Salvage Report of USS *S-4*

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SALVAGE REPORT OF U. S. S. S-4

COMPILED BY

COMMANDER H. E. SAUNDERS (C. C.), U. S. N.
SALVAGE OFFICER, "S-4," SALVAGE FORCE

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TECHNICAL REPORT ON THE SALVAGE OF THE U. S. S. "S–4"

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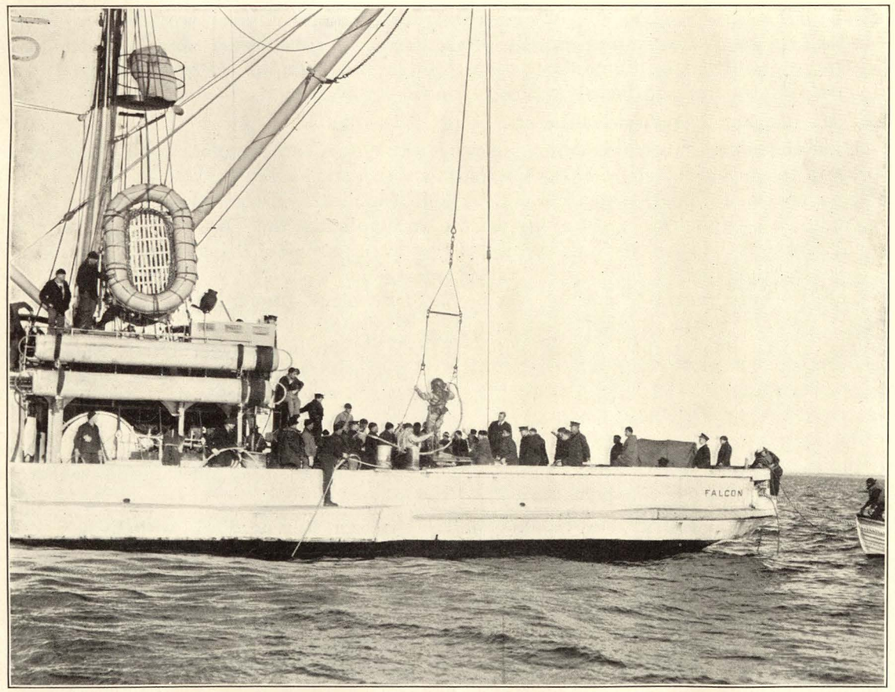
TECHNICAL REPORT ON THE SALVAGE OF THE U. S. S. "S–4"

Part II.—Preface. Section 1. Scope of Technical Report.

The Technical Report on the Salvage of the U. S. S. *S–4* is intended to supplement the General Operations Report of the Salvage of the *S–4*, as prepared by the commander of the *S–4* salvage force, Capt. Ernest J. King, United States Navy, and as forwarded by him under date of March 25, 1928, to the Chief of Naval Operations.

The technical report covers much the same ground as the general operations report, but in much more detail, giving figures, data, statistics, and similar information, all of which it is hoped



will be of value on future salvage work covering not only operations on submarines but operations in cold weather and work in general with deep sea divers.

The Technical Report on the Salvage of the U. S. S. *S–4* is based largely upon photographs, plans, figures, and diagrams as the best medium of illustrating, explaining, and describing the work done. There is a great dearth of photographs of salvage work in the Navy, especially in connection with salvage of submarines, and an effort has been made in the within report to fill this gap in a proper manner.

In the preparation of this report, an endeavor has been made to reduce the narrative to a relatively brief chronological outline and to extract from the complete log of the operations a description of certain technical aspects which, when discussed by themselves, may thus be more convenient for use by anyone conducting salavage operations in the future. The disposition and location of the complete salvage log and of all data collected during the *S–4* salvage operations is noted elsehwere in this report, Part XVI.

A glance at the table of contents will indicate the nature and extent of the subdivision and will show the subjects treated. As is customary in a report of this nature, the purely statistical data has been subdivided and placed in appendixes. A number of the subdivisions may be considered as explanatory or supplementary to certain reports and publications already issued, such as the Diving Manual, etc.

This report deals solely with the *salvage* operations on the *S–4*, as distinguished from the rescue operations, except in so far as certain work done on the vessel during the course of the rescue work had a bearing on the subsequent salvage. Similarly, this report discusses only the work done on the *S–4* or related directly to that work and touches on the administrative and other features of the expedition only to show the relation of the direct salvage work, if it may be so called, to the work of the salvage force as a whole.

PART II.—Section 2. Acknowledgments.

While the salvage officer was acting under instructions from the commander *S–4* salvage force to prepare the technical report along the lines of the operations report, he has frankly copied the arrangement of the latter very closely. The three months of work which has been required to compile the within report have only served to emphasize the most complete and concise manner in which the story of the *S–4* was told by Capt. Ernest J. King, United States Navy, in his general operations report to the Navy Department.

The appendix on winter clothing was prepared by Lieut. Leonard Kaplan (C. C.), United States Navy, and the photographs accompanying it were taken by him.

The official photographs were taken by Mr. H. Baldwin and Mr. W. C. Staples, yard photographers at the navy yards, Boston and Portsmouth, respectively. The smaller photographs were taken by Chief Gunner Tibbals, Lieutenant Hartley, Lieutenant Kaplan (C. C.), United States Navy, the salvage officer, and others.

The writer desires to express his appreciation of the kindness of the International Newsreel and the Boston Post in permitting publication of the numerous news photographs which were taken on the spot by Mr. Joseph E. Marsland and others.

Part II.—Section 3. Narrative of Casualty and Subsequent Rescue Work, with Events Leading Up to Salvage Operations.

The U. S. S. *S–4* (SS109), while emerging from a southwesterly submerged run across the "inner" measured mile off Provincetown, and proceeding at a speed estimated at about 6 knots, was struck on the starboard side well forward of the gun, at an angle of about 45°, by the bow of the Coast Guard destroyer *Paulding* (CG17), which was traveling toward the *S–4* at a high rate of speed, about 18 knots. The submarine, which was rising by the bow at the instant of collision, but which had not emerged sufficiently to bring her hull out of water, rolled to port and sank underneath the *Paulding*, bow first.

The *Paulding* stopped immediately and lowered boats. The Wood End Coast Guard Station, where the casualty had been observed, sent out surfboats and lifeboats almost simultaneously, but the boats were able to find nothing on the surface except air bubbles. The naval tug *Wandank* arrived upon the scene shortly and dropped three buoys around the bubbles. Until darkness set in, an hour or so after the casualty, nothing was observed to come to the surface save the air bubbles and a small amount of oil.

The casualty occurred at 3.37 p. m. on Saturday, December 17, 1927. Within an hour and a half, all naval stations in the vicinity had been notified and active preparations for rescue and salvage work were under way. The submarine tender *Bushnell* left the navy yard, Portsmouth, N. H., at 6.50 p. m. on Saturday evening and arrived upon the scene at 1.10 a. m. Sunday, December 18, and found conditions too severe for diving, even had the exact location of the *S–4* then been known. The *Bushnell* was followed by the *Lark*, *Mallard*, and *Sturtevant* from the navy yard, Boston, at intervals of a few minutes. About 1.20 a. m. the *S–8* arrived and at 8 a. m., the *Falcon* came in from New London with the commander control force, Rear Admiral F. H. Brumby, United States Navy, on board. It is of interest here to note that the *Falcon* made preparations for getting under way at New London at 5.10 p. m. Saturday and left at 6.32 p. m. for Provincetown, within two hours. Eight veteran deep-sea divers arrived at Provincetown before daylight on Sunday morning, having come over the road by automobile from Newport. Capt. E. J. King arrived at 1 p. m. on Sunday, having come from Norfolk to New York by rail and from New York to Provincetown by airplane. The tug *Sagamore* left the navy yard, New York, at 5.20 p. m. on December 18, towing three 80-ton salvage pontoons. The *Sagamore* arrived at Provincetown with these pontoons at 2 p. m. on Monday, within 47 hours of the casualty. The tug *Mohave* arrived from Boston at 11 a. m. on Monday with a steel coal barge loaded with salvage material.

Returning to the narrative and beginning again at the sinking, the boats on the surface, particularly *CG–2339* under the direction of Capt. W. F. Gracie, who was in charge of the Wood End Coast Guard Station and who was an eyewitness of the collision, began a search for the exact position of the *S–4* by dragging with grapnels. Hooking a submarine in this manner is no easy task and it was 10 p. m. before Captain Gracie was able to report that he had a grapnel line on what was thought to be the *S–4*. He held on with his picket boat in the rough sea until nearly 1 a. m. on Sunday, just before the arrival of the *Bushnell*, when his grapnel line carried away. Captain Gracie came to the *Bushnell* for a more suitable grapnel and line and it was not until about 10.30 a. m. on Sunday, the 18th, that he was able to pick up the *S–4* again. This incident is described at length to illustrate the difficulties encountered by an experienced seafaring man like Captain Gracie, in a well-handled boat and with a fairly accurate first-hand knowledge of the position of the submarine, to locate her definitely in water as shallow as 110 feet.

After Captain Gracie had succeeded in locating the *S–4*, and in buoying his grapnel line with a gasoline drum, the *Falcon* anchored to windward and moored over the *S–4*, holding herself in position temporarily with lines to the *Lark* and the *Mallard* as described later. Diving began at 1.38 p. m., December 18, exactly 22 hours after the casualty.

The first diver down, Eadie, reported signs of life on board and identified taps from within the torpedo room, but there were no signs of activity or life from the after end of the vessel. The second diver down, Carr, proceeded to connect an air hose to the main ballast tank salvage valve, in an endeavor to blow the tanks and bring all or some part of the vessel to the surface. In view of the localized damage, it was possible that the actual negative buoyancy might be small and that blowing the tanks might bring the ship up. The wind at this time was northwest, force 4 to 5, barometer falling, and sea rising, but Carr made the connection (see fig. 1) and when he telephoned that he was ready, air was turned on. This was not later than 4 p. m. Carr waited to insure that air was going in through salvage connection, then came up at 4.28 p. m. The stern of the *Falcon* was moved to port to clear the submarine, as it was thought that the stern might come up first and the *Falcon* should be clear. Discontinued diving temporarily as it was not desired to have a diver on the *S–4* when the ship was likely to rise. At about 5 p. m., after about an hour of blowing, air bubbles appeared over what was apparently the starboard quarter of the *S–4*, of a volume about equal to the air that was being forced in.

Continued blowing, but *S–4* did not rise. Although it was then dark, the wind and sea still rising and the *Falcon* yawing badly, it was decided that as life and death were involved, another dive would be attempted in an endeavor to connect an air-blowing hose to the compartment salavage line. In the meantime, communication was being carried on between the *S–4* and the *Falcon* by oscillator from the latter vessel and by tapping from the former. Michels, the third diver, was sent down at 7.49 p. m. with an air hose to connect it to the compartment air salvage valve on the *S–4*.

