The Salvage of the "S-51"

A Feat of Engineering Without Precedent in Naval Records

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Officer directly in charge of the salvage and diving operations

THE *S-51*, which has recently been recovered from the bed of the sea where she had lain in 132 feet of water for the greater part of a year, is one of a class of four similar submarines. She has the following dimensions: Length, 240 feet; beam, 21 feet, 11½ inches; surface displacement and speed, 1,001 tons and 14.2 knots; submerged displacement and speed, 1,230 tons and 9 knots. She was practically new, only about three years old.

She was sunk at 10:24 P.M., September 25, 1925. At that time she was operating as a surface vessel, course about northwest, speed 11.5 knots. She was struck 30 feet forward of the conning tower on the port side by the *City of Rome*, the angle of impact being 40 degrees abaft the port beam (actually measured in drydock from trace of stem and forefoot of the *City of Rome* in the *S-51's* side). A hole 13 feet deep and 2½ feet wide was made at frame 54, coming about the middle of the battery room, which is the main living compartment.

Admission of a large volume of water forward caused the *S-51* to trim deeply by the head, and it appears that she planed under before she actually took in enough water to sink her. She disappeared in less than one minute, still going ahead with considerable speed, and struck bottom in 132 feet of water, bow first, with such force as to buckle up the shell plates completely around her hull at bulkhead 43, this being the point where she changed from single to double-hull construction.

Dove Six Feet into Hard Clay

At the time of collision, all interior doors were open for ventilation purposes, in accordance with the operating design of the boat. All hatches were closed, except the conning-tower hatch. All valves from the external ventilation main to the compartments were open.

The crew were all drowned with the boat, with the exception of three men who were asleep in the battery room at the instant of collision. These men escaped, and being clothed only in their underwear, managed to keep afloat. The captain, two other officers, and two seamen, who formed the bridge watch, were on deck as the vessel sank; but all were drowned, as they were unable to keep afloat in their heavy clothes until the *City of Rome* could get a boat over. Two other seamen from the inside of the boat also escaped, but were drowned outside. Twenty-six members of the crew, including three officers, were drowned inside the boat, their bodies being found in every compartment. While the boat was sinking, it is evident that the crew inside did their utmost, as the bodies were generally found at their stations, and in many cases, still grasping valves or controls. Owing to the rush of water, no doors could be closed, and the boat was found completely flooded.

As discovered (by an oil and air slick) the next morning, the *S-51* was fourteen miles to seaward of Block Island and about fifteen miles southward and eastward of Point Judith. She was resting at an angle of 13 degrees to port, and buried about six feet deep in a bed of hard clay, mixed with some sand. The *S-51* was headed practically north (350 degrees).

As a desperate measure, in case life existed inside the boat, an attempt was made to lift the stern with derricks hired from a wrecking company. Five days elapsed before a sea prevailed that was calm enough for the wrecking company to allow their derricks to leave the Harbor of Refuge at Point Judith. The two derricks hooked to wire slings around the stern, took their maximum lift (250 tons), failed to budge the stern, were cast loose, and hurried back to harbor. The navy then undertook to salvage the vessel with its own facilities.

Salvage operations were under the command of Admiral Plunkett, Commandant 3rd Naval District, at New York. Captain E. J. King, Commander Submarine Base, New London, was in command of the salvage squadron, and was Officer in Charge of salvage operations. Lieutenant-Commander E. Ellsberg, Construction Corps, was Salvage Officer, and directly in charge of all salvage work and diving operations.

The salvage squadron consisted of the *U.S.S. Falcon*, a minesweeper specially fitted for diving

Photograph by International Newsreel

THE FATAL WOUND

In this photograph is shown the port side of the S-51, *from about the angle at which the* City of Rome *overtook and cut her down. The swift inrush of water doomed the ship*

and salvage work, equipped with high and low pressure air compressors, a recompression chamber, wrecking pumps, both steam and electrical, and special bitts and chocks for handling weights. The *U.S.S. Vestal*, a repair ship, fitted with shops of every nature, manufactured all special equipment needed, berthed the extra personnel, and acted as a portable breakwater. Two seagoing tugs, the *Sagamore* and the *Iuka*, were used for miscellaneous towing, but mostly as portable moorings.

