A VISUAL GUIDE TO THE S-CLASS SUBMARINES
1918-1945
PART 1: CONCEPT DEVELOPMENT

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BY

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Throughout the rich history of the United States Navy Submarine Service, there are several submarines that have become iconic and are among the first mentioned in history texts. The *Holland*, *Gato*, *Nautilus*, and *George Washington* always receive top billing when discussing submarine history and deservedly so. They were technological pathfinders or the parent of large and important classes that won wars or kept the peace. But, in the 1920's, an entire class of submarines achieved that iconic status and came to represent the Silent Service in the minds of the public.

Designed during WWI when German U-boats were running amuck in the Atlantic, the S-class submarines were to be our Navy's first true ocean-going attack submarines. All previous classes had been designed for harbor defense or coastal patrols and were not suited for blue water operations. The S-class, while not a true Fleet Submarine as the Navy defined that term, were to be longer ranged, faster, more heavily armed, and more habitable than any previous submarine class. They wound up being too late to see action in WWI, but they began to enter the fleet just as the Roaring 20's started. The 51 submarines of this class comprised the largest single class of submarine in the U.S. Navy until WWII, and it made up the bulk of our Navy's submarine force during the 1920's and 30's. Some of the S-boats served right up to the end of WWII, an unthinkable longevity for the time.

One of the accepted definitions of the word *class* is "a number of things regarded as forming a group by reason of common attributes, characteristics, or qualities." In the Navy, a class of warships will meet this definition, but in addition the ships will also look and be outfitted in such a manner as to be nearly identical. The layman might be surprised to learn that the 51 S-class submarines were anything but a homogenous, identical group and were in fact a class in name only. The S-class was actually made up of no less than six distinct groups that were built by four different manufacturers. The Navy considered all 51 boats a single class because they were all intended to meet the same set of performance and war-fighting specifications.

The first two years of World War I, 1914-1916, proved to be revelatory ones for the U.S. Navy's Submarine Service. The rapidly changing naval situation abroad indicated that some long held beliefs about how submarines were supposed to be operated were losing strategic and tactical validity. The bulk of the service was made up of the H, K, L, and N-classes. These were designed as coastal patrol submarines, intended to range out from American bases and attack an enemy fleet as they approached the coastline. In essence, they were looked upon as a mobile minefield in which an enemy fleet would impale itself. Since these boats were never intended to be very far from their operating base, they were short-ranged, lightly armed, and very nearly uninhabitable after a few days at sea. As intelligence reports from Europe began to trickle in it was realized that German U-boats were routinely spending 2-3 weeks in the war zone off Great Britain and the eastern Atlantic. The advanced state-of-the-art of the German submarines and the depredations they were inflicting on British and Allied shipping drove home the fact

that our submarines were woefully inadequate for that type of war. This was perceived as a dangerous strategic weakness, especially if Great Britain were to fall.

Studies conducted in the summer of 1916 by the USN's Bureau of Construction & Repair (C&R) and Bureau of Engineering (BuEng) were intended to develop specifications for a submarine that could cross the Atlantic on its own and stay there long enough to inflict serious damage on the enemy. These specifications as codified were approximately 800-1000 tons submerged displacement, length approximately 250 ft., submerged speed 14 knots for 1 hour and 10 knots for 3 hours, with a surface range of 3,400 nautical miles at 14 knots and 5,400 nautical miles at 11 knots. Armament was to consist of four 21-inch bow torpedo tubes (two reloads each). These studies and the strategic situation in Europe convinced the Navy Department of the need for the 800 tonner, so appropriations for Fiscal Year 1917 included funding for three of the new boats, to be called the S-class. Follow on boats were authorized in wartime appropriations in March and October 1917.

Prior to this point, the Navy would develop a set of generalized specifications that they wanted a submarine to meet, then put out those specifications to industry for bids and proposals. The Navy had no design experience itself, so it was forced to accept whatever was proposed to them by industry. There were really only two private firms in the United States that were capable of building submarines, as this process required a set of specialized skills. The Electric Boat Company (EB) of New York City (later Groton, CT.) and the Lake Torpedo Boat Company (LTB) of Bridgeport, CT. were those companies. The reliance on private firms for the detailed design work forced the Navy to accept whatever was offered to them, and the Department had little influence in that process. The two firms obviously wanted to build a submarine at a profit to its owners and investors, and the Navy wanted the most lethal weapon system possible. These two philosophies were often incompatible, and the result was that the Navy often did not get the boat it wanted.

C&R had developed some experience by building three submarines under license from Lake and EB at the government owned Portsmouth Navy Yard (PNY) in Kittery, ME. and the Puget Sound Navy Yard in Bremerton, WA. A lot was learned from that experience, so by the time that the S-class was being developed the Department was confident enough in its abilities that it felt it could provide some direct competition to EB and Lake by designing and building elements of the S-class at government yards. Portsmouth was designated as the lead submarine design center for the Navy, and they developed their own design to meet the S-class specifications. One each of the three designs made up the three boats authorized in the FY-17 appropriations, with follow-on boats assigned to each yard in the subsequent bills. Series production of all three designs was intended from the start.

ELECTRIC BOAT DESIGN

Electric Boat's model became the USS *S-1* (SS-105). This design is sometimes referred to as the "Holland" S-boat, a reference to one of EB's founders, inventor John Holland. It was a single hull design (Figure 1), with all ballast tanks internal to the pressure hull, in essence a scaled-up version of all their previous designs. The hull was a rounded spindle

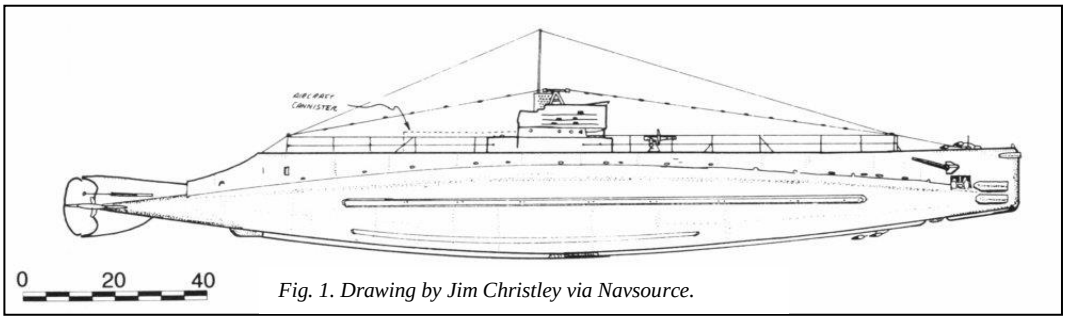

Fig. 1. Drawing by Jim Christley via Navsource.

shape with a narrow superstructure atop it that ran ¾ of the way to the stern before the skeg tapered down to the rudder. The rudder itself was placed at the very end of the hull, in line with the hull's axis and aft of the twin screws. She had four 21-inch torpedo tubes forward, a prominent towing fairlead pipe at the far forward, upper end of the bow, and a single starboard side anchor. A squared off conning tower fairwater sat dead center on the superstructure, supporting the periscopes and radio aerials. Figure 2 shows her on her trial runs, with a portion of the conning tower fairwater surrounding the bridge not yet installed, a common construction technique of the time. As built, she sported a small 3-inch/23 caliber Mk 9 deck gun that partially retracted, breech end first, into a watertight tub that penetrated the superstructure forward of the fairwater and into the pressure hull in the forward battery compartment. A circular gun shield attached to the barrel formed the watertight top of the tub. A desire to reduce drag and thereby increase underwater speed led to the adoption of this unusual gun. Lessons from German experience with larger guns were still forthcoming. Her bow planes retracted aft into the superstructure, one of the earliest examples of this feature. EB did not at this time have the large construction yard in Groton and thus contracted the *S-1*'s construction to the Bethlehem Quincy yard of Quincy, MA. (formerly Fore River Shipbuilding Co.) A slightly later photo (Figure 3) shows the angular, slab-sided fairings for the bow plane pivots on the forward superstructure. She also has had her bridge fairwater installed. Once accepted into the Navy she was quickly repainted in the standard Haze Gray paint scheme. Overall, the *S-1* had even, well-proportioned lines. This was mostly due to the fact that alone among the three prototypes, EB split the boat's main battery into two halves, with half forward of the control room, and half immediately aft. This was a favored feature of EB designs, which added a level of electrical redundancy.