At this time the *Falcon* was moored with her stern approximately over the conning tower of the *S–4*. She was riding to both of her own anchors and her stern was held in position by two 8-inch manila mooring lines which led out through her stern chocks, one on each quarter,

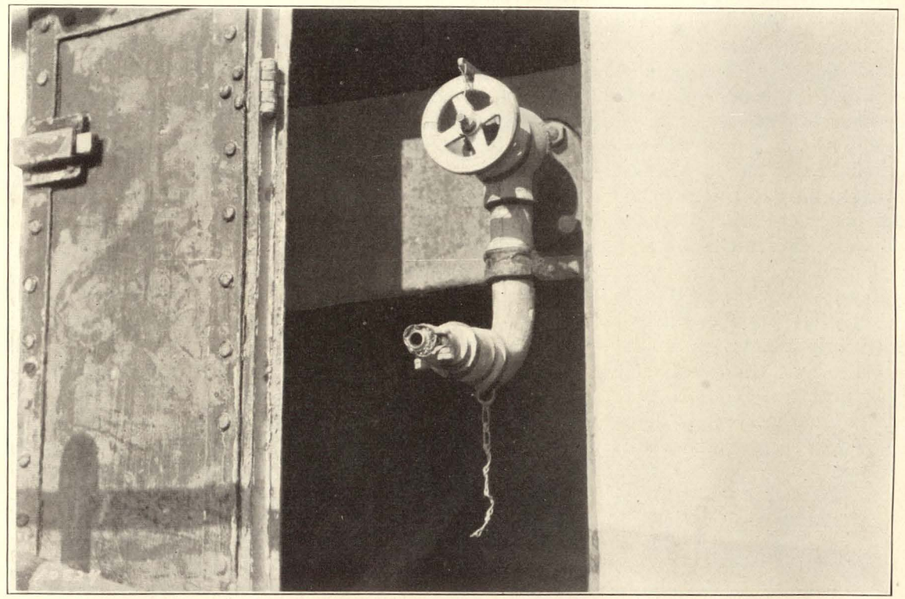


FIG. 1.—Main ballast tank salvage air connection, port side, conning tower fairwater, with fitting and end of hose originally connected by Diver Carr on December 18, 1927

to the bows of the mine sweepers *Lark* and *Mallard*, respectively, which were anchored on either beam of the *Falcon* with their bows approximately abreast the *Falcon's* stern. All three vessels were yawing badly in the wind and sea and since the mine sweepers were each riding to anchors laid out to windward, their bows swung back and forth at right angles to their anchor chains, carrying the stern of the *Falcon* with them. The result was that the *Falcon* was constantly changing heading and was rapidly swinging and moving from side to side. Whereas at one moment the stern of the *Falcon* would be directly over the *S–4* and the descending line hauled taut, a minute or so later the stern of the *Falcon* would move off to one side and it would be necessary to pay out on the descending line to prevent the latter from carrying away. It was not always possible, even by tending the descending line, to keep all the slack hauled in when the ship moved back to normal position, since the seas would pull on the line

and the movement of the *Falcon's* stern up and down precluded any systematic attempt to haul the descending line taut and watch it. The result was that the stern of the *Falcon* would frequently move back toward its normal position over the *S–4* before this was evident to those on deck and the slack which was then formed in the descending line would drop down over the submarine.

In order to explain how dangerous diving may become when the diving vessel is not or can not be held fixed in position over the wreck, a rather lengthly description of the experience of Michels is given here. When Michels slid down the descending line and before he reached bottom, the descending line became slack and the extra length dropped over the side of the submarine so that when Michels landed on the bottom he found himself up to the waist in a

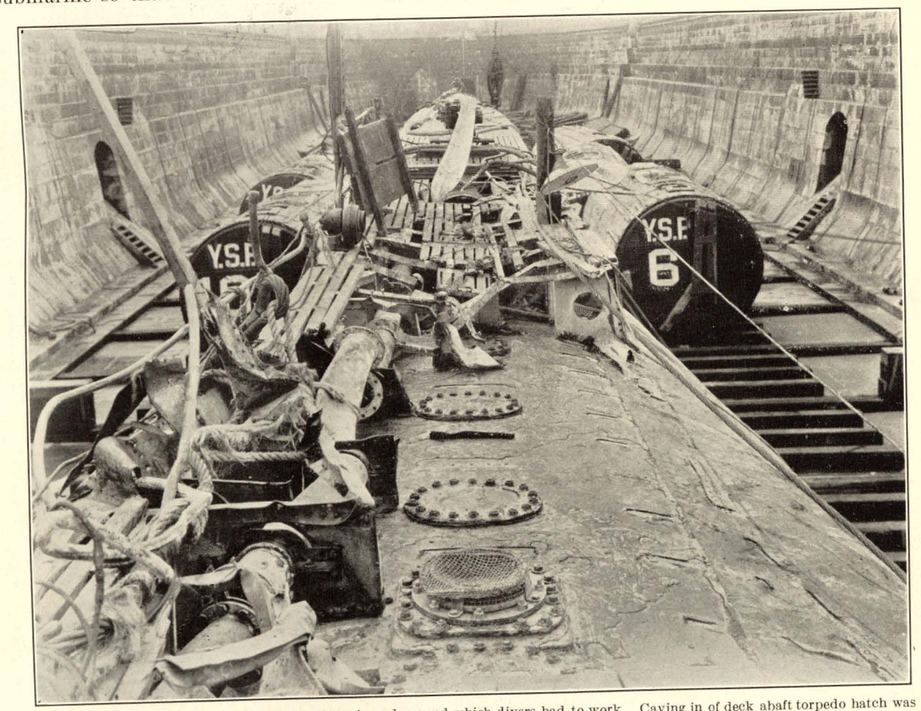


FIG 2.—General view forward, showing wreckage in and around which divers had to work. Caving in of deck abaft torpedo hatch was done by starboard middle pontoon

pile of soft mud which had been banked up alongside the *S–4* when she sank to the bottom. Michels described his predicament and reported that he could not free himself, whereupon he was hauled bodily up out of the mud by the exertion of some 10 or 12 men on the *Falcon*. When the slack was taken in on the descending line, he managed to land on the deck of the *S–4*. Instead of being aft near the conning tower where the descending line was made fast, he was forward near the gun and in the immediate vicinity of all the wreckage. (See fig. 2.) Before he could get himself straightened out and clear the air hose which he was carrying down to connect to the *S–4*, it had again become necessary to pay out slack on his life line, and air

hose due to further movements of the *Falcon* sideways. When the *Falcon* moved back toward her normal position, the slack in Michels' life line and air hose could not be taken in quickly enough, for reasons explained above, and the bight of his hose fell over the side of the *S–4* and became caught underneath some of the wreckage. While endeavoring to clear this loop, his air hose and life line were dragged in the other direction by the *Falcon* and a similar loop was formed on the opposite side of the *S–4*, which also caught under projecting portions of the wreckage. In an endeavor to assist Michels in clearing his hose, the *Falcon* hauled in the slack but, unfortunately, this served only to jam the loops tighter in the wreckage. Michels soon found himself lying on the deck of the *S–4*, face downward, with the intermediate section of

International Newsreel Photo

FIG. 3.—Lieut. Henry Hartley, United States Navy, and Diver Thomas Eadie with ship's bell recovered from the *S–4*

air hose and life line between the two loops drawn so tightly over his back that he could not get out or help himself in any way. It was then that Eadie was sent down to clear him and, in one of the most heroic acts in the annals of diving, Eadie (fig. 3) finally succeeded in cutting off with a hacksaw one of the projecting pieces of wreckage, whereupon he was able to clear first one loop of Michels' air hose and then the other loop, thus releasing him and saving his life.

Any further diving after Michels and Eadie were brought up just before midnight on Sunday, December 18, would not only have positively endangered the lives of the divers, but would have been of no assistance whatever to the personnel of the submarine as no useful work could have been performed under water. At about 1.30 a. m. on Monday, December 19, it

was learned from the *S–4* that the men in the torpedo room had opened the compartment salvage valve and had found the line flooded.

With the wind force 6 to 7 and rising, and the sea still increasing and with the prospect of Michels passing on unless he could be given hospital treatment without delay, the *Falcon* proceeded to the navy yard, Boston, on Monday, December 19, sent Michels ashore and picked up a number of men and a considerable quantity of equipment for rescue and salvage work, returning to the *S–4* on the afternoon of that day.

Since it had not been possible to get the hose from the *Falcon* connected to the compartment salvage line, other means were considered of getting air to the torpedo room. Suggestions to burn a hole in outer shell and drill into torpedo tubes was followed by suggestion to burn away hull at after upper corner of torpedo tube shutters and remove torpedo tube relief valve, then screwing in an air hose connection. The suggestion to use the SC tube for air connection was followed by orders to *S–3* and *S–8* to remove rubber balls and get exact sizes of the ends

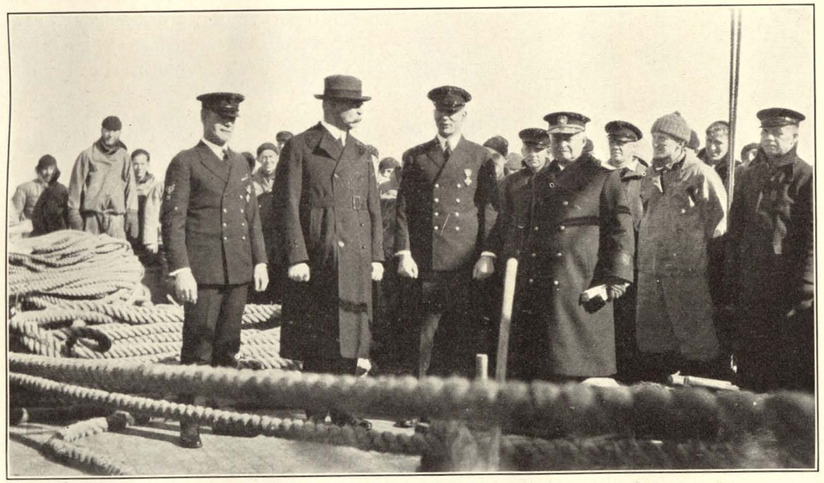


FIG. 4.—Presentation of Navy crosses on board U. S. S. *Falcon*, Sunday, March 4, 1928, by Admiral C. F. Hughes, United States Navy, Chief of Naval Operations, for heroic work during *S–4* rescue operations. Left to right: Diver William J. Carr, Admiral Hughes, Diver Fred H. Michels, and Rear Admiral Philip Andrews, United States Navy, commandant, first naval district and navy yard, Boston

of the acoustic tubes. Short lengths of divers' hose, with valves, were then prepared to slip over these tubes. *S–8* reported having heard from *S–4* that oxygen bottle in torpedo room was empty and suggested a diver placing soda line and emergency rations in torpedo tube, the crew first opening the outer door on signal from the surface, then closing outer door and opening inner door. The *Falcon* made preparations for sending down to the *S–4*, via the torpedo tubes, flasks of oxygen, cans of soda lime, cans of fresh water, packages of chocolate, and flashlights, sealed in a rubber inner tube. A photograph of one of these packages is included. (Fig. 5.) After the rescue operations, this tube was put over the side in 115 feet of water and left for 30 minutes or more. When hauled up and opened for examination, the contents were found dry and undamaged.

The weather continued bad on Tuesday, December 20, so that it was unsafe to hang anchors over the side of the *Falcon* and attempt to plant them for moorings. However, the weather moderated sufficiently on Wednesday so that two anchors were laid off the quarter of the *Falcon* and preparations were made to resume diving.

During the storm of Monday and Tuesday, the 4-inch manila descending line on the *S–4* carried away, the spherical buoy drifting away with the upper section of line and going ashore on the cape some miles to the eastward. Later when the *Falcon* picked up the cork floats and air hose which had been connected to the main ballast tank salvage line, all the hose came up on deck, leaving the *S–4* with no marker or line whatever. It apparently had been cut or chafed through, all but a few threads of fabric. (See fig. 1.) The 4-inch line and the air hose must have been subjected to excessive chafe or they must have been wound around some parts which were later cleared away, for it is interesting to note that these were the only buoy lines and hoses which carried away under similar circumstances throughout the whole winter.