The *Falcon* planted seven heavy anchors around the wreck, each with a mooring buoy, to which buoys the *Falcon* moored herself. The *Vestal* normally anchored to windward to break the seas. The *Sagamore* and the *Iuka* were normally anchored directly to windward and lines run to them from the *Falcon*, to assist in holding in position. In this manner, and by this unprecedented use of ships as breakwaters and moorings, the *Falcon* was able to hold position and send down divers in rough weather, with wind blowing force 5. Otherwise, diving days would have been so scarce that it is doubtful if anything could have been done. The location was in the open sea, out of sight of land, and in a position notorious for continued bad weather. This reputation was found to be fully justified.

The first endeavor was to seal up undamaged interior compartments, these being the control room, the engine room, the motor room, and the tiller room (these last two were handled as one). In each case, the compartment was wholly isolated, the doors closed, all valves closed, and the compartment made an independent unit. This involved an immense amount of difficult and dangerous work inside the boat on the part of the divers.

Certain valves in the ventilation system required special treatment as they would not stay closed under an internal pressure. To seal one of these valves, a section of heavy copper pipe, nine inches in diameter, was unbolted under water by the divers and a blank flange put on. To close off two others, a 1¼-inch hose was screwed into the valve body in each case, and cement was run under pressure from the *Falcon* through 250 feet of hose into the valve. A mixture of two parts of neat cement and one part of fresh water was used. This, experiment showed, would flow and would safely harden under salt water. The cementing operation worked very successfully. The cement hardened quickly and the valves thereafter showed no leakage whatever.

How Buoyancy Was Obtained

The hatches to each compartment, which were unable to resist internal pressure, were removed and special salvage hatches installed by the divers. These were held in place by a strongback designed to take the full internal pressure. Each hatch was fitted with blowing connections for compressed air, test connections to show the level of water in the compartment, and a four-inch spillpipe which extended to the bottom of the compartment and through which the water was expelled. Each spillpipe had attached to its lower end a non-return valve which prevented water from leaking back, and also acted as a relief valve for the air as the submarine rose to the surface.

The salvage hatches weighed 700 pounds each. Their installation by the divers was a difficult job. It would have been an impossible one if the divers had not been provided with special davits, booms, and chain falls, all made on the *Vestal*, which were first secured to the *S-51*, so as to plumb the hatch trunks. The hatches were then lowered from the *Falcon* to the deck of the *S-51*, where the divers hooked the hatches with chain falls from the special davits and thus handled them. Aside from the four main compartments, mentioned above, fourteen smaller compartments (ballast and fuel tanks, et cetera) were sealed up and used for lifting.

In many of the above tanks it was impossible to get at the interior valves or valve operating gear. To utilize these tanks, a hole was burned in the lowest point of the tank, using the underwater torch designed by the writer. An air hose was pushed through the hole so burned. On turning on the air, the water was forced out the same hole till the compartment was completely dry. The hole later served as a vent for the escape of air as the vessel rose, and thus prevented disrupting the tank by subjecting it to undue internal pressures. In the manner stated above, a total buoyancy of 527 tons was obtained.

To provide the remainder of the buoyancy required, as well as a margin for contingencies and a reserve, eight pontoons were provided, each with a net lift of 80 tons. These pontoons were steel cylinders, 32 feet long, 13 feet in diameter, sheathed outside with four-inch yellow pine planks. Each pontoon was built like a section of a submarine, and was suitably stiffened with frames and girders, being designed to resist the full internal bursting pressure in case of a sudden rise to the surface. Through the vertical center of each compartment was run a 12-inch hawsepipe, riveted to a heavy casting, top and bottom, with eight internal brackets to distribute the load from the hawsepipe castings to the pontoon itself. Two and one-half inch anchor chain, threaded through these hawsepipes, formed the cradle for the boat.

Cutting Tunnels With Water

Each pontoon was fitted with a six-inch flood valve at the bottom of the vertical bulkhead on each end. This flood valve was operated by a rod reaching to the top of the pontoon, easily accessible to the diver. Alongside the flood valve was a six-inch spring-loaded relief valve, set to blow at an excess pressure of 10 pounds. On top of the pontoon, each compartment was fitted with a one-inch connection for the blowing hose, located near the center bulkhead, and a three-quarter inch vent connection located near the end bulkhead.

The buoyancy conditions required that six of the pontoons be located in the forward half of the boat, where the internal buoyancy was slight; the other two pontoons were located at the stern.