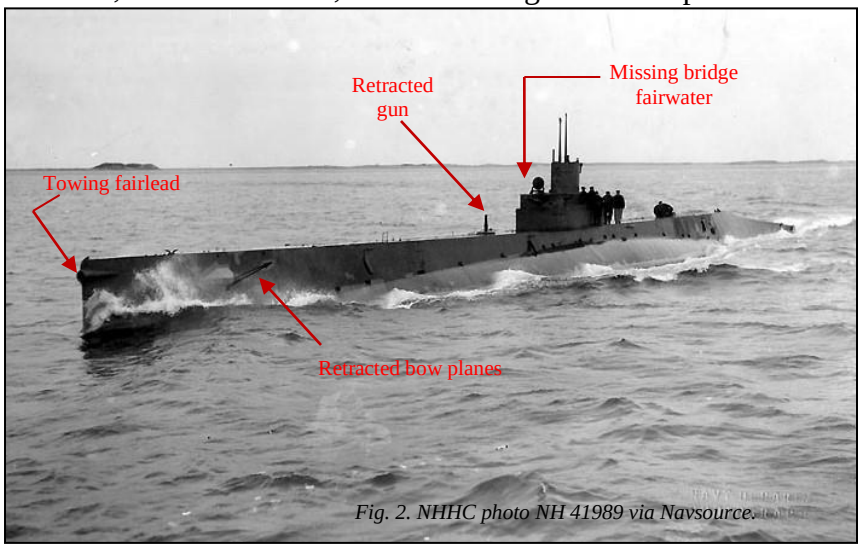

Fig. 2. NHHC photo NH 41989 via Navsource.

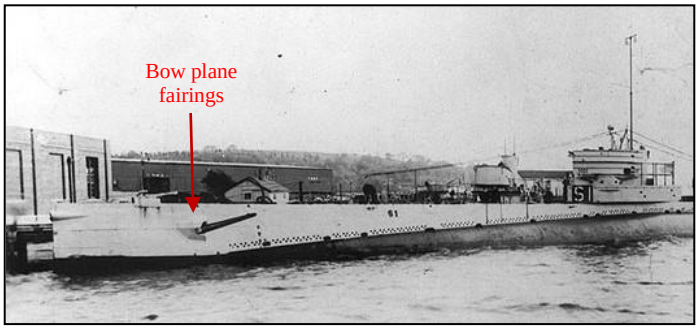

Fig. 3. NHHC photo NH 80594 via Navsource.

The *S-1* was chosen in 1926 to conduct the Navy's first (and as it turned out, only) tests in carrying and launching an airplane from a submarine (Figures 4 & 5). For these experiments, she was fitted with a horizontally mounted cylindrical hangar aft of the fairwater. It held a single Martin MS-1 floatplane partially disassembled. In order to accommodate the hangar, and to give additional space to extract and assemble the plane, the superstructure was expanded outward on either side of the conning tower fairwater and aft towards the stern. The angle at which the skeg tapered down to the rudder was sharpened and the stern light repositioned. She was also refitted with a larger, more powerful 4-inch/50 caliber deck gun (coincidentally also designated Mk 9), necessitating the widening of the deck sponson around the gun. This gun replaced the 3-inch/23 caliber "disappearing" mount that was roundly disliked by the crew as being unreliable and lacking punch, and because the gun tub took up space in the forward battery compartment.

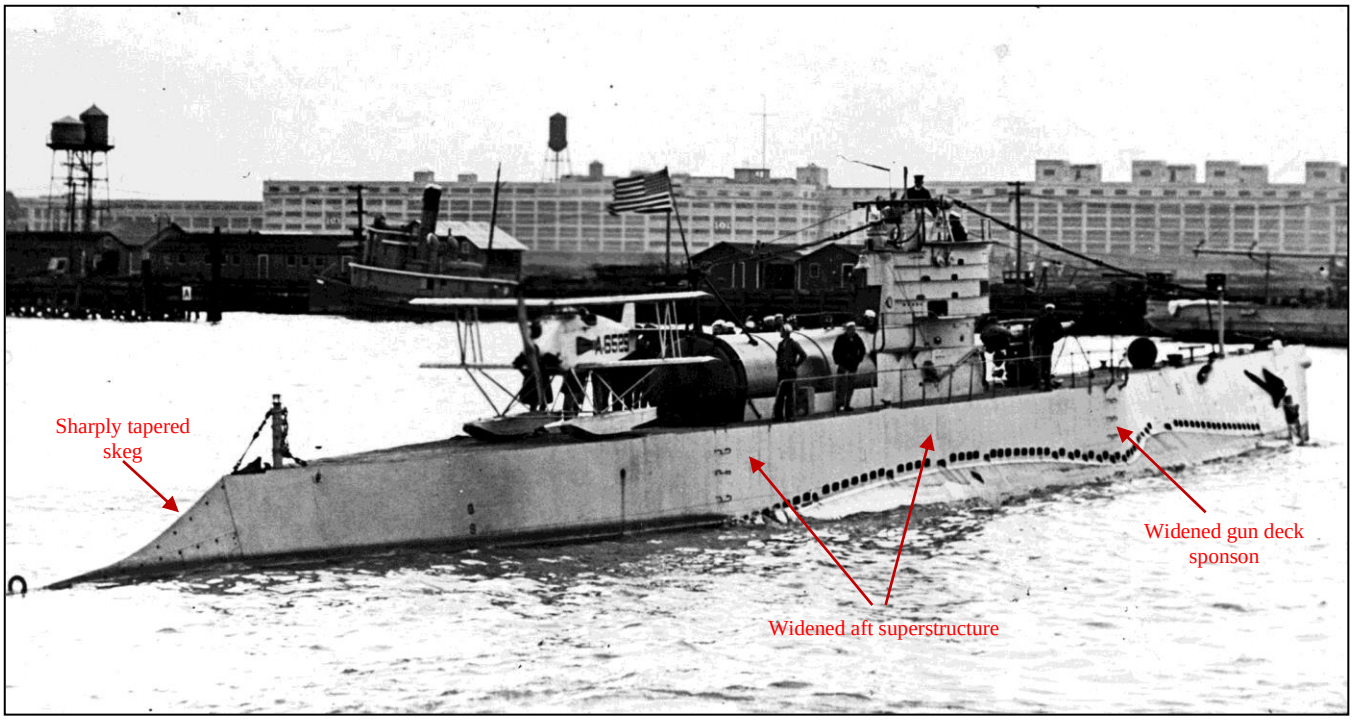

Fig. 4. NARA photo 19-N-475A via PigBoats.COM

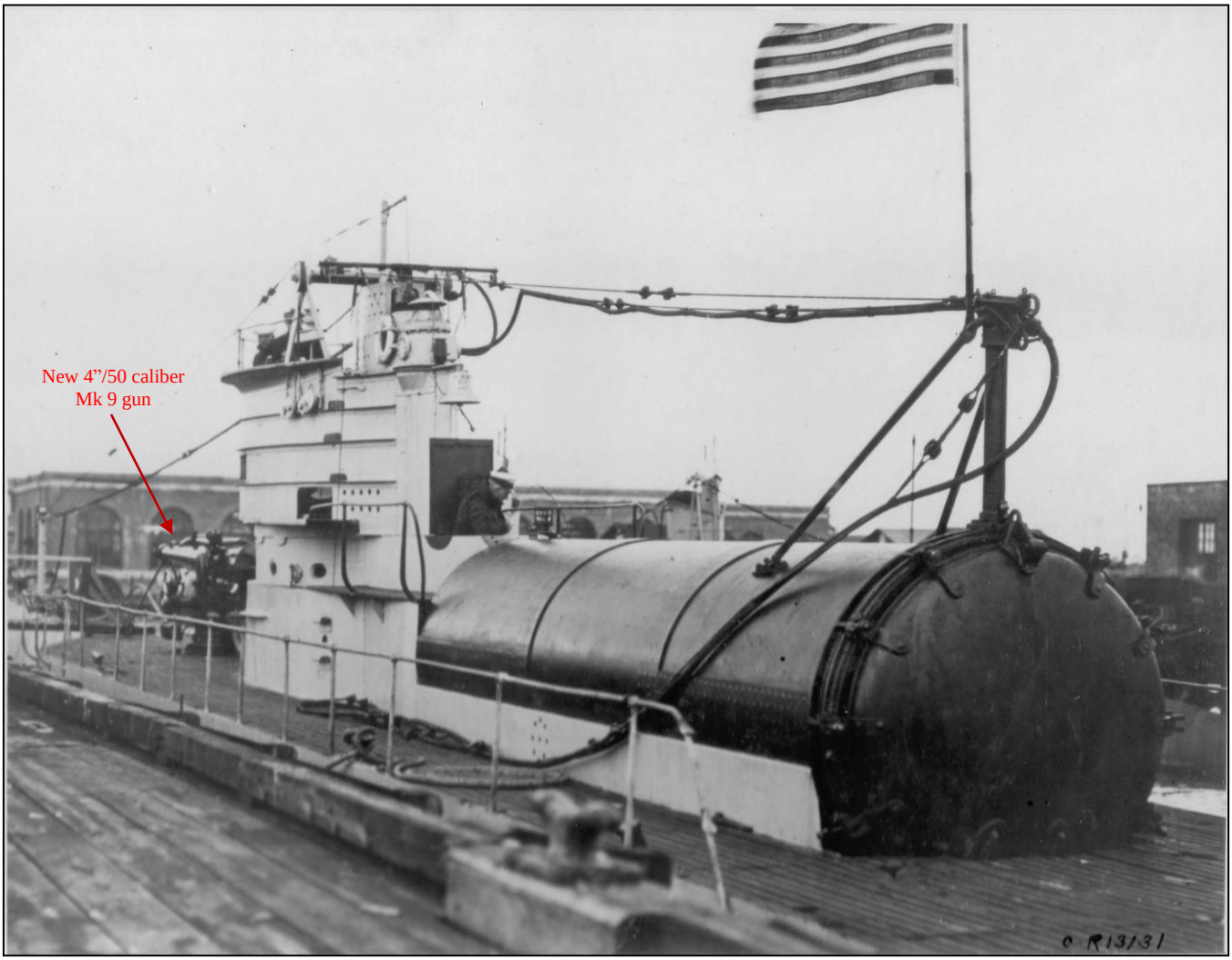

Fig. 5. Close up view from aft. Note the time-consuming latching system for the hangar door, all individual bolts. NARA photo 19-N-13131 via Navsource.