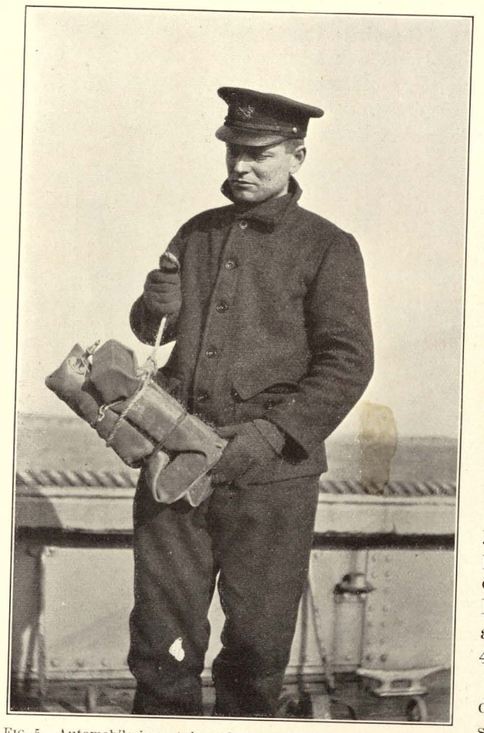
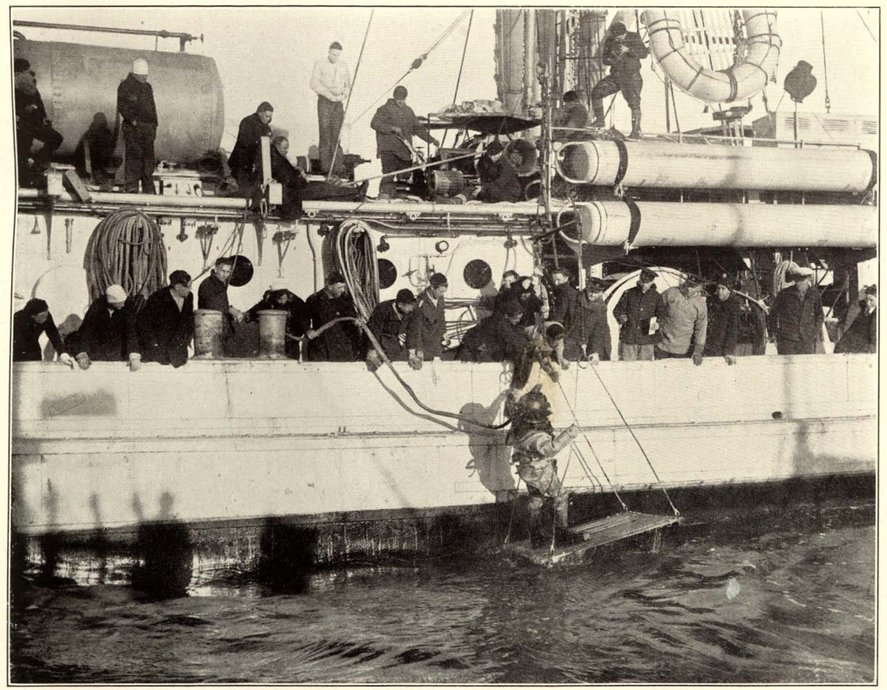


FIG. 5.—Automobile inner tube sealed water-tight, containing cakes of chocolate and flashlights, for insertion in torpedo tube or lock by divers on the outside. This gear proved water-tight and pressure-proof on test at 115 feet

As an indication of the difficulties which were again experienced in picking up the *S–4*, witness the *Falcon* mooring on Wednesday, December 21 (see fig. 6), having available and close by a can buoy which was known to be anchored just off the starboard quarter of the *S–4*, having known bearings of 2 points less than a mile distant—an excellent landmark bearing and a bearing and distance (about 200 yards or so) from one of the range buoys—yet putting several divers over within 10 or 15 feet of the vessel and not being able to find her. Dragging with the boats and grapnel lines was again resorted to and the *S–4* located at about 4 p. m. on December 21.

Between 10 p. m. and midnight on Wednesday, December 21, 4 days and 6½ hours since sinking, air hoses were attached by Wilson, Eiben, and Eadie to both ends of the SC tube and the process of clearing the air in the torpedo room was begun. As a guide to any similar blowing and venting operations which may have to be conducted in the future, it is to be noted that the connections to both ends of the SC tube were made by standard diving hose of ½-inch bore, slightly larger than the openings in the terminals of the SC tube. The pressure was first built up to 7 pounds per square inch, then vented to 4 pounds per square inch and the process repeated. In order to obtain a more rapid venting and to expedite the change of air in the torpedo room, the pressure was subsequently built up slowly to a maximum of 15 pounds per square inch, which when vented caused the exhaust air to flow much more rapidly than when the torpedo-room pressure had been limited to about 7 pounds per square inch. For a time one hose was used for blowing and the other was used simultaneously for venting, but the external pressure on the venting hose caused it eventually to collapse so as practically to shut off the flow of air. This hose was renewed by Eiben on the afternoon of Friday, December 23, and both hoses were capped and buoyed off about 7 p. m. that evening, as with wind and sea coming up on the port beam, it was necessary for the *Falcon* to get out of her moorings. Some time later, possibly during the next 48 hours, one of the terminals of the SC tube carried away, permitting sea water to enter and partially flood the torpedo room.

The complete log of blowing and venting operations and testing of air in the *S–4* torpedo room may be found on file L11–1 at the navy yard, Portsmouth, N. H.



Boston Post Photo.

FIG. 6.—Diver being brought in to deck of *Falcon* on stage, December 21, 1927. The long cylindrical objects at the right are log buoys for the permanent mooring anchors, all carried as part of the regular equipment on the *Falcon*

On the afternoon of Thursday, December 22, divers Wickwire, Ingram, Eadie, Eiben, and Ellsberg inspected the *S–4* and reported that the vessel was listed about 3° or 4° to starboard and was buried in the mud up to within about 5 feet of the fender stroke with the forefoot apparently clear. Steering rudder was about 15° left, stern planes about 15° rise and bow planes about zero or slight rise. From a subsequent inspection of the vessel in dock, where it was noted that the port plane was about level or was bent slightly backward, and the starboard plane was at about 19° rise, it is believed that the *S–4* may have hit bottom with a heavy list to port so as to bend the port plane backward and bring it level. Also that a diagonal

gash had been cut in the deck, that the superstructure had been cleaned off the outer hull on the starboard side forward of the gun, and that there was ragged wreckage on the starboard side.

Since the crew of the *S–4* during the early part of the week had reported that they did not know whether the control room was flooded and since there had been no response at any time from compartments other than the torpedo room, it was assumed that the four after compartments were more or less filled with water, although all of the divers who had previously been down reported that small streams of air bubbles were escaping in way of the bridge and periscope fairwater, over the conning tower and control room.

It was decided that the only means of getting the vessel to the surface expeditiously was to lift her by means of external buoyancy, using pontoons. The next divers down accordingly began washing a tunnel at frame 19, which was the location selected for the forward pair of pontoons. The tunneling was begun by Carr and continued by nine other divers who worked on through Thursday evening and until almost 4 a. m. Friday, when the list of divers for the day was exahusted. After daylight on the morning of Friday, December 23, Eadie and Wilson rove 4-inch manila lines in the tunnel at frame 19 and Carr started washing in the tunnel for the second pair of pontoons at frame 46.

On Friday evening, just as darkness set in, a southwest wind blew up, taking the *Falcon* nearly on her port beam. In an endeavor to send around one of the mine sweepers and have her anchor to windward so as to hold the *Falcon* in position, the mine sweeper caught the *Falcon's* port quarter mooring between the anchor and the log with her anchor and dragged it about one-half a mile toward Wood End. Fortunately at this time no divers were down, so that, aside from the necessity for replanting the mooring, no damage was done. However, this incident serves to emphasize the necessity for the most careful seamanship and the most expert handling of craft acting as tenders to the diving vessel and the necessity of having them remaining constantly on watch during diving operations so as to be acquainted at all times with "the lay of the land" and to anticipate, if practicable, the needs of the diving vessel.

After a visit of the Secretary of the Navy and the Chief of Naval Operations on Saturday December 24, the rescue phase was considered terminated. Instructions were given to continue with the work as a salvage job until the *S–4* was raised, all the facilities of the Navy being placed at the disposal of the force in the meantime.

Part III.—Problem and Working Conditions. Introduction.

The rescue work having terminated on December 24, 1927, the salvage operations were begun under the organization known as the *S–4* salvage force. The prospects for a satisfactory continuance of the diving work throughout the winter and a successful termination of the enterprise were anything but bright, having in mind the fact that on the *S–5*, in 1920, it had been necessary to discontinue work for the winter on November 19, not to be resumed until the following June; and on the *S–51*, in 1925, the cold weather and heavy seas had stopped all work on December 7 until April of the following year. The best information obtainable at the beginning of the *S–4* salvage operations indicated that only two or three diving days per week could be expected for the winter and spring.

Notwithstanding all the unfavorable signs, 37 dives had actually been made in the week ending December 24, 1927, and the job was tackled with the idea that nothing was impossible until it had been proved so.

Part III.—Section 1. Estimate of the Situation.

The estimate of the situation follows, supplemented by comments concerning conditions as they were actually found at later stages.

The *S–4* lay just to the southward of the sandy land forming the extreme tip of Cape Cod, in the position indicated by Plate 1 and Figure 7. She was resting in soft mud, at a charted

depth of 102 feet, on the crest of a shallow ridge running parallel to the southerly tip of the Cape, separated from the beach by a sort of ditch which was scoured out by the tides to a depth of 120 feet. Wood End Light bore 312°, distant about 1,860 yards, and Long Point Light bore 19°, distant about 2,900 yards. The shore at the nearest point was 1,300 yards away.

The Pilgrim Monument lay almost due north and served as an excellent landmark. The beach was sufficiently close and the tidal range large enough to permit of a rough approximation of the height of the tide by eye. The direction of the tide could be observed by watching one of the mooring buoys which was not in use. The *S–4* lay almost directly in the path of larger

FIG. 7.—Airplane view of Wood End, Cape Cod, during moderate northwest gale. Buoy "AA" at southwest end of inner measured mile is shown in the photograph; the *S–4* lay outside of the picture, at the lower left hand corner

vessels leaving or entering the harbor of Provincetown from the westward but the traffic for the winter season, aside from fishing craft, was limited to Coast Guard cutters, small steamers, coastwise schooners, and tows which came into the harbor for shelter during storms.

A wreck buoy, bell and flashing green, was placed about 600 yards southsouthwest of the *S–4* and just to westward of the buoy was placed a black spar. All fishing-vessel traffic was well inshore from the *S–4*; all other traffic was required to keep to the southward of the wreck buoy, thus clearing the mooring buoys and the *S–4* buoys by a safe margin.

The location of the *S–4* was free from ocean swells and was fairly well sheltered from local swells and sea for the semicircle extending from northwest through north, northeast, east, and

to the southeast. Local swells from the west to northwest built up in the sweep across Massachusetts Bay under the influence of the west and northwest winds which generally prevailed. Local swells from the south and southwest were somewhat more troublesome as the wind and sea picked up rapidly and unexpectedly from those quarters. On the other hand the wind and sea died down even more rapidly upon a shift of the wind. While it was frequently possible to moor and undertake diving a few hours after wind and sea conditions had been impossible, it was even more frequently necessary to discontinue diving and unmoor on account of the rising or shifting winds and seas when conditions had been very favorable. (See Figs. 8, 9, and 19.)