At the extreme bow and stern, the submarine was clear of the bottom. To get the chains through here, the divers first passed small manila reeving lines under, two lines being required for each pair of pontoons. To get these reeving lines under the *S-51* for the other locations, tunnels had to be dug. The tunnels were cut by washing away the clay with a stream of water from a firehose. On account of the depth and the hard bottom, no other means was available. It was found that 1½-inch hose with 60 pounds pressure was as much as a diver could hold. Under these conditions, it took two weeks work to run one tunnel under the submarine. The second tunnel was run much faster, as a new nozzle, which eliminated all pressure reactions, was utilized on this tunnel. With the new nozzle, a diver was easily able to manage a stream of water from a 2½-inch firehose under 200 pounds pressure, and with the resulting stream of water, the second tunnel was cut through in two days.

The pontoons weighed 40 tons each, and were difficult to handle. If one broke free and fell on the submarine, it would crush it in. Such pontoons had never before been used except in shallow water, where they could easily be dropped into position. Here they required to be lowered to a considerable depth and placed exactly, especially in the forward half of the submarine, where a clearance of only eight feet could be allowed between pontoons in a fore and aft direction.

It was found that as a pontoon was flooded down enough so that it just submerged, it lost all longitudinal stability and invariably went down one end first if an attempt was made to lower it. Furthermore, under the increasing pressure, more and more water was forced through the flood-valves into the pontoon, which thereby increased in weight as it sank until it broke the lowering lines, unless these were able to take the full weight of 40 tons.

To overcome these troubles, it was found after some calculation and checking, that at a negative buoyancy of 10 tons, the internal water-plane was sufficiently reduced so that the pontoon could be kept level, provided it was lowered evenly at both ends. To prevent any increase in weight during lowering, the pontoon was held just below the surface for a period long enough to flood it to a weight of ten tons; after which the air vents were closed off to prevent the escape of air and the flood valves were closed tightly. The pontoon was then lowered and acted as a fixed weight. To lower the pontoon, a manila line four inches in diameter was secured to each end of it by a pelican hook. These two lines were strong enough to take the full load, if it should accidentally be applied.

To get the 2½-inch chains, that passed below the hull, from pontoon to pontoon, into position, a manila line one-half inch in diameter was first run under the submarine by the diver, both ends of the line being carried to the surface. A manila line 1½ inches in diameter was next hauled around by the *Falcon*, using the small line to haul. With the 1½-inch manila line as a hauling line, a one-inch plow-steel wire cable was hauled through. The wire cable had a breaking strain of about 35 tons. Using this to haul, a 2½-inch iron chain 90 feet long and weighing three tons, was lowered down on one side of the submarine and hauled under the keel until the chain was equalized on both sides.

With two chains in position, and a wire cable running to the surface from each end of each chain, the lowering of the pontoons was begun. Assuming that the starboard side pontoon was first lowered, the wire cables on that side were threaded through the two hawsepipes of the pontoon, and all four wire cables then hauled moderately taut to hold the chain cables vertical above the submarine. The slack in the manila lowering lines was taken in, and the pontoon vented and flooded until it submerged about four feet. Here it was held by the lowering lines until it weighed about 10 tons, when all vents and floods were closed. The pontoon was then lowered gradually and evenly until it had descended about 90 feet. At this depth it was held while two divers went down and landed on the pontoon. If the pontoon was in proper position (as it always proved to be), it was gradually lowered under the diver's direction until the chains showed through the hawsepipes. When sufficient chain showed through, the pontoon was held again. Here the diver burned a stud out of the chain link just above the hawsepipe (in some cases the stud was removed before lowering the chain) and inserted a 3¾-inch by 3¾-inch nickel-steel bar 40 inches long which spanned the hawsepipe and passed the load from the chain to the pontoon. Over a span equal to that across the hawsepipe casting, 18 inches, one of these bars was successfully tested to a load of 235 tons before reaching its yield point.

Shift in Buoyancy Proved Troublesome

The diver locked this bar in position in the chain link by two long one-half inch steel bolts which passed through holes in the nickel-steel bar, one hole each side of the link.

Having secured his chains, the diver was lowered with the pontoon to the bottom where he opened the flood valves, let go the hauling wires on the chains, and cast off the lowering lines.

When the second pontoon of the pair was lowered, the process was varied; but limitations of space prevent a detailed description of the variation.

Having lowered and secured eight pontoons in the manner stated, they were leveled off in their afloat positions over the submarine and then lashed in place with one-inch wire cables to prevent their slipping in the raising process.