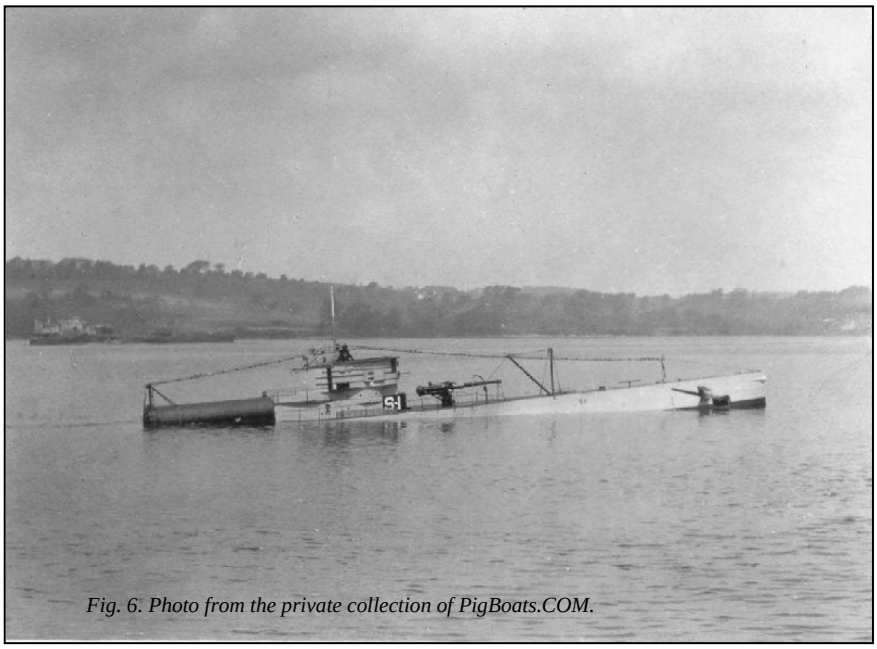

Fig. 6. Photo from the private collection of PigBoats.COM.

Literally making up doctrine as they went along (Figure 6), normal practice for launching the aircraft was to surface the boat, open the hangar and pull the aircraft and its components out. It would then be assembled on the aft deck, manned by the pilot, and the engine started. The boat would then flood down the after group ballast tanks and the aircraft would float off and make its take off run. Recovery would be the opposite of this procedure. The approximately one hour that it took for this action and the necessity of having glass calm seas showed the concept to be unworkable and it was never repeated on a U.S. submarine (although it was considered for inclusion on the later fleet boat *V-4*, but dropped from the design prior to construction).

LAKE TORPEDO BOAT CO.

The brilliant but eccentric Simon Lake and his Lake Torpedo Boat Company were EB's only real competition in the years leading up to the S-boats. Lake submitted a design that became the USS *S-2* (SS-106). It was a modified double hull design and thus was generally cylindrical in shape (Figure 7), but it tapered sharply upward forward and aft, giving the amidships portion a somewhat squat, almost pregnant look. The stern was a flat, horizontal "shovel" shape, a Lake trademark that provided needed buoyancy at the stern. Her rudder was mounted beneath the stern (as opposed to EB's axial mounted rudder), and the rudder pivot structure also supported the stern planes. To match the position of the stern

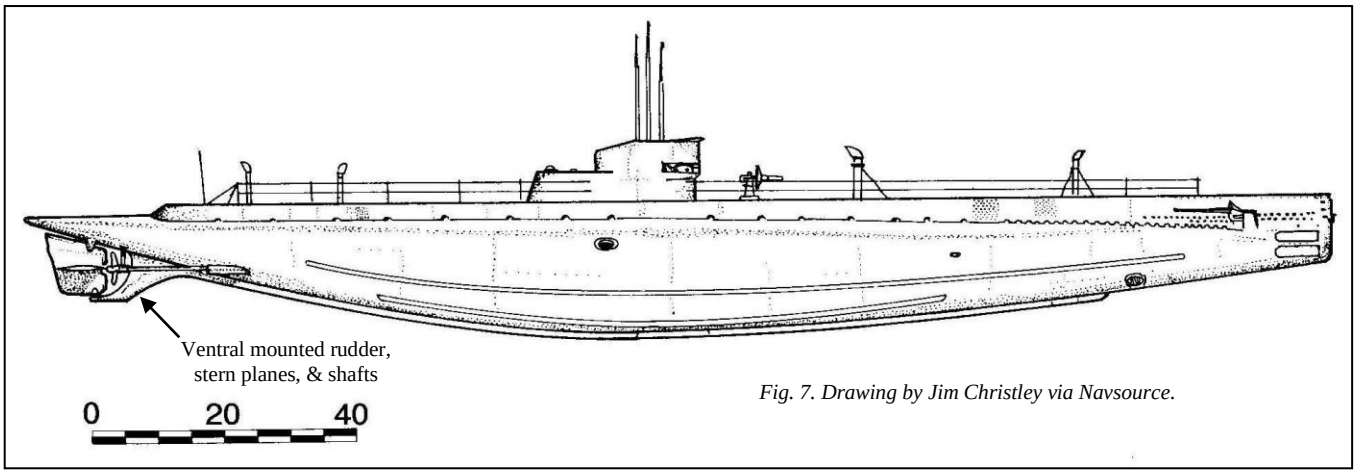

Fig. 7. Drawing by Jim Christley via Navsource.

planes, the propeller shafts also exited beneath the hull. The superstructure ended short of the stern. She also had a starboard side anchor and fully retractable bow planes. Her battery was situated in one compartment forward of the control room, and that had the visual effect of pushing the conning tower fairwater aft a little. Like the *S-1*, she conducted her initial sea trials without the bridge fairwater installed (Figure 8).

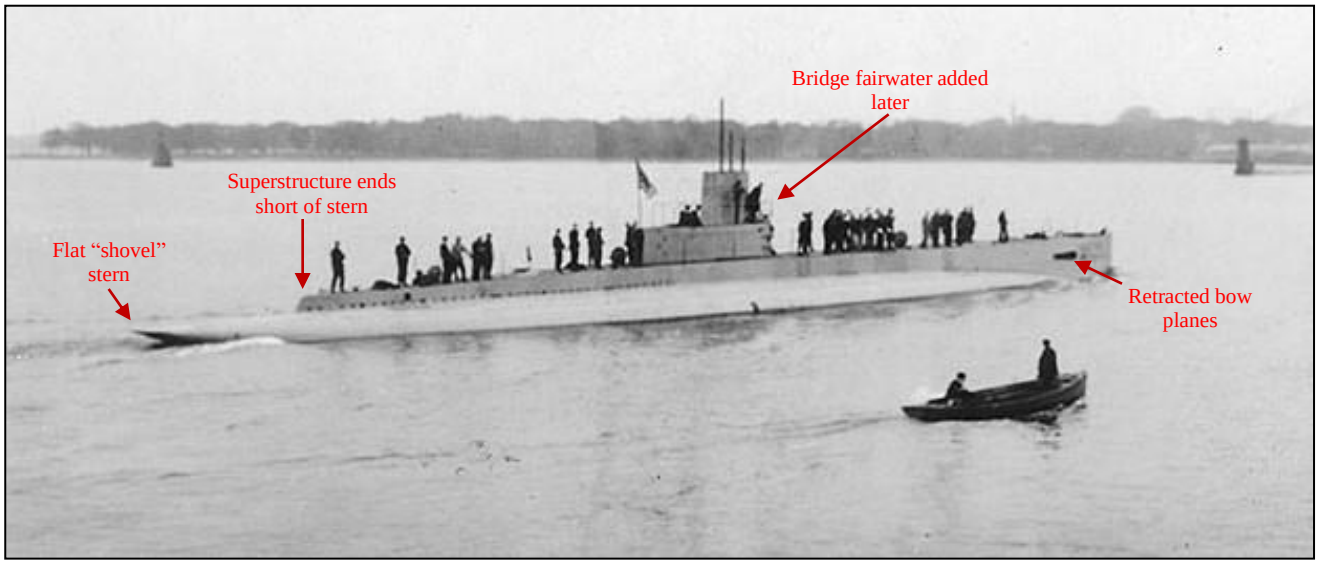

Fig. 8. S-2 on builder's trials, Sept. 1919. NHHC photo NH 41993 via Navsource.