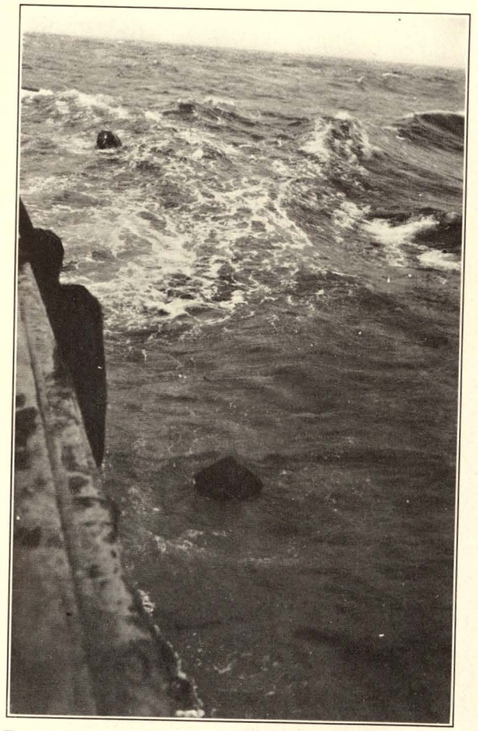


FIG. 8.—*Falcon* moored in a cross sea. Note cork buoys on descending lines alongside

The winds were quite variable and they rose and fell at a rate which was greater than might have been expected for a locality which was so nearly surrounded by water and where more uniform climatic conditions might have been expected. The wind velocities encountered during the winter varied from 0 to a maximum for a very short period of over 80 miles per hour, corresponding to a range of force on the Beaufort scale of from 0 to 10. The atmospheric air temperatures varied from a minimum of 8° above zero Fahrenheit on February 26, 1928, to a maximum of 43°, which was reached on January 13, February 1, and March 14, 1928. It is understood from conversation with "all-the-year-'round" residents of Provincetown that temperatures of 12° above zero are considered quite low for the winter and that temperatures down to 0° F. are unusual. The barometric pressure during the winter operations varied from a minimum of 28.84 inches on January 25, 1928, to a maximum of 30.80 inches of mercury, the latter on February 3, 1928.

Icing and freezing up were to be expected and were encountered, to the annoyance, discomfort, and inconvenience of all when this took place. The surfboats were frequently covered with a solid sheet of ice (figs. 10 and 11), and in that condition working in and around them was a most hazardous proceeding. Hawsers iced up and froze (fig. 12); the fishermen told how to thaw them out, as explained later. Cooling water in motor-boat engines froze, necessitating the adoption of a number of ingenious contrivances, to be described subsequently. Not only did the diver's hoses freeze up but the salt-water lines on the air coolers froze, and even ice in the pipe stopped the flow of oxygen and air to the torches.

The winter was unusually free from heavy snows and rains, although the relative humidity reached 100 per cent with great frequency, and the periods of high humidity were of almost daily occurrence. During the first part of the operations, continually until about January 27,

the relative humidity and the amount of moisture in the atmosphere had a direct effect upon the diving operations, in that a high moisture content in the diving air caused snow to precipitate and ice to form in the air lines. After the air-conditioning plant was put into operation

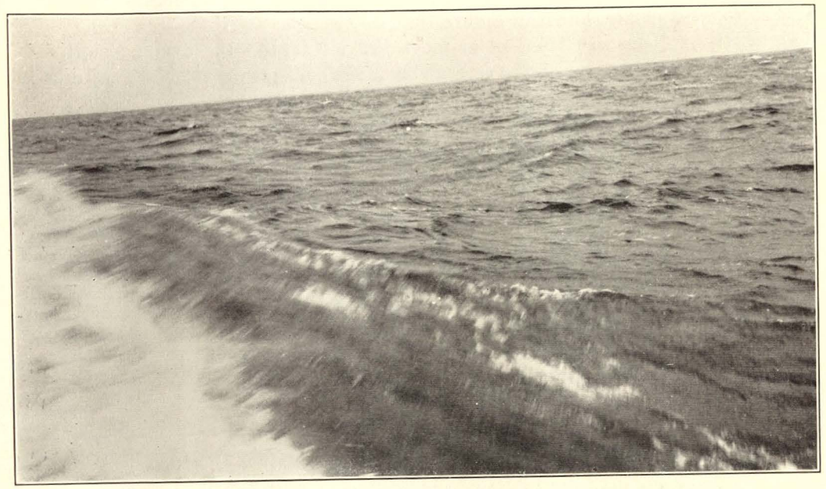


FIG. 9.—Seas breaking alongside *Falcon* while moored

FIG. 10.—The *Falcon* surfboat was kept moored astern when not in use

it was found possible to condition air at all atmospheric temperatures down to about 10° F. even with a relative humidity of 100 per cent. The hydrostatic conditions of the atmosphere then became more a matter of observation and record than a matter of concern to the salvage

force. It is noticeable from the hydrograph records that there were marked diurnal changes in the relative humidity, the moisture content increasing during the night and during cloudy and squally weather and decreasing preceptibly during the day, with a minimum value at about noon. A characteristic hydrograph record for the salvage operations during the week of January 15 to 23, 1928, is shown in Figure 13.

The depth by chart was 102 feet at mean low water, but the average depths of water as actually found around the vessel at various stages of spring and neap tides were as follows:

FIG. 11.—*Falcon's* surfboat, completely coated with ice. February 26, 1928. Temperature, 8° F.

	Spring tides	Neap tides		Spring tides	Neap tides
	Feet	*Feet*		*Feet*	*Feet*
High water	118	116	Low water	106	108
1 hour after	116	114	1 hour after	106	109
2 hours after	114	112	2 hours after	109	111
3 hours after	112	110	3 hours after	112	113
4 hours after	111	109	4 hours after	114	113
5 hours after	110	108	5 hours after	117	114

Range of tide varied from an average of 9.5 feet for the period December 18 to 31 to 11 feet for the period February 1 to 15, 1928. The average range was about 10.5 feet.

The temperature of the sea water at the beginning of operations was somewhat erratic, varying from a minimum of 34° and 36° to a maximum of 51° for the first week of the operations. The higher temperatures were recorded when the wind and tide carried the warm water from the shallow part of Cape Cod Bay toward the scene of operations and the higher temperatures were recorded when the cold water from the ocean was carried in the opposite direction. There were marked differences in the surface and bottom temperatures of the sea during the first two weeks of the operations. The one which caused particular comment was on December 26, when the surface was 38° F. and the bottom temperature was 50° F. The sea-water temperatures slowly decreased from an average of about 38° during the first part of January to an average of about 32½° during the latter part of February and the first part of March, reaching a minimum of 32° F. Following this the sea-water temperatures gradually rose to an

average of about 35° on March 16, when the last diving was done. For the period January 5 to March 16 the surface and bottom temperatures remained within 1° F. of each other, the surface and the bottom being alternately the colder without any apparent rule. The coldest sea-water temperatures lagged about a month or six weeks behind the coldest atmospheric air temperatures.

There were perceptible tidal currents at the point where the *S–4* was sunk, these currents sweeping across the vessel at an angle of about 45° to the center line and at a maximum velocity of about 1¼ knots. While the tidal currents had to be reckoned with in the mooring of the *Falcon* and in the handling of lines and hose to the divers and to the *S–4*, and while the divers frequently spoke of the presence of tidal currents, it can not be said that the tide interfered materially with the salvage operations at any time.

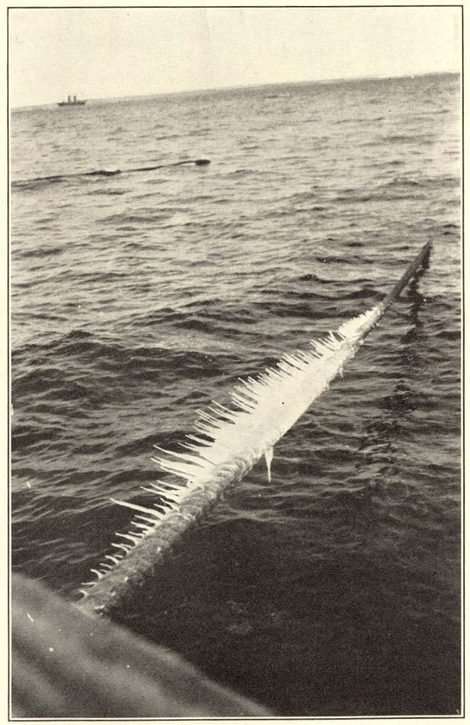


FIG. 12.—Mooring hawsers iced up. These hawsers must be dropped in the water and thawed out before they can be handled without damage to them

The charted character of the bottom in way of the *S–4* was "soft mud." The bottom had an upper layer of very soft silt or mud not more than 1 foot deep. Underneath this the bottom was more soft than hard; of a decidedly sandy character, mixed with minute shells. The texture of the bottom was sufficiently coarse to permit the passage of water through it, as when blowing the main ballast tanks with the Kingston valves well buried in the mud; yet it was sufficiently firm to hold its position when excavating tunnels underneath the vessel. Due to the permeable characteristic of the bottom it is estimated that the so-called "suction effect" on the *S–4* was practically nil. The *S–4* sank into this soft mud until her keel was buried 7 or 8 feet. The "mud line" is clearly discernible on the photographs (figs. 133, 134, and 135), and has been laid in throughout on the diagram, Plate 4.

The salvage operations were for the most part carried on under the disadvantage of short winter days and low altitude of the sun (24½°), both acting to shorten the effective daily working time and to decrease the illumination and visibility on the bottom. At the latitude of Provincetown, about 42° north, daylight for the greater part of the winter extended only from about 7 a. m. to 5 p. m.; it was only during March that daylight was available from about 6 a. m. to 6 p. m. The altitude of the sun reached a maximum of 46⅔° at the conclusion of the salvage operations.

It should be noted that although the salvage operations were carried out during the dead of winter the season was fairly mild. Even the worst storms were of relatively short duration and none of them were what might be termed destructive in character, causing serious damage

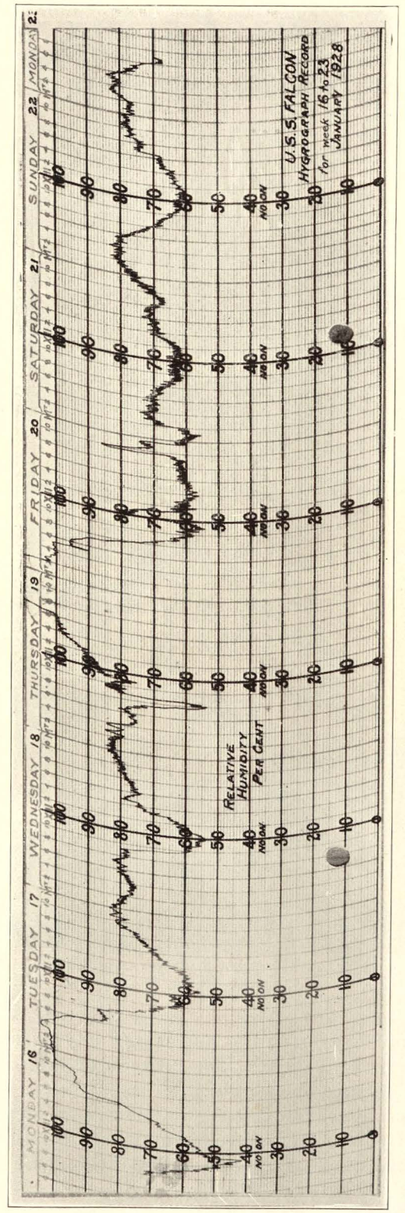


FIG. 13

to vessels of the force, moorings, buoys, etc. In fact, the weather proved to be favorable beyond any expectation, and this enabled the salvage work to proceed at a very rapid rate, considering the exposed location and the winter season.