As submarines have small longitudinal stability while submerged, a transfer of a ton or two of water from bow to stern will create a large change in trim. In this case, where the internal buoyancy of the pontoons could not be accurately checked while blowing, and considerable free water existed even in the compartments blown dry, it was out of the question to attempt to bring the submarine up both ends together, as one end was bound to become buoyant and rise before sufficient buoyancy could be given the other end. It was decided to bring the submarine up stern first, and all pontoon arrangements and lashings were put on in accordance with that design, together with taking advantage of all structural features of the submarine to prevent the pontoons slipping aft.

All work was completed June 21, 1926; the submarine and the pontoons were partly lightened in preparation for the final raising on June 22.

Why She Was Worth Salvaging

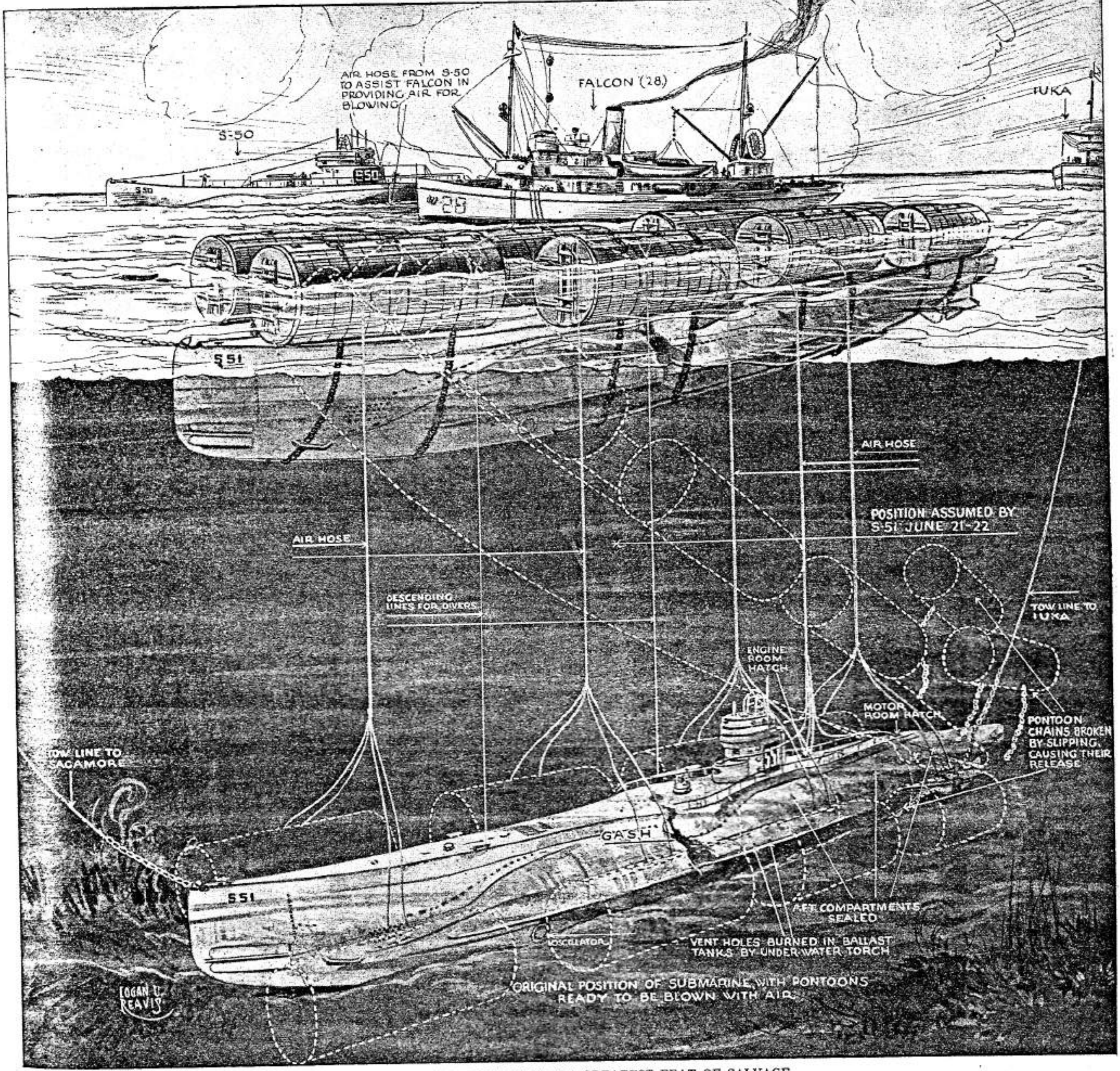
A storm broke on June 22 and prevented the raising attempt. The effect of the seas on the bottom apparently rocked the lightened submarine enough to break the bottom-suction and tear the bow loose. While the *Falcon* was preparing to unmoor and run for shelter, the *S-51's* bow came up almost under her, and the first four pontoons showed above the surface. These pitched heavily in the storm and started to batter each other to pieces. Under these circumstances, an attempt was made to lift the *S-51's* stern and get away. However, when the stern pontoons had gained considerable buoyancy, their chains slipped forward a few feet and hit the vertical keel, where they snapped under the impact and freed the pontoons which floated up. As it was then impossible to lift the stern, the valves were opened on the pontoons at the surface and the bow sunk to avoid further damage from the storm. This was a hazardous undertaking; but the men tackled it willingly and the job was successfully carried through.