Initially built without a gun, she was also refitted with a 4-inch/50 caliber Mk 9 weapon. Similar to *S-1*, her deck around the gun mount had to be expanded outward to provide adequate space for the large gun, in this case a considerable amount (Figure 9). A portion of her superstructure amidships was

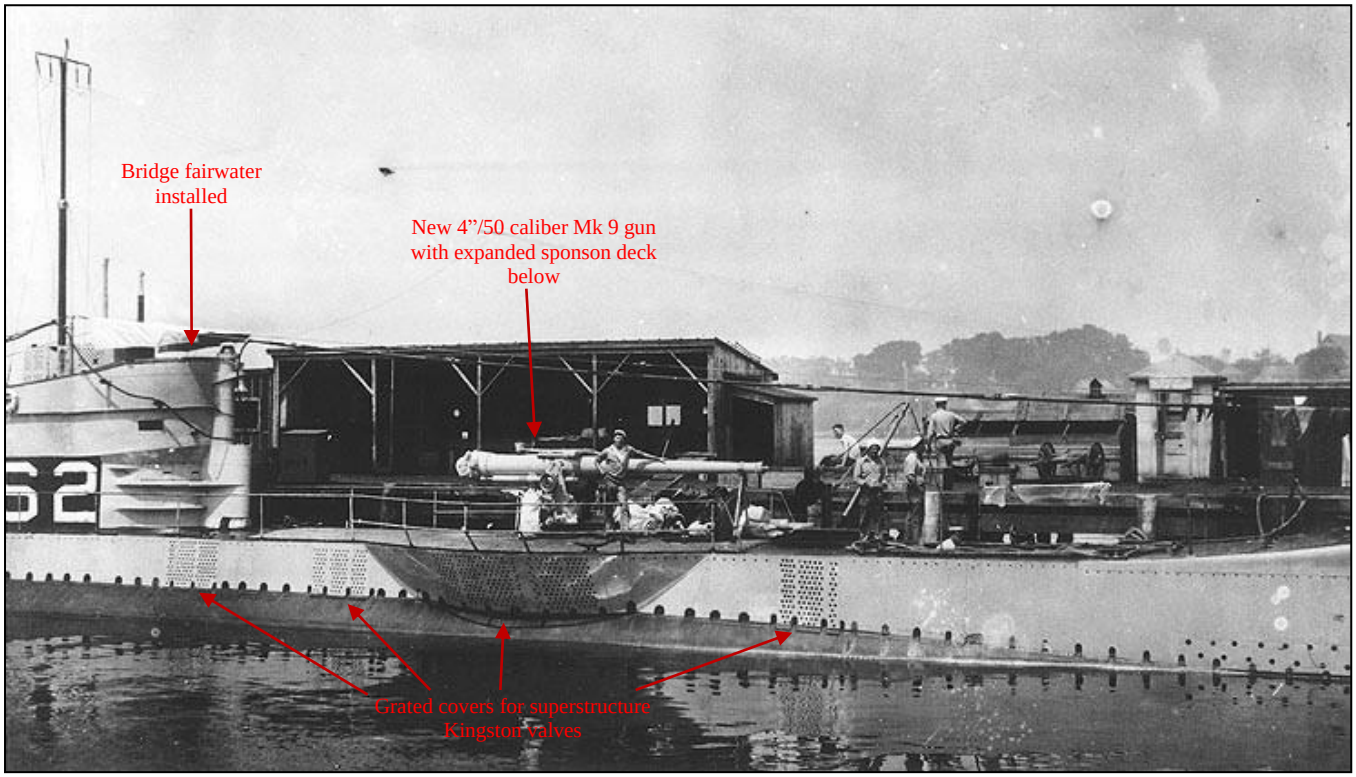

Fig. 9. S-2 at Portsmouth Navy Yard, 22 July 1921. NHHC photo NH 101010 via Navsource.

designed to be watertight while surfaced. This was to provide additional surface reserve buoyancy, a characteristic somewhat lacking in the EB design. In the photo above, grated covers can be seen fore and aft and underneath the gun deck. These protected the Kingston flood valves for the superstructure tankage. A thorough series of sea trials after her commissioning revealed that she tended to burrow into the waves while surfaced, making for a very wet deck and bridge. Accordingly, Simon Lake designed a fix for this problem that resulted in the addition of a bow buoyancy tank external to the superstructure.

This gave the *S-2* a distinct look from the rest of the S-boats and was reminiscent of several British designs (Figures 10 & 11).

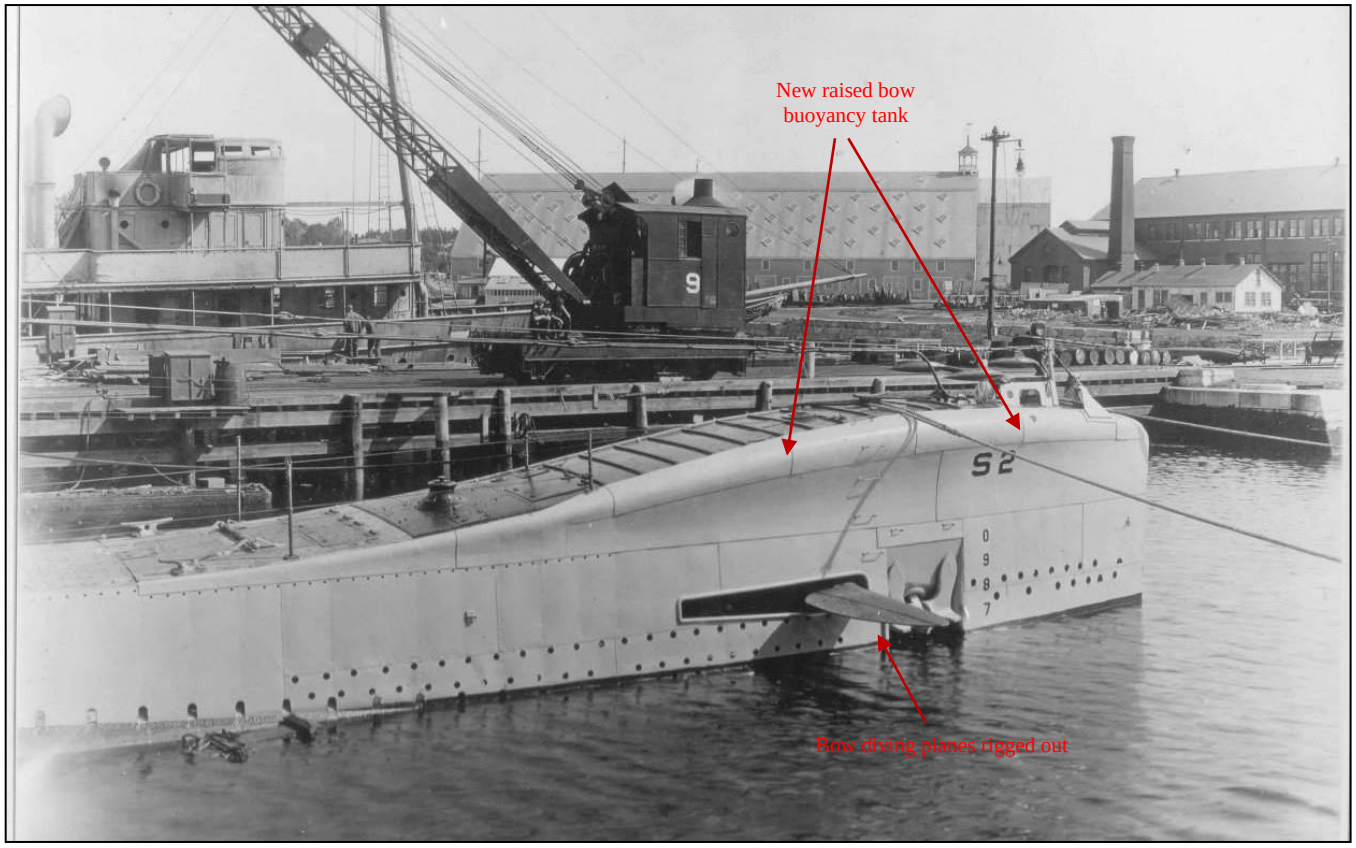

Fig. 10. S-2 at Portsmouth 04 June 1921 showing new bow. NARA photo 19-N-7606 via Navsource.