Finally, Provincetown Harbor was only 2 miles away and Boston Harbor (navy yard) only about 45 miles away, so that it could be reached in from two and one-half to three hours by destroyer and from four to five hours by tug.

Part III.—Section 2. Diving Conditions.

When the *S–4* sank she plowed up a furrow in the soft mud and built up a bank of silt and mud along each side and around the bow which was from 3 to 5 feet deep, causing the first divers to sink up to their waists when they landed in it. As the tidal currents continued to sweep past the *S–4*, this bank was slowly washed away on each side, so that during the operations in March, when the divers were frequently on the bottom, they found that the layer of silt and soft mud had decreased to a more or less uniform and normal depth of about 6 inches. Whereas it required the services of from 12 to 14 men to haul Michels out of the mud on the night of December 18, the divers found it fairly comfortable working on the bottom at the conclusion of the operations.

The visibility on and around the *S–4* was generally poor, averaging from 4 to 6 feet and reaching a maximum of perhaps 8 feet for large objects. A certain quantity of very fine silt mixed with the bottom mud made the sea water cloudy and murky whenever a diver disturbed the thin layer of silt which lay on all parts of the vessel. Visibility inside the vessel for the greater part of the operations was very poor, due to the fact that the *S–4* was practically sealed until the divers entered her and all the oil and muck which was in her bilges remained in the water until it was gradually cleared out with the movement of divers' air from within the vessel.

Visibility in the tunnels was practically nonexistent, due to the stirring up of the fine mud which followed even the most cautious movements of the diver. At times the muddy water was so opaque that when the 1,000-watt diving lamp was held directly against the faceplate of the diver it was impossible for him to tell whether or not the lamp was lit.

As is the case with much of the rescue and salvage work on submarines, the divers were almost always subject to entanglements in loose lines and wreckage (see figs. 2 and 70), and they were to a certain extent hampered by incomplete knowledge concerning the exact condition of the various parts of the vessel upon which work was to be done.

Water temperatures were undoubtedly about as low as will ever be experienced in diving operations in our Navy. The low temperatures were of such extended duration as to requeir a complete adjustment of diving practices to suit them, all of which are described elsewhere in Appendix I to this report under the title "Diving procedure."

Part III.—Section 3. Divers.

There were available on December 27, 1927, 24 divers, drawn from all parts of the country, who were qualified for work in depths exceeding 90 feet, of whom only 14 were of known abilities

FIG. 14.—A group of divers and tenders engaged in *S–4* salvage work, January, 1928. Standing, left to right: Kallinoski, Doherty, Schmidt, W. C. Johnson, Applegate, Burns, Burd, Campbell, Michels, Eadie. Kneeling, left to right: Nickerson, Deady, Sherwood, McNulty, Von der Wall, Carr, Grube, Eiben, Nicol, Wickwire, Crilley, Bailey, Kelley, Holden, Wilson, Stanley, Ingram. "Jake," the dummy diver, is in the left background

and of whom only 8 were considered capable of work under the vessel, washing tunnels. A group of the divers and tenders working during the early stages is shown in Figure 14.

Experience on the *S–51* indicated that, with a cold winter ahead and severe working conditions in prospect, this number might dwindle to a mere handful in the course of two or three months. In other words, that before the salvage work was completed the salvage force might find itself at a standstill for lack of men to perform underwater work.

Part IV.—Organization and Composition of Salvage Force. Section 1. Subdivision of Work, with Detailed Organization, Duties, and Instructions.

The orderly prosecution of a salvage job by naval forces at a distance from a naval base, as was the case with the *S–4* and the *S–51*, necessitates careful and thorough organization, with its accompanying subdivision, delineation, and delegation of work and duties. The principal

parts of the work of the *S–4* salvage force was under the direction and supervision of the following officers and the work was divided about as described below. This outline is intended not so much as a description of the organization employed on the *S–4* salvage as an indication of the subdivision of work and duties for an expedition of this kind.

(*a*) The officer in charge of salvage operations was in command of the salvage force and exercised complete control over the movements of all vessels of the force, as well as general control over the work of each vessel and each unit of the force.

(*b*) The senior aide, corresponding to the chief of staff of a regular naval organization, had general charge of logistics, communications, personnel, etc., under the direction of the officer in charge.

(*c*) The commanding officer of the rescue vessel, to which were attached all the divers, tenders, and enlisted personnel actually engaged in salvage work, was in general charge of diving operations and of course in direct charge of the movements of his own vessel, in addition to which he acted as a supervisor for all matters connected with the salvage involving seamanship and as a relief for the salvage officer.

(*d*) The diving officer and diving supervisors were in direct charge of all diving operations, including recompression, and were charged with the prosecution of all work in accordance with the requirements of the Diving Manual.

(*e*) The salvage officer was in direct charge of all work on and about the submerged submarine, laying out the work and supervising its execution by the divers and others.

(*f*) The commanding officers of tenders, tugs, dispatch vessels, and other craft belonging to the force exercised the same functions as was customary for any kind of naval operations.

The detailed organization and general administration of the *S–4* salvage force, as governing the assistance which each component of the force was to render toward the accomplishment of the task assigned, is set forth in the commander, *S–4* salvage force, letter of January 26, 1928. A portion of this order will be quoted and elaborated upon hereunder to indicate the relation of the other parts of the force to what may be termed the purely "salvage" portion.

OFFICERS

Commander H. Gibson, senior aide.
Ensign J. M. Smith, aide (communications).
Commander H. E. Saunders (CC), salvage officer.
Lieut. H. Hartley, deputy salvage officer.
Lieut. L. Kaplan (CC), assistant salvage officer (material).
Chief Gunner C. L. Tibbals, diving supervisor.
Chief Gunner W. F. Loughman, assistant diving supervisor.
Chief Gunner F. J. Kaiss, assistant diving supervisor.
Lieut. Commander G. H. Mankin (MC), diving medical officer.
Lieut. Commander A. Osenger, force engineer and repair officer.
Lieut. J. A. Topper (MC), force medical officer.
Lieut. C. E. Sandgren (SC), force supply officer.

SHIPS AND DUTIES

(*a*) *Bushnell* (flag), depot vessel for material and personnel—repair vessel, Lieut. Commander H. M. Branham.
(*b*) *Falcon*, salvage and diving vessel, Lieut. H. Hartley.
(*c*) *Wandank*, tender to *Falcon*, Lieut. T. Fertner.
(*d*) *Sagamore*, tender to *Falcon*, Chief Boatswain G. Cregan.
(*e*) *S–6*, model for *S–4*, Lieut. W. Wakefield.
(*f*) *Mallard*, tender for pontoons, barges, etc., Lieut. R. Rohange.
(*g*) *Mahan*, dispatch vessel (as assigned), Commander G. N. Barker. *Maury*, Commander J. B. Glennon.
(*h*) C. G. *No. 171* (or substitute), local dispatch service.

DUTIES OF SHIPS

(*a*) *Bushnell*, procure, distribute, and account for all material, provisions, etc. (navy yard, Boston, is supply base); utilize shops for fabrication, repair, and overhaul of material of all vessels; house and mess personnel; furnish boats as required; furnish working party to *Falcon* daily as required; station near *Falcon*.
(*b*) *Falcon*, as above, moored over *S–4*.
(*c*) and (*d*) *Wandank* and *Sagamore* tend *Falcon;* portable moorings, handling lines and gear, wreck watch, etc.
(*e*) *S–6*, available for examination (as sister ship to *S–4*), trial of apparatus, rehearsal of divers, etc.; station near *Falcon*.
(*f*) *Mallard*, tend derrick lighter *United States* and other floating equipment, tend and tow pontoons and barges, and other duties as assigned.
(*g*) Dispatch vessel.—Leave Boston daily about 0930 for Provincetown (*Bushnell*); leave Provincetown (*Bushnell*) daily about 1500 for Boston; transport passengers, mail, provisions, material, etc.
(*h*) C. G. *No. 171* (or substitute), maintain daily local schedule as ordered.

GENERAL INSTRUCTIONS

(*a*) All orders and requests coming from *Falcon* that relate in any way to salvage work shall be obeyed as if coming direct from the force commander.
(*b*) All vessels *report daily* at noon by flag or visual or radio (1) fuel on hand, (2) water on hand. Notify *Bushnell* (flag) specially by dispatch when fuel oil or fresh water or fresh provisions fall below 50 per cent of capacity.
(*c*) Keep *Bushnell* informed of all requirements as to material, provisions, repairs, etc.
(*d*) Tugs and sweepers operate *evaporating plants* to capacity, conserve water and fuel. *Bushnell* and *Mallard* maintain water tanks filled to capacity at all times.
(*e*) While diving is going on all vessels except those stationed with pontoons and barges in inner harbor shall be *ready to get under way* on not more than 15 minutes' notice; at other times they shall be on "one hour's notice."
(*f*) Vessels requiring *boat* hoist international "T", *Bushnell* send boat.
(*g*) *Communications.*—Radio traffic will be handled via *Bushnell*. When out of signal distance of *Bushnell* maintain continuous radio watch; when within signal distance, keep continuous signal watch.

Part IV.—Section 2. Personnel, Duties and Qualifications.

The detail duties and qualifications of personnel engaged directly upon the salvage work on the *S–4* are briefly described in the paragraphs following.

The salvage officer was in direct charge of all work done on and about the submarine; in other words, practically all work done under water. He was charged with the preparation and maintenance of working schedules, tasks, and assignments of divers, and daily log of salvage operations. This officer was a commander in the construction corps who had had upward of 13 years' continuous experience with submarines.

The commanding officer of the salvage and diving vessel was a lieutenant of the line, with a wide and varied experience in handling vessels, including invaluable experience in command of the salvage and diving vessel during the salvage operations on the *S–51*. This officer was charged with all matters on the diving vessel relating to seamanship, mooring and unmooring, and the securing and rigging of all gear which was handled or worked upon by the divers. This officer was also deputy salvage officer, acting in the capacity of salvage officer during the absence of the latter.

The assistant salvage officer for material was a lieutenant of the construction corps, who in this particular case had been ship superintendent for the *S–4* at her home yard just previous to the accident, so that he was not only familiar with material in general which was to be used during the salvage operations but was acquainted with the vessel being salvaged. He was charged with the procurement and preparation of all special material required for the salvage

operations proper, including gear regularly and specifically issued to the diving vessel for this salvage job but excluding gear regularly issued in the usual course of events to the vessels of the force.

The technical assistant to the salvage officer, Mr. J. C. Niedermair, was the supervising draftsman in charge of the scientific and computing section of the hull drafting room at the navy yard, New York. He had acted in a similar capacity throughout the salvage operations on the *S–51*, and hence was a very valuable member of the organization. It was his duty to record technical data, make the necessary calculations in connection with the salvage work, prepare sketches for special articles to be fabricated, and maintain a statistical record of certain aspects of the work.

