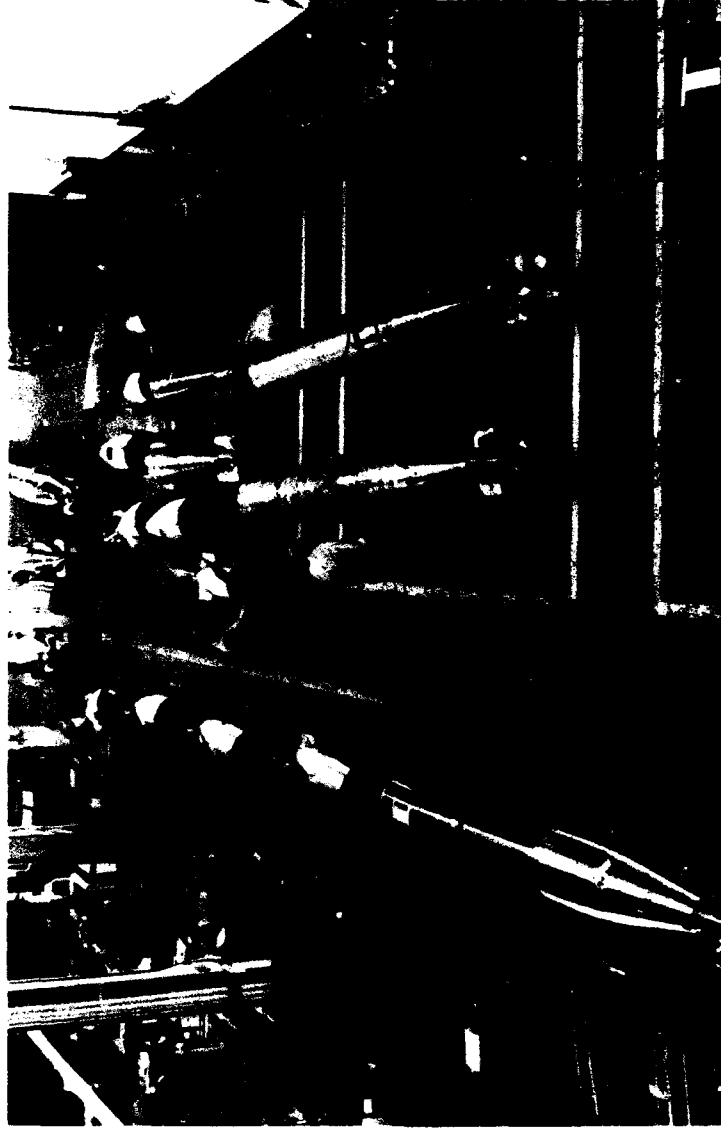
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It took almost 1-1/2 years of frantic effort to correct warshot problems that could have been identified before the war if realistic warshot torpedo firing exercises had been conducted during the peacetime years. From mid-1943 on, with the warshot problems corrected, the Mk 14 demonstrated itself to be a highly reliable and effective weapon. Ultimately, when the post-war statistics were compiled, the Mk 14 proved to be a premier, world-class torpedo that had sunk over 4 million tons of Japanese shipping. Only the Germans' G-series (G-7-a and G-7-e) torpedoes had put more tonnage on the bottom of the ocean.

Production Plant Difficulties. When World War II began in Europe, NTS Newport, as the nation's only torpedo production activity, had huge back orders to produce the new Mk 13, Mk 14, and Mk 15

torpedoes. There were valid concerns that this single activity could not produce the quantities of torpedoes required to support a major war, and a concerted effort was initiated to activate additional torpedo production facilities. In a short period of time, new torpedo plants were established at NTS Alexandria, VA; at NTS Keyport, WA; and at the Naval Ordnance Plant, Forest Park, IL. When the war started, NTS Newport faced the dual problem of providing the essential specialized technical expertise to get the newly activated production facilities at other locations "tooled-up" to produce torpedoes, while at the same time working to solve serious fleet problems with warshot torpedoes. Fleet problems were further complicated because the new production plants were unfamiliar with the fine details and special artisan techniques required to build torpedoes. Consequently, the plants

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Typical Mk 14 and Mk 16 torpedo assembly area.