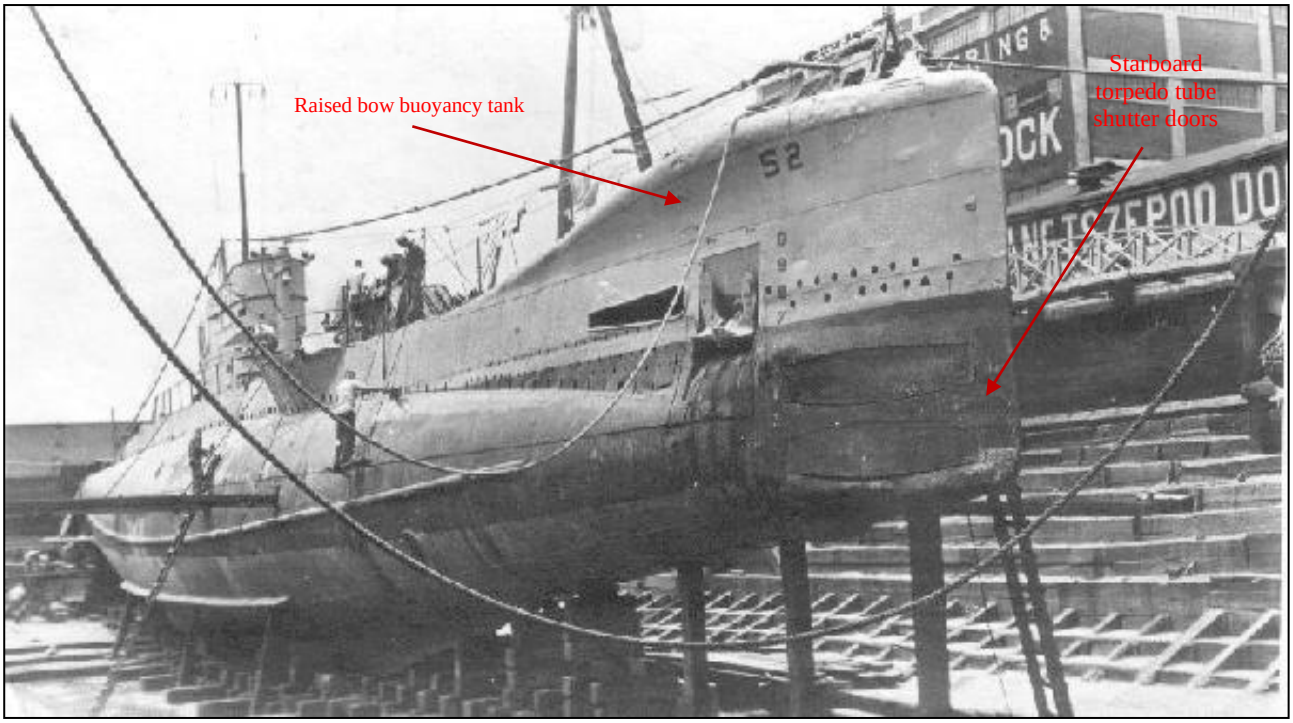

Fig. 11. S-2 in drydock in Tsingtao, China approximately 1922. Photo from the Rick Larson Collection via PigBoats.COM.

PORTSMOUTH NAVY YARD

The government's design for the S-boats (sometimes called the "Bureau" design, after the Bureau of Construction & Repair) was built at the Portsmouth Navy Yard and eventually commissioned as the USS *S-3* (SS-107).

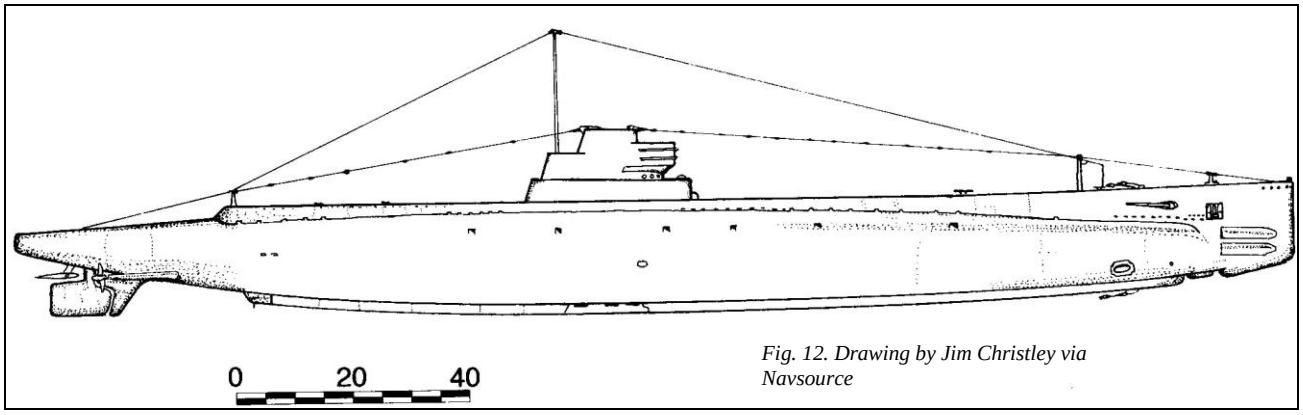

Fig. 12. Drawing by Jim Christley via Navsource

A full double hull boat, all of her main ballast tanks were contained exterior to the pressure hull (Figure 12). She was considerably longer (231 ft. vs. 207 ft. for *S-2* and 219 ft. for *S-1*) and a little wider than the other two boats, giving her a long, sleek appearance. Although a unique design by Portsmouth, *S-3* incorporated several Lake patents, which the chronically underfunded Lake allowed (for a nominal fee of course) believing it would help him financially. Similar to *S-2*, her battery was contained in one large compartment forward of the control room, which had the visual effect of pushing her conning tower fairwater well astern. Despite this, some believe that the Government design was the most visually striking of the three, with graceful lines that are more appealing than the boxy, squared off look of the EB design. The long hull had far less curve to it than the *S-1* or *S-2* and the stern ended in a sharp vertical "chisel". The rudder was underneath the stern (one of the Lake patents), but the stern planes were suspended on their own support post above the rudder.

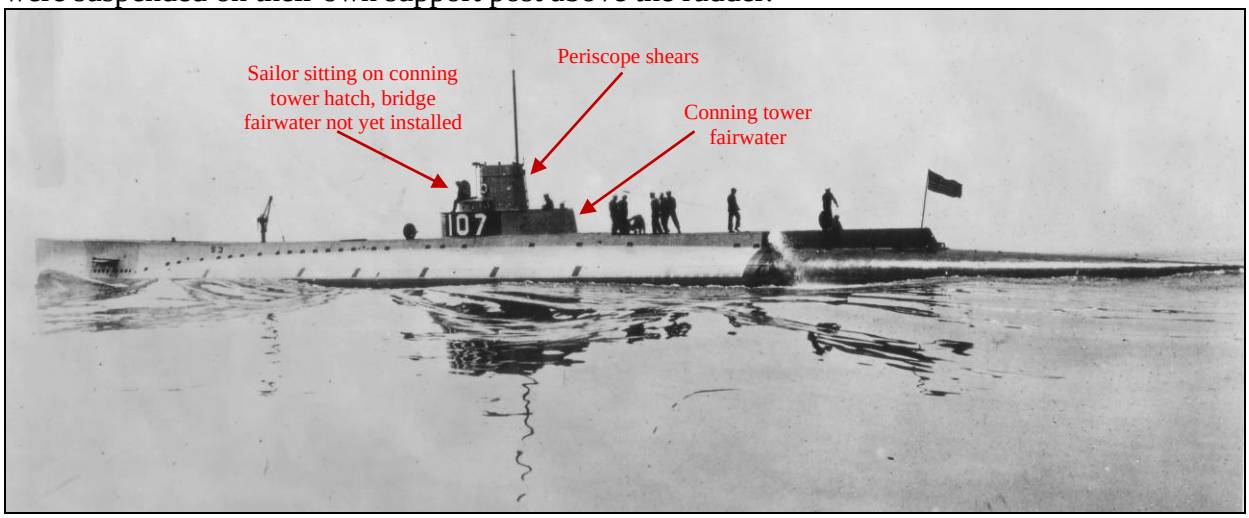

Fig. 13. S-3 on builder's trials, 1919. NARA photo 19-N-3597 via Navsource.