The diving supervisor and assistant diving supervisors were in direct charge of all diving operations so far as related to diving practices, recompression, and the observance of rules and

FIG. 15.—Twenty-six-foot motor surfboat of the type used by the United States Coast Guard employed by *Falcon* for running mooring lines. The use of this type of boat is absolutely indispensable, and the work which must be performed by it can not be done by any other type of boat known

precautions laid down in the Diving Manual. They were chief gunners of long experience, all ex-divers, and all thoroughly familiar with every aspect of modern deep-sea diving. The diving supervisor, in addition, had had previous experience as a wreck master and as officer in charge of experimental diving for the United States Navy.

The derrick *United States* was manned by a civilian crew from the navy yard, Boston, consisting of one engineman, one fireman, and one first-class rigger.

To speak in particular of the qualifications of the one in charge of all technical affairs, it may be stated that a salvage officer who can not bring up in his mind a fairly complete mental image of the work which lies before him but out of sight is well-nigh lost before he begins his work. No pictures or diagrams which can be drawn by a human being will keep him posted well enough, on a submarine job particularly, to know just what effect one operation may have upon the whole.

He must possess sufficient imagination to picture to himself several possible conditions of affairs with which he must deal and contend, yet be sufficiently fixed in his mind to guard against shooting off at tangents upon the receipt of startling or unusual information from the divers.

He must manifestly be willing to ask and accept the advice and counsel of others and big enough mentally to give logical and conscientious consideration to suggestions which may be made by all hands, for one never knows the source from which the germ of a brilliant and saving idea will spring.

Part IV.—Section 3. Ships, Characteristics and Duties.

The *S–4* salvage force was composed of the following ships: *Bushnell, Falcon, Wandank, Sagamore, S–6, Mallard, Mahan, Maury,* floating derrick *United States,* and steel coal barge. These represent the average number and type of vessels that are desirable and necessary for independent salvage operations of this character.

The submarine tender *Bushnell* was the flagship of the force and acted as a base vessel or depot for material and personnel and as a repair vessel. The tender provided quarters for the salvage officer, assistant salvage officer for material, technical assistant to the salvage officer, one assistant diving supervisor and a party of divers, tenders, dressers, telephone talkers and others, numbering about 41 in all, for whom there were no available quarters on the *Falcon.* In addition, the tender furnished each day a working party for the salvage vessel of some 10 or 12 men in charge of one petty officer. All special material required for salvage operations within the capacity of the shops of this tender was manufactured on board; the larger and more complicated items of material were obtained from the navy yard, Boston. The *Bushnell* acted also as a stores ship for material ordered and delivered until that material was actually needed by the *Falcon* and other vessels of the force.

Keeping the motor boats of the *Bushnell* in operation in order to perform all the boating duties required of them was a problem in itself.

(*a*) Fender guards of heavy 10 and 12 inch manila were finally added all around the boats to prevent smashing them up when making landings or lying alongside.

(*b*) Spray screens were fitted over the forecastles and forward of the engines to protect men and machinery.

(*c*) Circulating water systems froze up and the boat engines were finally run with a cooling system consisting of an open galvanized steel can of 20 or 25 gallons capacity, connected at the top and bottom by rubber hoses to the circulating water discharge and suction, respectively, on the engines. This facilitated draining of the engines at night and insured heating in the morning, when the can was filled with hot water.

(*d*) The two-cycle boat engines were the object of more deprecatory remarks and outbursts during the winter than almost any other single item in the whole force. After repeated attempts to make them run, the salvage force succeeded in having them replaced by four-cycle engines, which gave good satisfaction.

(*e*) Blended gasoline was used for fuel, consisting of 1 part aviation gasoline to 2 parts ordinary gasoline.

The salvage and diving vessel *Falcon* was a mine sweeper of the bird class, specially fitted out with air compressors, recompression chamber, and other apparatus essential to work of this character. The displacement of this vessel with all the special gear on board was about 1,525 tons, considerably greater than that of her sister vessels. This increased displacement resulted in a decrease in free board of several feet, all of which acted considerably to her disadvantage. The duty of this vessel was to provide a working platform from which diving and actual salvage operations could be conducted, and for this purpose she was required to maintain

a position positively and accurately over the submarine. The diving supervisor and one assistant, the diving medical officer, and about three-fourths of the divers, tenders, and dressers, in addition to the full crew of the *Falcon*, were quartered and messed on this vessel.

The boats used for running mooring lines to and from stand-by tugs and to mooring buoys were two 26-foot motor surfboats of the type used by the Coast Guard, illustrated in Figures 15 and 16. One was a Coast Guard boat used by the *Falcon* during the *S–51* operations, subsequently purchased by the Navy Department and issued to the *Falcon*. The other was a Coast Guard boat loaned by that department from the Gurnet Coast Guard Station, across the bay. Both boats were clinker-built, of the self-bailing type, fitted with 4-cylinder, 4-cycle Kermath engines. These engines would start without hesitation in a boat which had lain all night in the bitter cold and which was covered with ice. These were excellent sea boats and were very

FIG. 16.—Twenty-six-foot motor surfboat can be run over mooring lines without risk of fouling them in propeller or rudder. In this photograph the surfboat crew is bringing over a preventer hawser from one of the tugs

handy. It is not too much to say that the work of the *Falcon* in mooring and unmooring could not have been accomplished without them.

Wandank and *Sagamore*, the two tenders to the salvage and diving vessel (fig. 19), were two seagoing tugs whose duty was to render assistance as necessary and to form temporarily fixed anchorages to which additional mooring lines could be run for holding the salvage and diving vessel in position. These vessels labored under the disadvantage of having anchor-handling gear which was not designed for continuous work, day in and day out; hence the work of anchoring and getting under way was particularly arduous.

Submarine *S–6*, the model for the *S–4*, was a sister submarine of the same class, whose duty was to remain reasonably close aboard the salvage and diving vessel so that divers could be sent over for inspection, instruction, and rehearsal at short notice. In addition, the officers and crew of this vessel were expected to keep themselves cognizant of the progress of the work and to offer suggestions and assistance to the salvage party whenever possible. The *S–6* was permitted to dive and carry out submerged maneuvers at hours when she was not needed by the salvage force.

The *Mallard*, the tender for the pontoons, barges, derrick lighter, etc., was a mine sweeper of the bird class, whose duty was to look out for all floating equipment of the force. The *Mallard* provided meals for the crew of the derrick lighter *United States* and rendered assistance to the latter personnel when necessary.

The principal dispatch vessels were two destroyers (light mine layers) of the mine force, *Mahan* and *Maury*, which were charged with the transportation of passengers, mail, supplies, special equipment, etc. These vessels made daily trips from the navy yard, Boston, to the salvage fleet at Provincetown, and they alternated, week in and week out, with this duty. Their average sea speed on this duty was 20 to 22 knots.

The lifting facilities of the force consisted of the derrick lighter *United States*, having a capacity of 100 tons. The lifting facilities should permit of handling the largest pontoons to and from ships and barges and the water.

The local dispatch vessel was a 75-foot patrol boat loaned by the United States Coast Guard, which made four or five round trips a day, carrying passengers, stores, and mail between

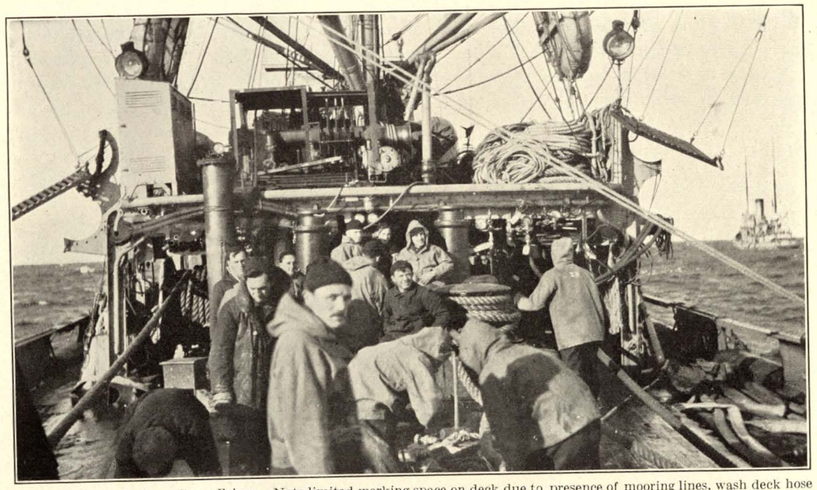


FIG. 17.—General view aft on *Falcon*. Note limited working space on deck due to presence of mooring lines, wash deck hose for tunneling, blowing hoses, cordage, and miscellaneous gear

the principal vessels of the force and the city of Provincetown. This vessel was too large to go alongside the *Falcon*, in and out among the lines and buoys, when the latter was moored. Communication was then established with the surfboats.

There were available at all times one or more steel coal barges of 500 tons capacity for transporting and storing the pontoons, pontoon chains, anchors, wire hawsers, and other heavy items of salvage material.

No description of floating craft would be complete without mention of the 50-foot motor launch with 4-cycle engine which was finally furnished to the *Bushnell* after repeated requests from the salvage force. It was a seaworthy and reliable boat, capable of carrying large working parties of men and freight in large quantities in all kinds of weather and sea. It was used on two occasions for transporting a pair of heavy 2½-inch pontoon chains and a pair of 1-inch reeving wires from the derrick *United States* to the *Falcon*, moored over the *S-4*.

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Part IV.—Section 4. Material, Preparation and Supply.

The tender was required to procure, distribute, and account for all stock and special material, provisions, etc., making use of the navy yard, Boston, as the supply base. All requests for material outside the force were made by the tender through the medium of dispatches; letters were written only when the delivery date of the material permitted and when there were sketches or explanatory notes to be forwarded. Dates for delivery of all special material on board the tender were definitely given whenever practicable, so that material might be received on time with the minimum of shift work at the navy yard, Boston.

It was the invariable rule when ordering and manufacturing special salvage material, fittings, and other parts which might become damaged in the underwater work or which might get adrift in the hands of the divers to order duplicates and in some cases to order three of each, of perhaps slightly different sizes or varying characteristics. The second was held in reserve in case the first became lost under water or in case it became necessary to make alterations or modifications such as cutting threads smaller or the like, whereupon the second was always available and no time was lost.

All parts when completed by the *Bushnell* or when delivered to that vessel from Boston were carefully tagged and marked. When it was known that they would be required in one or two days they were taken to the *Falcon* workshop and hung on racks, where they were under no circumstances to be removed or disturbed except by the salvage officer or one of his assistants.

Requests for material, even though it was known at the time of ordering on the tender that this material would be actually furnished by naval supply bases, by other navy yards, or by private firms, were invariably addressed to the navy yard, Boston, as the central point for procurement.

The navy yard, Boston, cooperated to the extent of placing all requests for *S-4* salvage material at the head of their priority lists and of having an officer on duty continuously, day and night, week in and week out, to take care of requests from the salvage force. The thoughtfulness manifested by Boston was deeply appreciated and the services rendered by that navy yard were most gratifying.

Part V.—Procedure and Routine. Section 1. Diving and General Procedure.

In the cold water, the temperature of which was then almost down to the freezing point, the time limit for work of divers on the bottom was to be one hour and a diver was to be considered as having performed a day's work in one dive. No attempt was to be made to dive or to moor when weather conditions were such as to incur any risk whatever to the divers and the personnel of the force, nor was work to be continued when the weather grew threatening or serious.