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experienced numerous production difficulties and they produced significant numbers of deficient torpedoes that contaminated the fleet inventory, making it even more difficult to isolate the warshot torpedo problems.

The problems encountered with warshot Mk 14 torpedoes, combined with a serious inventory deficiency, were matters of serious concern during the early part of the war, and the Navy initiated emergency measures to ensure an adequate supply of submarine torpedoes. The Westinghouse Corporation was contracted to build a new electric torpedo, based on a German G-7-e electric torpedo taken from a captured U-boat. Designated the Mk 18, this electric torpedo incorporated the German motor and battery design, but its depth mechanism and warhead/exploder systems were similar to those used in other U.S. Navy torpedoes.

The wakeless Mk 18 torpedo entered the fleet in May 1943 and, although it was slower (having a top speed of 29 knots) than the Mk 14, it proved to be a simple and effective weapon, almost a million tons of Japanese shipping were sunk by Mk 18 torpedoes during World War II.

To simplify the Mk 14 torpedo design and increase production, BUORD initiated development of a single-speed version. Unfortunately, by the time this simplified configuration, designated the Mk 23 torpedo, was developed and produced, the steadily increasing Mk 14 production had caught up with fleet demands. Given a choice, the submarine fleet preferred the increased tactical flexibility of the two-speed Mk 14 torpedo; consequently, few of the single-speed Mk 23 torpedoes were used. At the time it was authorized, the

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Mk 23 torpedo was a valid solution to a pressing problem; but by the time it entered the fleet in 1943, the problem it was designed to solve no longer existed, and most of the Mk 23 torpedoes ended up in storage.

tons of shipping. This highly effective campaign deprived the island empire of the food and raw materials vitally needed to prosecute the war and drove Japan to the brink of strategic defeat. By 1945 oil was in such short supply that even high-priority combat operations had to be curtailed.

Mk 14 Torpedo's Role in Victory at Sea

Ultimately, the Mk 14 torpedo proved to be a highly reliable and effective weapon that played a major role in the outcome of World War II. The 50,000-man submarine force represented less than 2 percent of the U.S. Navy's wartime complement; yet, fleet submarines, employing Mk 14 torpedoes as their principal weapon, accounted for 55 percent of Japan's maritime losses. These submarines decimated the Japanese merchant fleet, sinking more than 5 million

Although severing Japan's sea lines of supply and communication was the submarine force's primary mission, SUBPAC submarines (and their Mk 14 torpedoes) also played a major role in the naval war, accounting for almost one third of all the Japanese naval warships destroyed during the war. SUBPAC submarines frequently went nose to nose with Japanese destroyers and escorts during convoy attacks and outfought them by a six-to-one ratio (six escorts sunk by submarines for every submarine sunk by an escort).

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There is no denying that the serious operational problems encountered early in the war placed the Mk 14 torpedo high on the Navy's problem list. Many Naval historians and other writers discuss the Mk 14 torpedo "scandal" in considerable detail, citing it as a classic example of the poor quality of the weapons provided to the fleet and the problems between the fleet and the producers. These problems were real and it is entirely appropriate that they be reviewed and addressed. It is unfortunate, however, that these writers, who have devoted many chapters to discussing Mk 14 warshot torpedo problems, fail to present and document its impressive wartime accomplishments. The final evaluation of a weapon is its demonstrated performance in combat, and the Mk 14 torpedo's world-class record for performance has been largely ignored. It is ironic that the Mk 14



Periscope view of torpedoesed Japanese cargo ship

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torpedo, which entered World War II as a problem-plagued and unreliable weapon, ended up being the single most destructive weapon employed by the U.S. Navy during the war. It accounted for about 80 percent of Japan's merchant ship losses and about 20 percent of Japan's naval ship losses. This massive destruction, accomplished with a wartime expenditure of fewer than 5000 torpedoes, attests to the able performance and overall effectiveness of the Mk 14; clearly, it was a first-rate weapon.