Figure 13 shows her on trials in May 1919. Like the other two boats, she ran trials without her bridge fairwater installed, and a sailor can be seen sitting on the top of the conning tower, a vertical watertight cylinder above the control room. The conning tower was a common feature on USN submarines. It contained a remote steering and periscope station, along with deadlight viewports around

the upper edge. The rest of the structure built around the conning tower and the periscope tubes is properly called the conning tower *fairwater* and *periscope shears*. Figure 14 shows that a distinctive, stepped bridge fairwater was soon added; bulging far forward and hanging over what would later become a ready-use ammunition locker. It also wrapped around the periscope shears. Figures 14 and 15 also show that *S-3* served the first few years of her life without a deck gun or expanded sponson deck. A 4"/50 caliber Mk 9 gun would be added later.

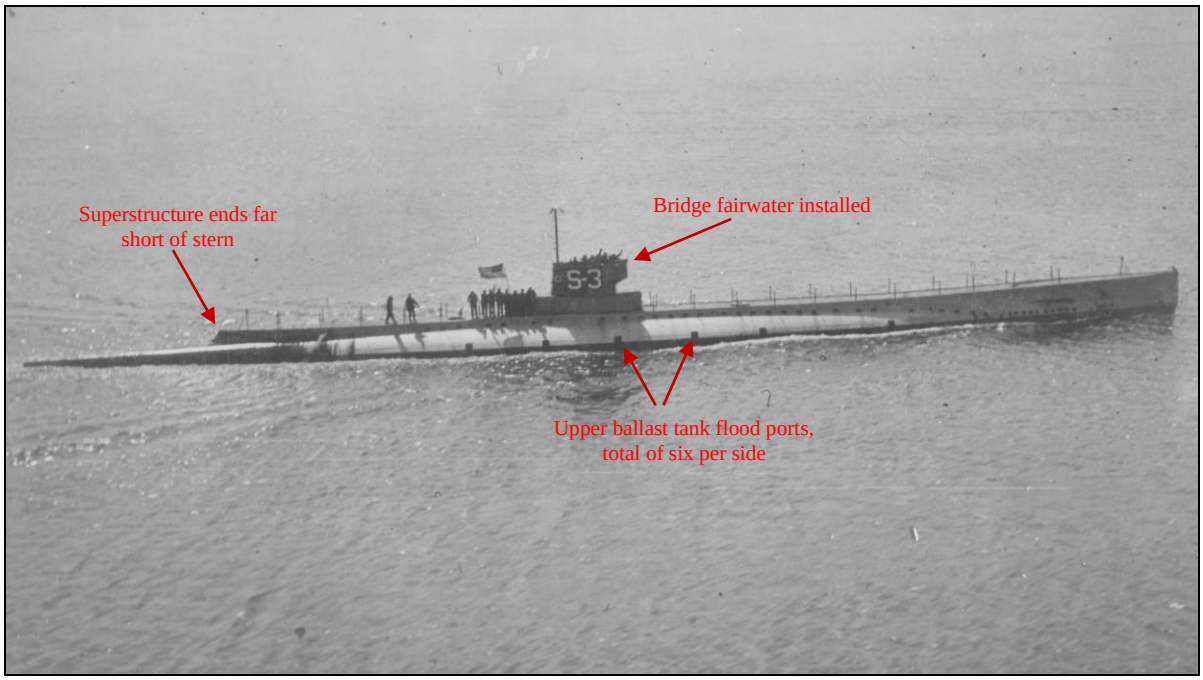

Fig. 14. S-3 underway shortly after commissioning, 1919 or early 1920. NARA photo 19-N-10680 via Navsource.

The superstructure was quite narrow and ended far short of the stern. Like the other two boats, she had a starboard side anchor and fully retractable bow planes, but did not have the prominent towing fairlead pipe at the bow like the *S-1*. The Government design tackled the surface buoyancy issue by dividing the main ballast tanks into upper and lower halves, with the upper half having separate flood ports and Kingston valves. These can be seen as dark squares spread out evenly along the waterline in both photos above. The support shears for *S-3*'s two control room periscopes initially did not extend above the rest of the conning tower fairwater (compare to her sister *S-4* alongside in the photo below).

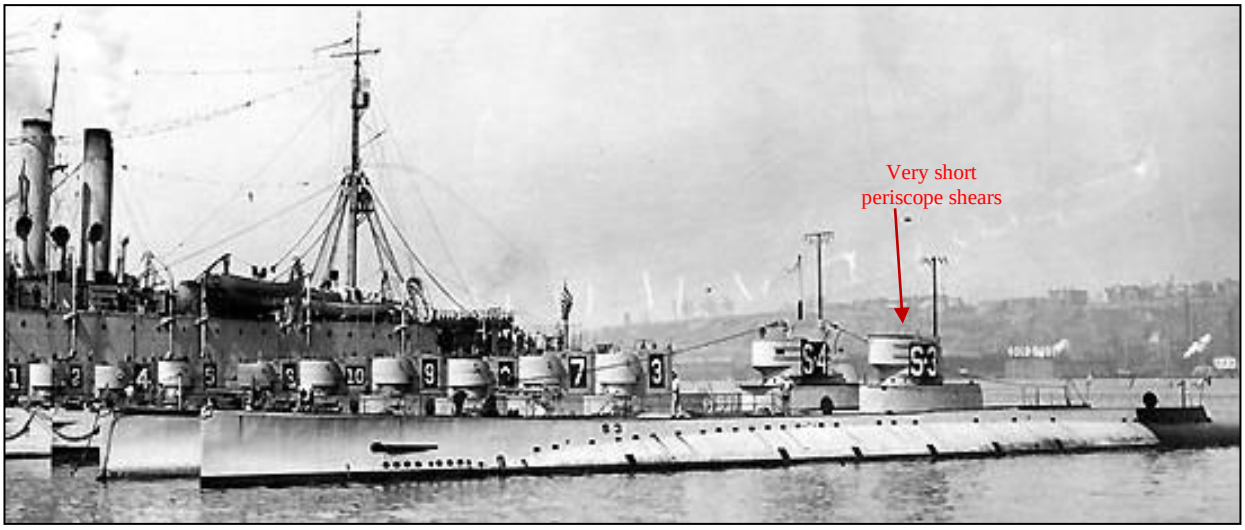

Fig. 15. S-3 alongside S-4 and R-class submarines in New York harbor, May 1920. NHHC photo 99892 via Navsource.