It was realized that the *S–4* salvage would be a long-drawn-out job at the best and that it could not be carried on with any degree of efficiency under the same high pressure as obtained during the first week of rescue operations.

Plenty of rest and sleep, normal working hours, proper food, dry and warm winter clothing—all were important parts of a reasonable working program which had to be outlined and adopted in order to insure the greatest return for the effort expended under the unfavorable winter conditions.

As a development of this program, it was decided, first, to work only during daylight hours, but to work every day—Sundays, holidays, and all—whenever the weather would permit. However, the day's work for divers and others was to be limited to that which could be performed continuously without reduction of energy or efficiency; second, that food would be adapted and ration allowances would be increased to suit the season; third, that the most suitable wind and weather proof winter clothing would be obtained; and, fourth, that anything

in the way of gear and equipment which would insure more or better work with less discomfort and consequent greater efficiency would be procured. Lastly, that all hands would be given periodic leave and change of scene.

Part V.—Section 2. Daily Routine.

The working day for the greater part of the winter began about 6.30 a. m., at which time the working party shoved off from the *Bushnell* and the *Falcon* hove short, ready to weigh anchor and get under way as soon as the working party was aboard.

The *Falcon* was moored within from 20 minutes to an hour or so of getting under way, depending upon whether the night had been spent near the *S–4* or in Provincetown Harbor.

It was generally 8 a. m. or later before the first diver could be put over the side.

Diving and other work was as a rule continued right through the day until operations were terminated by weather or darkness or by exhaustion of the list of divers. Meals and reliefs for various members of the salvage party were arranged accordingly.

Work was discontinued for the day at about 5 p. m., on account of darkness.

Finally, on March 8, the working day was begun at 6 a. m. and it was then possible to work until 6 or 7 p. m. On March 13, the working day was begun at 5.30 a. m.

On March 14, the *Falcon* having been moored over the *S–4* all night long, it was possible to put the first diver over the side at 6.35 a. m. On March 15 the *Falcon* got under way at 5.35 a. m. in Provincetown Harbor, was moored over the *S–4* at 6.12 a. m., and the first diver was sent down at 7.04 a. m. These were the earliest dives on the whole job.

The stormy days did not by any means cause a cessation of activities. On the other hand, they gave the force an opportunity to catch up with itself and to perform certain work which had to be done but which was very rarely of sufficient importance to justify a discontinuance of diving operations to do it. There was always a certain amount of paper work and there were certain materials and gear to be prepared which could not always be made ready in time to keep up with the procession. There were problems to be studied on the *S–6* and instructions to be given to the divers on that vessel (when they could get to her through the seas), and there were repairs to gear and equipment to be made which could not be accomplished when it was in use.

Weekly reports of the time of civilian employees were forwarded by dispatch so as to be received in the respective yards by Monday of the following week, the time being covered from Sunday to Satuday, inclusive.

Part V.—Section 3. Mooring of Salvage and Diving Vessel, U. S. S. "Falcon."

The manner of mooring the salvage vessel followed the methods used with success on the *S–51* operations, as described on pages 10 and 12 of the report on salvage operations on that vessel. Two 8-inch manila mooring lines were used forward on the *Falcon*, run to mooring buoys on the bow. These were handled as best they could by the gypsy heads on the anchor windlass and were then belayed on the bitts forward. One or two additional 7 and 8 inch manila lines were run from forward, as occasion demanded, for preventers or for holding the ship in a fore-and-aft direction if her own anchors were not down.

Two 8-inch manila mooring lines were used aft, one on each of the two large sweep drums on the towing engine. (See figs. 17 and 30.) These two lines ran out of the afterchocks and thence to the quarter moorings, so that by hauling on one and veering on the other the stern of the *Falcon* could be moved from side to side. A 7-inch manila line, run through the afterchock to a mooring buoy astern, held the ship from going ahead. This line was handled by the after-capstan and then had to be belayed on the towing bitts if the capstan were to be used.

On the outboard end of each mooring line was a pelican hook, which the surfboat crew carried out on the end of the mooring line and made fast to the bail on the buoy. Slipping was performed by pulling out the locking pin with a boat hook.

On February 10, 1928, six mooring lines were run and the *Falcon* secured in position in 17 minutes. The vessel got under way from a position to eastward on the *S–4*, laid out a bow anchor, ran the six lines, and was moored, ready for diving, in exactly 30 minutes.

Preventer lines from the tugs acting as tenders were generally handled from the tugs, the end going to the *Falcon* and being belayed at some convenient point and the tug heaving or veering on the line by visual signal from the afterdeck of the *Falcon*.

It was customary to moor, especially in the latter part of the operations on the *S–4*, when the weather became consistently more adverse, by first running through the moorings and heading past the *S–4* to windward, anchoring the *Falcon* with one or both of her bower anchors, then dropping back on the chains and mooring over the *S–4* in the regular manner. This served very well so long as the wind remained constant in direction, but whenever the wind shifted

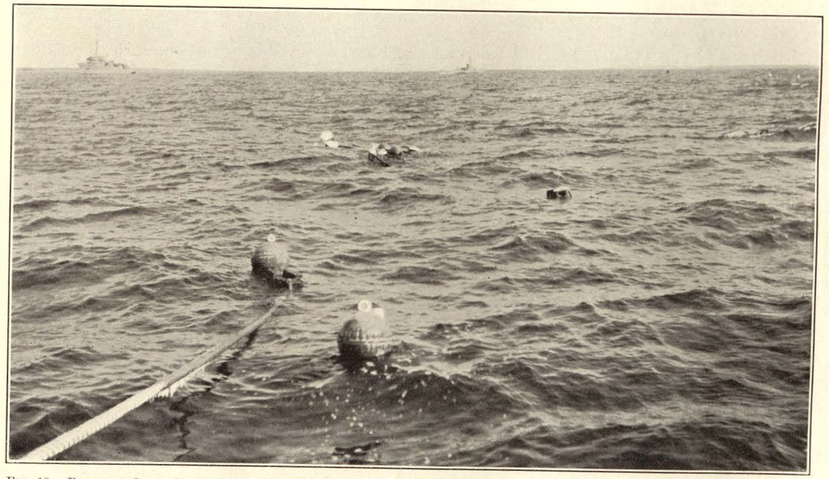


FIG. 18.—Buoys on descending lines and blowing hoses capped with ice. It was almost always necessary to have one or more of the mooring lines lying in and around the buoys and hoses

to the beam, especially when it put the buoys from the *S–4* on the lee side of the *Falcon* (see fig. 18), the process of getting out of the moorings without carrying away any lines or hoses from the *S–4* or without fouling the moorings was one which required the exercise of seamanship of the highest order. The manner in which this was accomplished, under the most unfavorable circumstances of any that were encountered during the winter, can perhaps best be explained by quoting the entry from the salvage log of Thursday, March 15, 1928, page 124, for the hours following the lowering of the second pair of pontoons to the *S–4*.

7.40 p. m., pitch dark. Discontinued operations; wind force 5, rough sea. Very difficult getting out of moorings with seas just forward of starboard beam and all the buoys and lines on the lee side. At this time following hoses and lines were out: 1 small descending line to motor-room hatch, 8 blowing hoses to *S–4*, 8 blowing hoses to middle and stern pontoons, 1 descending line to gun, 1 to torpedo hatch, and 1 to extreme bow, as well as buoy line to *S–4* towing pendant and line to bow towing bridle—22 in all, not including buoy line on stern fast, which was then clear of *Falcon*.

Wandank had previously been anchored to windward of starboard bow and *Mallard* off starboard quarter and mooring lines run from each. Had *Mallard* heave around on her line first, hauling stern of *Falcon* to starboard and to windward, clearing buoys on compartment and pontoon hoses on port quarter. *Falcon* cast off lee moorings and stern line. Then *Wandank* and *Mallard* both hove 'round, taking the *Falcon* bodily to windward, while *Falcon* hove 'round slowly on her anchor chain until buoys on port bow were clear. As *Falcon* eased forward on her anchor *Wandank* continued to heave around to take *Falcon* safely between N. and NW. moorings. Let go line from *Mallard* and went ahead slow while heaving 'round at full speed on anchor. All buoys and moorings cleared. Under way and anchored off.

The general position of mooring anchors, buoys, and lines for the *S–4* operations are shown on Plate 2, including a typical position for one of the tugs acting as tender. The mooring buoys never "watched" when there was a strain on the lines and the presence of numerous lines extending out from the *Falcon* on all sides made it impossible for any but small boats to come alongside.

For reference, the manner of mooring the *Mallard* and the *Falcon* in the open sea during the diving operations of 1920 and 1921 on the *S–5* is shown on "U. S. S. *S–5*, Position of Buoys

FIG. 19.—*Falcon* moored in heavy cross sea, showing special mooring line in foreground to tug *Wandank* and second mooring line in background to tug *Sagamore*. Holding the *Falcon* in position in such a beam sea was a precarious operation and the *Falcon* was about to unmoor when this photograph was taken

and Probable Location of Wreck," dated November 7, 1920, a print of which is in file 2–SS110–2. vol. 2, in the Bureau of Construction and Repair.

Part V.—Section 4. Rules for Mooring and Unmooring.

In mooring the *Falcon* over the *S–4*, Figure 19, the following fundamental rules were established and observed:

1. By all means, avoid dragging or carrying away the moorings—for reasons of safety when divers are down and for reasons of expediency when they are not, since the moorings will only have to be repaired, reset, or replaced.

2. If in doubt about the weather, stay out of the moorings.

3. If there is a decided shift in the direction of the wind and it appears desirable to shift heading, get out of the moorings entirely and come back in again, heading in the proper direc-

tion. It is always quicker to get out of moorings and back than to attempt to shift in the moorings.

4. If there is doubt as to the ability of the diving vessel to remain in the moorings, especially near nightfall, always get out "while the going is good." It is altogether too precarious, difficult, and dangerous to slip moorings with the boats and to handle lines on deck after dark or after the weather has gained the upper hand to risk operations of this sort just to gain a few doubtful minutes or hours of diving time.

Part V.—Section 5. Weather Forecasts and Reports.

Daily weather reports were received from Boston, by radio, giving a description of the weather at Boston and at Highland (Cape Cod Light). Neither were of any particular use or advantage, since Boston was so far away that the weather was almost never the same and Highland was so near that no report was necessary to tell what the weather was like.

Daily weather forecasts were received by radio about noon, and it was found that the predictions under "Ocean forecast" came nearest to being an indication of the weather that might be expected at Provincetown.

The decision as to the ability of the salvage and diving vessel to moor and to undertake work over the *S–4* was made upon the state of wind and weather at Wood End, and not necessarily upon the weather forecast. However, when the weather grew worse and when there was a question as to the advisability of mooring or unmooring, continuing or discontinuing, the weather predictions quite naturally had a certain amount of influence.

The best indication of all of really bad weather was a sight of the fishing craft, of the tugs and tows, and of other craft seeking shelter in Provincetown Harbor. These craft were all manned by men whose principal business was to know the weather—and they almost never failed.

When it became time to make a decision as to the date of raising of the *S–4*, special weather forecasts were asked for and sent out from Boston. Those made by Mr. E. B. Rideout and sent on March 16, 17, and 18 were remarkably accurate.

Part V.—Section 6. Disposition of Force.

On working days the vessels of the force were generally disposed with reference to the *Falcon* as follows, as shown on the diagram on Plate 1. The various vessels of the force may be seen in the offing in a number of the photographs.