The damaged pontoons were raised, towed 15 miles to Point Judith, repaired, and towed back to the *S-51*. In three successive days all six pontoons were again lowered and secured to the submarine.

All work was again completed about noon on July 5, 1926. At 12:17 P.M., the blowing process started, air being sent to the engine and the motor rooms first, then to the control room. Air was next admitted to the stern pair of pontoons, and at 2:06 P.M., while the stern pontoons were being blown, the stern rose. All air was then concentrated on the forward set of six pontoons. These rose at exactly 3 P.M., bringing up the bow.

The *S-51* was then started for New York, 150 miles away. The first 20 miles of the tow were through the open sea, in moderately rough weather, which caused no special trouble. Two tugs, the *Iuka* and the *Sagamore*, towed in tandem ahead; the *Falcon* towed about 150 feet astern of the *S-51* for the double purpose of serving as a jury rudder and to supply air. While no leaks developed, no chances were taken and the *Falcon* constantly kept pumping air to all compartments and all pontoons.

Long Island Sound was safely navigated, and the tow passed through Hell Gate at high water slack. The pilot endeavored to pass between Man of War Reef and Ferry Reef, instead of sticking to the main channel. As a consequence, the *S-51* was stranded on Man of War Reef at the top of the high tide. The impact broke the chains on the second pair of pontoons from the forward end, which pontoons floated up and drifted away. As the tide dropped, the position of the *S-51* became precarious, as she listed more and more, finally resting about 30 degrees to starboard. By resinking the other forward pontoons until they were out of sight below the water and shortening their chains, all the reserve buoyancy in them was brought into action. When the evening high tide arrived, these pontoons were



HOW THE NAVY PERFORMED ITS GREATEST FEAT OF SALVAGE

The S-51, weighing 1,200 tons, lay on the bottom in 132 feet of water, 14 miles from the nearest land and in very exposed and rough waters. Because of the gash in her side, the forward half of the boat could not be sealed. The after half was sealed and the water blown out. Eight pontoons, each with an 80-ton lift, brought the boat to the surface

again blown dry and just managed to float the *S-51* free of the reef. She arrived about 11 P.M. at the Navy Yard and was docked next day.

Here the vessel was examined. The bodies of eighteen members of the crew were removed. (Nine others had been previously removed by divers.) All bodies were promptly identified.

Both hull and machinery were found in good shape with no corrosion or electrolytic action from submersion.

It is estimated that 600,000 dollars will be required to repair the hull and overhaul and replace the machinery, of which cost about two-thirds is for the machinery. As the vessel cost nearly 3,000,000 dollars and is only three years old, reconditioning is obviously a good business proposition.

All told, 30 divers worked on the salvage job, although 24 was the maximum number present at one time, and only thirteen were in condition to work at the end. The others were incapacitated by "bends," pneumonia, and physical exhaustion. However, no diver was ever hurt by an accident. All the divers employed have now recovered and are in good health, although some can never dive again.

The operation was exclusively a navy undertaking, handled throughout by naval personnel, with all divers recruited from existing navy divers, or specially trained for this particular job by a diving class run last winter at the Brooklyn Navy Yard.

The job as an engineering undertaking is without precedent. It is the only occasion on which a submarine has been brought up by any nation from deep water in the open sea. This was also the only time in which submersible pontoons have been used in deep water; and, finally, the 150-mile tow of a submerged submarine in a pontoon cradle was unique both from a salvage and a seamanship point of view.

The engineering skill and the unconquerable spirit of the officers and men who made the job a success make this operation stand out as one of the brightest spots in the record of the Navy's peacetime activities.