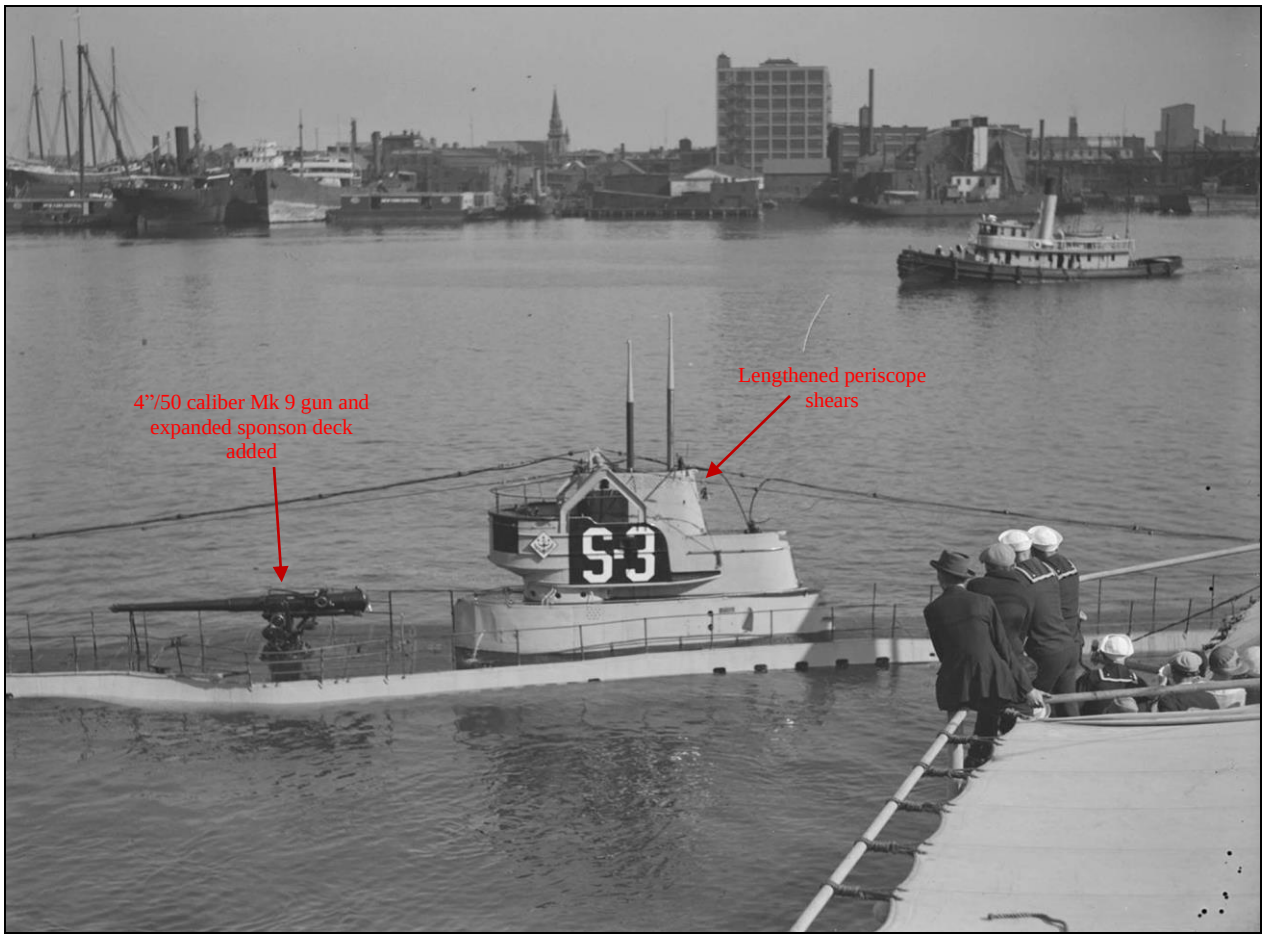

Fig. 16. S-3 making a test dive in the Little Mystic Channel just off the Boston Navy Yard, late 1920. Photo courtesy of the Boston Public Library, Leslie Jones Collection via Navsource.

The shears were eventually lengthened to ameliorate periscope vibration problems while running submerged. A short, 10 ½ foot third periscope was installed in the conning tower. Figure 16 shows a partially submerged *S-3* with the lengthened shears and angle brackets that were installed to support the conning tower periscope. Also built without a deck gun, *S-3* had a 4-inch/50 caliber Mk 9 gun added, and this necessitated the creation of a widened sponson deck forward of the conning tower fairwater.

CONCLUSION

Electric Boat's *S-1* had good underwater maneuverability, was a comparatively fast diver, and her single hull construction eased exterior maintenance. However, the superstructure proved to be weakly built, especially aft. She lacked in surface buoyancy, giving her a wet deck and bridge and thus making her a less than optimal gun platform. An EB subsidiary, NELSECO, supplied the engines and these proved problematic. *S-1's* engines were completely wrecked during trials by excessive torsional vibrations. Investigations showed that the crankshaft was of insufficient diameter, and this proved to be a major design flaw for all of the 8-EB-15 engines used in the EB S-boats. Solving the problem proved difficult, and this greatly delayed the entire EB series. The problem was eventually worked through, and ultimately the EB S-boats gave yeoman-like service throughout the 1920's, 30's, and WWII.

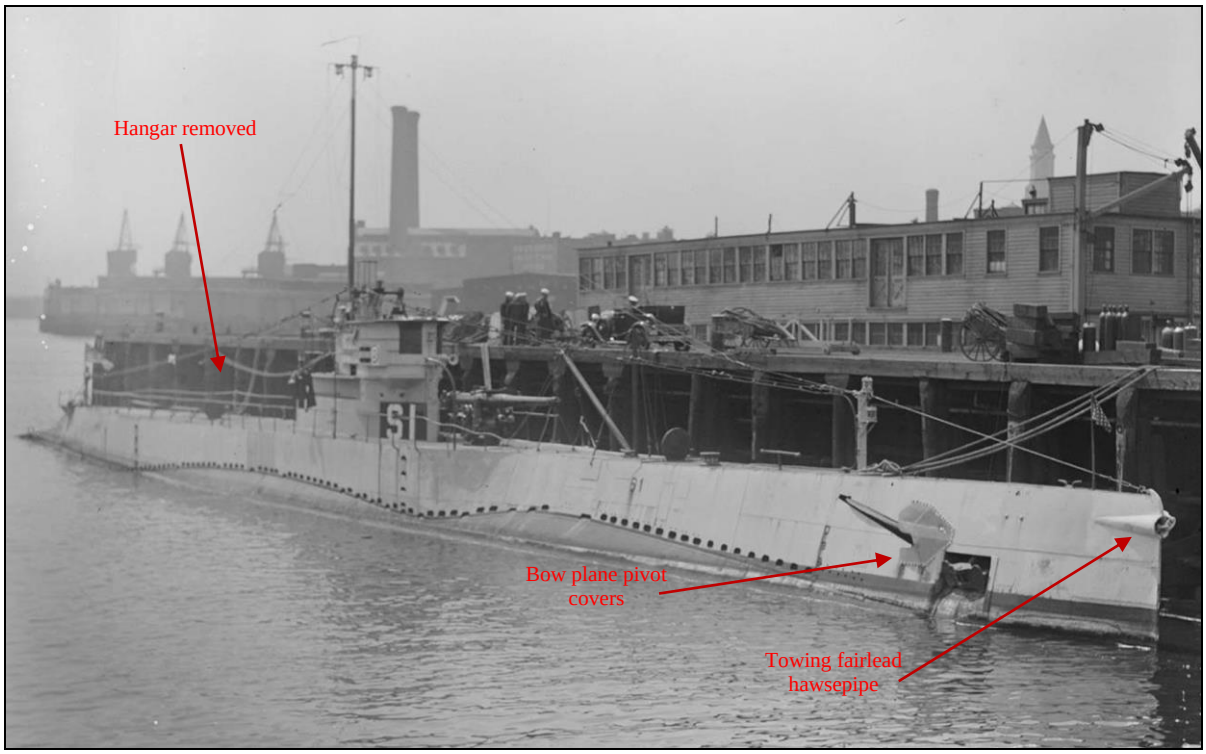

Fig. 17. S-1 at Boston, 1930. Photo courtesy of the Boston Public Library, Leslie Jones Collection via Navsource..

In the summer of 1927, the aircraft trials were completed and the concept was shown to be unworkable. The hangar and associated rigging was removed and the *S-1* returned to normal duties (Figure 17). However, she retained the expanded superstructure and this gave her a look distinct from the other EB design S-boats. These two photos were taken at the Boston Navy Yard in May 1930. They give a good overview of the *S-1* after the hangar was removed. The towing fairlead hawsepipe at the very bow is a prominent feature of the EB design and is not repeated on the Government boats. The slab sided covers for the bow plane rigging and operating mechanism are quite apparent in Figure 18. This design was repeated for the follow on 20 series (*S-18* to *29*, except *S-19*) boats, but in the 30 series (*S-30* to *41)* the covers had become rounded and less conspicuous.

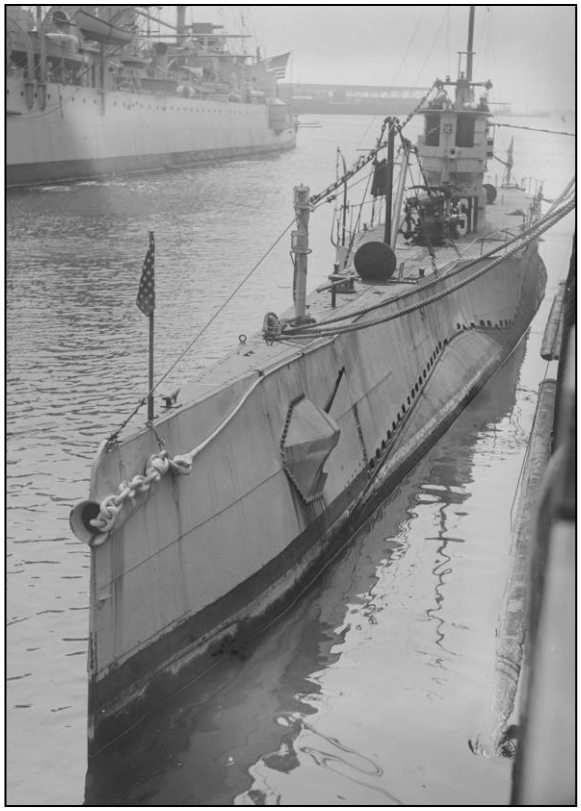

Fig. 18. Boston Public Library, Leslie Jones Collection via Navsource.

S-1 served well until 1937 when she was decommissioned and laid up in Philadelphia. She was re-commissioned in 1940 and eventually transferred to the Royal Navy and renamed HMS *P.552*. She served until the end of the war and was scrapped in 1945.

The *S-1* and the follow-on production boats (*S-18* to *47*) proved to be the last single hull axial design built by EB and its contractors. The engine fiasco and a dearth of submarine construction between 1925 and 1930 very nearly put EB out of business. When they returned to the fold, the Navy had completely altered its submarine acquisition process and now dictated the design elements to a very high degree. EB jumped back into the business

with the construction of the USS *Cuttlefish* (SS-171) in 1931 and quickly regained its reputation as the nation's premier civilian submarine builder.