A Post-War Look at the Mk 14

Most of the Mk 14 torpedoes produced during World War II were Mk 14 Mod 3 torpedoes designed to operate with mechanical submarine fire control systems that employed gears and shafts to mechanically preset the torpedo's depth, speed, and

course prior to firing. In the post-war period, as new fire control systems (Mk 101 and Mk 102) were developed, a 65-conductor cable (called an A-cable) was designed to provide electrical preset information directly to the torpedo. Mk 14 Mod 3 torpedoes were modified to accommodate the new A-cable, and the depth and course control systems were redesigned to make them compatible with the new electric preset system. The torpedoes modified for use with the new electric fire control systems were designated as the Mk 14 Mod 5 and, during the 1950s and 1960s, the Navy's inventory of Mk 14 Mod 3 torpedoes was converted to the new Mk 14 Mod 5 configuration. During this period a limited number of new, wakeless Mk 16 torpedoes, using concentrated hydrogen peroxide (Navol), were issued to the submarine force; however, the fleet was less than enthusiastic

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about handling the volatile Naval on submarines, and the Mk 14 Mod 5 torpedo remained the submarine force's weapon of choice for antiship warfare until it was replaced by the dual-purpose (antisubmarine and antiship) Mk 48 torpedo.

A total of 12,526 Mk 14 torpedoes were produced during World War II: 5594 by NTS Newport, 5517 by NTS Alexandria, 390 by NTS Keyport, and 1025 by the Naval Ordnance Plant in Forrest Park, IL. Post-war records indicate that estimates for projected inventory requirements were high; of the 12,526 Mk 14 torpedoes produced, only 5035 were issued to the fleet during the war. It is interesting to note that the 5594 torpedoes produced by NTS Newport were actually sufficient to meet wartime requirements. Torpedoes produced at the other facilities ended up being surplus

inventory at the end of the war.

Four Decades of Service

The Mk 14 torpedo was the last of the U.S. Navy's artisan-built torpedoes that were direct descendants of, and closely resembled, the early Whitehead designs. Its life cycle, from initial development in the early 1930s to its retirement in 1980, spanned almost half a century, and it was the Navy's principal antiship torpedo for more than four decades. During the Mk 14's later life, the submarine force developed a sentimental attachment to it. Even the skippers of nuclear-powered, ballistic missile submarines, with their massive nuclear destructive potential, enjoyed conducting Mk 14 torpedo firings. The Mk 14 was the last link with the World War II submarine era, a time when submarine warfare involved

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making an undetected approach, getting a target ship in the periscope cross-hairs, generating a fire control solution, and watching the torpedo's wake intersect the target. The last of the gyro-guided, straight-running torpedoes, the Mk 14 dramatically demonstrated the destructive potential of guided weapons during World War II. But the Mk 14 was overtaken by new technol-

ogy as homing torpedoes replaced guided ones. When the wire-guided Mk 48 Mod 1 torpedo, with its active/passive homing system, began entering the fleet in the early 1970s, the Mk 14 Mod 5 torpedoes were removed. By 1980, all operational submarines were Mk 48 equipped, and the Mk 14 torpedo, with more than four decades of active service, was "retired with honors."



World War II fleet boat USS Spikofish (SS 404).

The assistance of Mr. Arthur Burke, a former NUWC Division Newport employee, in the researching and writing of this brochure is gratefully acknowledged.

The Naval Undersea Warfare Center acknowledges the Nautilus Memorial Submarine Force Library & Museum, Groton, CT, for providing the photo on this page and also those found on pages 3, 7, 11, 16, and 23. All other photos are from NUWC Division Newport archives.

Front cover photo: Model of the Mk 14 submarine-launched torpedo.