Simon Lake's *S-2* had her share of problems and was not well liked by her crews. An inveterate tinkerer, the perfectionist Lake constantly modified the boat and thus he could not offer the Navy a "finished" design suitable for mass production. Lake's ideas, although generally sound in nature, were often proved less than optimal in practice. She was a slow diver due to her partially watertight superstructure and poorly designed flooding and venting mechanisms for the main ballast tanks. Her flat top internal ballast tanks (as opposed to EB's patented U-shaped tanks) required more bracing and greatly reduced internal available space, making her a very cramped boat. The piping arrangement leading to the ballast tanks was overly complicated and her forward and aft trim tanks were so large that they were prone to develop a free surface effect, which adversely affected underwater control. This was Lake's last internal design to be accepted by the Navy. No contract for any further boats of this type was awarded to Lake. After a short commissioned life of just nine years, she was decommissioned and laid up in November, 1929. Two years later she was sold for scrap, un-mourned by the Navy. Lake and his company clung to life by agreeing to build Government type S-boats under license (see part two of this series), but once the last of these was delivered (*S-51*) the perpetually cash-strapped Lake closed his doors for good in 1924.

The Government built *S-3* fell between the EB and Lake designs in merit. It was the first C&R design built from the keel up at Navy yards. Three previous boats had been built at Portsmouth and Puget Sound (*L-8*, *O-1*, & *O-2*), but these had actually been Lake and EB designs built under license.

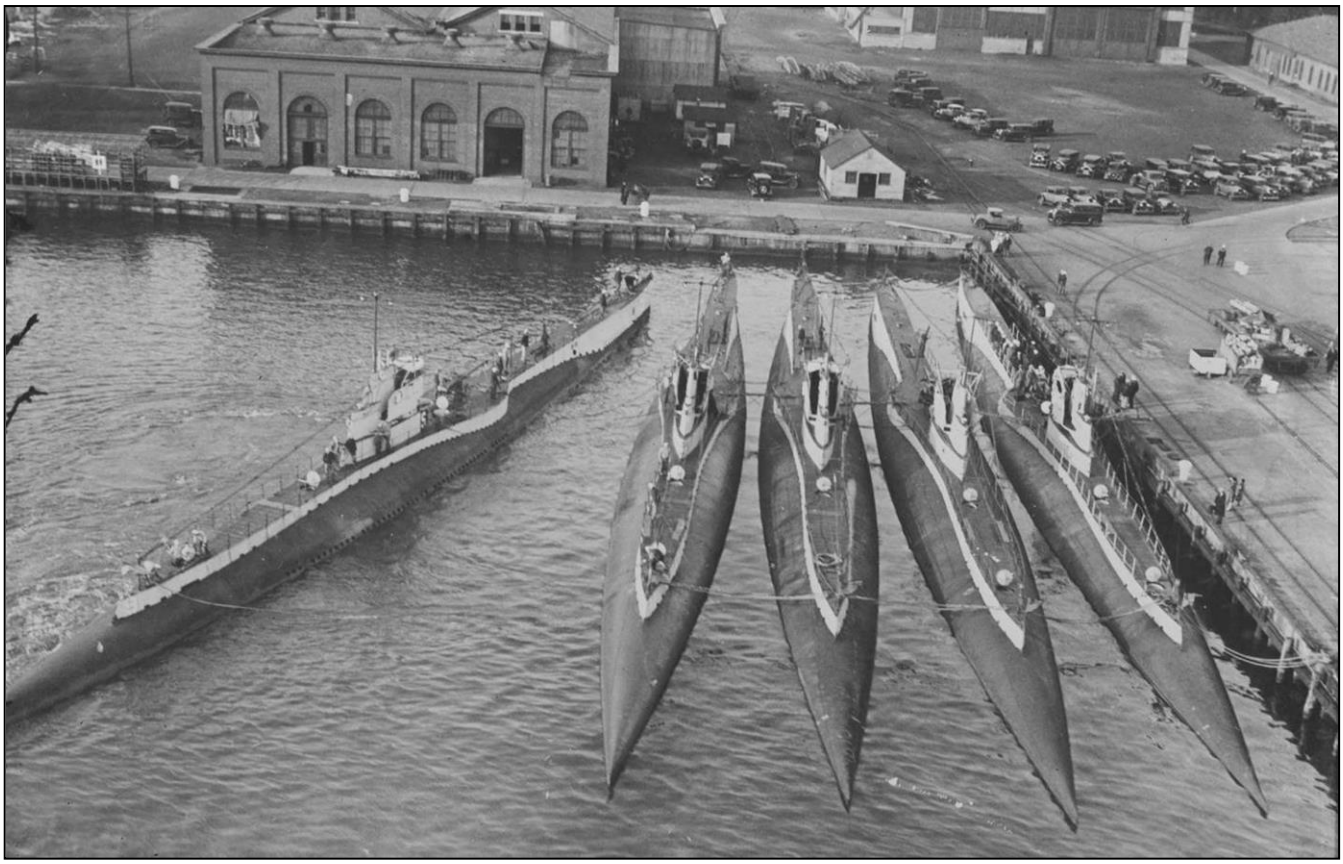

Fig. 19. S-3, S-6, S-7, S-8, and S-9 at the Philadelphia Navy Yard, 23 October 1930. Boston Public Library, Leslie Jones Collection via Navsource.

Thus, Portsmouth's learning curve was quite steep with the S-boats. The *S-3* was a very slow diver (100 seconds to periscope depth vs. 60 seconds for the *S-1*) due to the divided ballast tank arrangement.

Underwater maneuverability was poor, with a submerged turning radius in excess of 40% beyond the design parameters. The double hull construction proved to be difficult to maintain due to the tight spaces between the inner and outer hulls. However, *S-3* exceeded the *S-1* in range, and her engines (although still a headache) were considered better than *S-1*'s. Once again, despite the flaws, the Navy ordered additional boats to be built at Portsmouth and by Lake. Six of the Government boats, *S-11* to *15*, and the heavily modified *S-48* served to the end of WWII.

In the end, the Navy felt that both types were nearly evenly matched, but EB ended up with the bulk of the construction, mostly due to the much larger construction capacity they enjoyed with their contractors Bethlehem San Francisco (Union Iron Works) and Bethlehem Quincy (Fore River Shipbuilding Co.)

POSTSCRIPT: THE *S-1* HANGAR

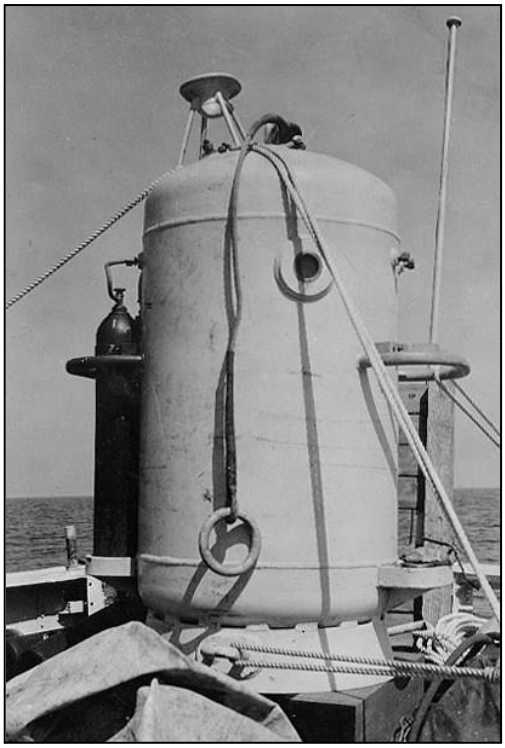

Fig. 20. McCann rescue chamber prototype created from S-1's former hangar. NHHC photo NH 57503 via Navsource.

The *S-1's* hangar found further service in a very important role as a pathfinder. Once removed from the boat, it was acquired by Commanders Allan McCann and Charles B. "Swede" Momsen (a former commanding officer of the *S-1*) and used to develop a submarine rescue chamber (Figure 20). This was in response to the multiple sinking disasters of the *O-5, S-51,* and *S-4*, in which the inability of the Navy to rescue trapped submariners was dramatically portrayed. The hangar was cut in half and modified into two open bottomed diving bells. The intention was to lower the bell to the downed submarine, mate with a hatch, and transfer the trapped crewmen inside. The concept, although a solid one, proved un-wieldy due to the open bottom of the bell. It tended to tip and fill with water. The two prototypes were extensively evaluated, with the data gathered used to develop a completely new design. A deck with a hatch divided the new chamber into dry and wet sections and it was operated by an internal winch which pulled it down to the submarine's hatch. It also had a larger capacity than the prototype. It was perfected and put into operational use in time for the rescue of the trapped crew of the USS *Squalus* (SS-192) in 1939.

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