Bushnell was anchored to the north-northeast of the *Falcon*, about 500 yards distant, and inshore, to make boating conditions as easy as possible. On January 12 the *Bushnell* was moved to windward of the *Falcon* for use as a temporary anchorage or mooring, but "before the party was over" she had dragged her anchors and swung around close to the tugs and made things uncomfortable generally for all hands concerned. On account of her unwieldliness no further attempt was made to use her in that manner.

Wadank and *Sagamore* were anchored about 150 yards off to windward, ready to assist in holding the *Falcon*. The *Sagamore* displayed commendable alertness and initiative in anticipating the needs of the salvage party on the *Falcon* by continually shifting to the position where she thought she might next be wanted.

S–6 anchored from 200 to 250 yards to the northward or to the eastward, generally inshore and in the lee, as close as she could lie to the mooring buoys, so as to reduce the time required to make trips to her from the *Falcon*.

Mallard remained in Provincetown Harbor alongside the derrick *United States*, unless wanted for special work.

Floating derrick *United States* was moored in Provincetown Harbor, with steel coal barge secured astern.

Despatch destroyers, during the two hours or so of their stay each day at Provincetown, anchored about 100 to 150 yards from *Bushnell*, always in the lee of that vessel, if practicable, so as to facilitate boating.

Before the *Gurnet* surfboat was available, one of the *Bushnell* motor boats was generally left alongside the *Falcon* for emergency trips and other work, as the *Falcon* surfboat was held in reserve for use only in handling mooring lines. After the receipt of the second surfboat, both of these boats were kept alongside the *Falcon* during the day, ready for instant use.

Part V.—Section 7. Leave.

As a result of the thought and consideration which had been given to the question of liberty and leave and change of scene during the salvage operations on the *S–51*, the commander *S–4* salvage force, early in the winter (January 5, 1928) promulgated the following order concerning leave during the *S–4* salvage operations. The body of the order is quoted in full:

1. The force commander has every appreciation for the unquestioning and willing devotion to duty which all hands have displayed since the sinking of the *S–4* on December 17, 1927, now nearly three weeks ago.

2. As the salvage operations are certain to last some weeks more under the best expectations and will undoubtedly be delayed and hampered by storms and bad weather incident to the winter season in this locality, it is desired to authorize such leave to officers and men as can be done without decreasing, in any degree, the greatest possible progress of the work at all times.

3. A survey of the personnel situation throughout the force is now under way, and it is expected that some additional personnel of suitable qualifications will have to be obtained and distributed where needed. Commanding officers will take immediate steps to provide (request if necessary) and train a relief for every officer and man whose present duties require his continued presence on board, i. e., whose absence will hamper the salvage operations in any way.

4. Beginning to-day, commanding officers are authorized to grant not to exceed three days' leave per calendar month to officers and men of their commands, provided the commanding officers are positive that the absence of any certain officer or man will not decrease the effectiveness of their ships or the progress of the salvage operations as a whole, and also that the number of men in any one leave party does not exceed 12 per cent of the crew.

5. The three days' leave will be given all at one time and must be counted from the time of leaving ship to time of return to ship, e. g., go 6th and return on board 9th, go 21st and return on board 24th. No extensions can be granted. The nonreturn of any man on time must be considered as probable cause for the postponement or stopping of some other man's turn for leave.

6. Special arrangements for leave for all divers will be made and regulated by the commanding officer *Falcon*, subject to the approval of the salvage officer.

7. Transportation via dispatch vessel is authorized.

On January 30, 1928, the work having progressed fairly well and the date of completion of the job being some three months off, a new order was issued concerning leave and liberty, from which the following essential paragraphs are quoted:

3. (*a*) Commanding officers may grant to each officer and man not to exceed four days' leave during the calendar month of February, provided the commanding officers are positive that the absence of any certain officer or man will not decrease the effectiveness of their ships nor delay the progress of the salvage operations as a whole.

(*b*) The four days' leave will be taken all at one time and must be counted from the time of leaving ship to time of return to ship, e. g., go 1st and return on board 5th, go 16th and return on board 20th.

(*c*) No substitutions nor duplications shall be allowed. No extensions can be granted. The nonreturn of any man must be considered as probable cause for the postponement or stopping of some other man's (relief's) turn for leave.

4. Emergency requests for leave, for both officers and men, shall be referred to the force commander with appropriate recommendation, by dispatch if necessary.

5. Special arrangements for leave for all divers will be made and regulated by the commanding officer, *Falcon*, subject to the approval of the salvage officer.

6. Daily liberty on shore in Provincetown may be granted to not more than 15 per cent of the crew, during afternoons and evenings, when practicable, and at the discretion of commanding officers. All such liberty shall expire not later than the departure from Provincetown Wharf of the C. G. patrol boat at 2200.

A subsequent order dated February 24, 1928, issued by the commander, *S–4* salvage force, continued the four days' leave and other arrangements through the month of March.

After about five weeks of salvage work on the *S–4*, when the number of "proved" divers had increased sufficiently, the divers were divided into three sections, of which two sections were working during any one week, the third section being on leave for a week. Thus each diver on the regular list was working for two weeks and was then permitted to take leave the third week, continuing in rotation.

Part V.—Section 8. Wreck Watch.

The following is quoted from paragraph 5 (*i*) of commander *S–4* salvage force letter of January 26, 1928:

Wreck watch.—Sagamore or *Wandank* (or *Mallard*), as assigned, will ordinarily take station 300 yards southwest of white can buoy AA, but in bad weather may anchor to leeward of wreck but close up. Keep continuous watch on mooring and marker buoys, warn off shipping—display red breakdown lights by night and danger signal by day. When *Falcon* is moored over *S–4* during fog, watch vessel will sound five long blasts on whistle every two minutes. When *Bushnell* and *Falcon* are both away from wreck, make report of weather and sea conditions every four hours. *Wandank* and *Sagamore* will alternate in 48-hour tours of duty, relieving at 0900 on *even* days.

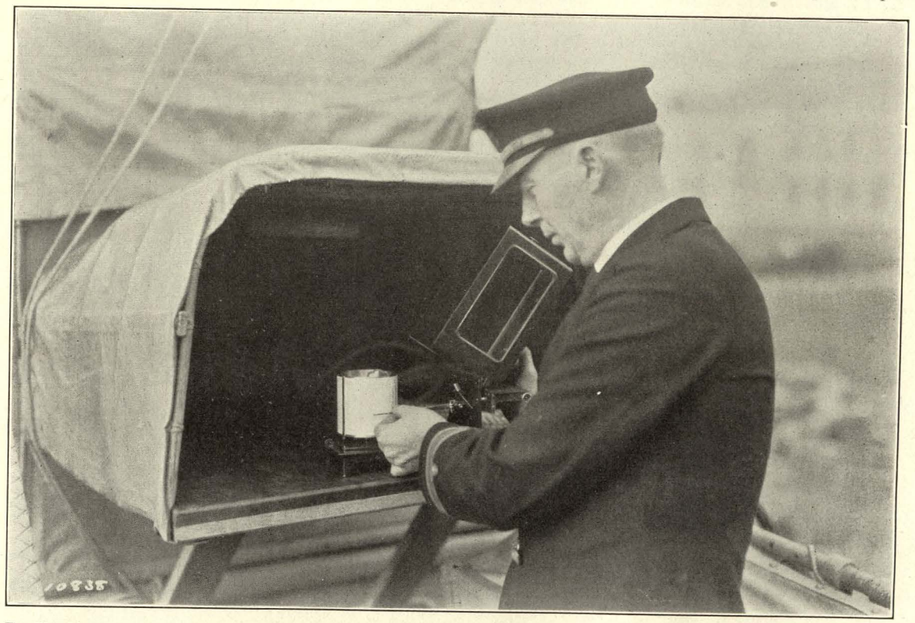


FIG. 20.—Lieut. Commander Gilbert H. Mankin (M.C.), United States Navy, with hydrograph as used during *S–4* salvage operations for recording relative humidity, as affecting operation of diving air plant

Part V.—Section 9. Operation of Diving-Air Plant, Diving Vessel.

It was customary, when diving operations were contemplated or were in progress, to have *both* diving-air compressors in operation, running on their governors, although air in sufficient quantities could be supplied by one alone. Should one compressor stop or fail to function, the other compressor was immediately available to take the load. The air valves of each diving compressor were overhauled every 48 hours—in other words, the air end of one compressor was cleaned every night, after diving had ceased.

After the installation of the air-conditioning apparatus on the *Falcon*, the operation of the diving-air plant became quite manifestly an important part of the routine. The plant was started daily at 5 a. m., so as to afford ample opportunity to heat up all the lines, clear out the moisture and stale air and have the system settle down to operating temperatures by the time that diving was to begin. A warrant officer or, during his meals, the salvage officer or a trained chief petty officer, stood a deck watch on the system continuously while diving was in progress, watching air pressures and temperatures and flow of circulating water and draining the apparatus of deposited moisture, as well as making routine or special reports to commanding officer, salvage officer, and chief diving supervisor concerning the functioning of the plant.

As a rule, the relative humidity decreased materially as the sun came up and increased again toward the end of the day when the sun went down. Since the relative humidity at no time was sufficiently low to insure the delivery of air from the compressors, after decreasing its volume about 11 times, at less than 100 per cent humidity, the relative humidity of the atmospheric air, as indicated by the hygrograph (fig. 20), was really not a determining factor in regulating the dew point of the air supplied to the divers. The relative humidity was, however, a gauge of the amount of moisture which had to be extracted from the air in the conditioning process, and hence served as a means of regulating the operation of the apparatus. At times when the relative humidity was from 50 to 70 per cent, it was customary to blow the moisture out of the cooler at intervals of from 15 to 20 minutes. When the humidity rose to 90 or 100 per cent, the moisture was blown out at intervals not exceeding 10 minutes.

Part V.—Section 10. Logs, Records, and Reports.

The technical log of the salvage operations was kept up to date, day by day, including a list of diving days, number of dives, and names of divers, in addition to which the schedule of outstanding work and record of work done on the *S–4* was revised from time to time. The additional data subsequently recorded is listed and described in Part XVI following.

At least twice each day, once after work was begun in the morning and again at the conclusion of the day's work, radio dispatches were prepared and forwarded to the department and to others concerned, giving a brief report of the weather, a statement showing whether diving was being undertaken and a list of the divers down, including a concise description of the work performed by each, and brief mention of any other activities.

At the end of each week, a report describing the week's work was prepared and mailed to the Chief of Naval Operations. This report covered the following headings:

1. Divers.
2. Diving days, weather, etc.
3. Divers' air (air conditioning) and diving apparatus.
4. Tools, telephones.
5. Boats.
6. Logistics, repair work, etc.
7. Transportation.
8. Pontoons, buoyancy, etc.
9. Progress of salvage.
10. Estimated date of completion.

Part VI.—Salvage and Diving Vessel. Section 1. Personnel, Organization, and Complement.

In view of the contemplated fitting out of at least five submarine rescue vessels and the necessity for assembling at least the nucleus of a competent salvage party on each vessel, the full organization and complement of the *Falcon*, when well under way on the *S-4* operations, is quoted in full.

ORGANIZATION U. S. S. "FALCON" FOR SALVAGE OPERATION

Lieut. Henry Hartley, United States Navy, commanding officer of ship, deputy salvage officer. Handle all matters pertaining to seamanship aft. To habitually remain on deck while divers are down.

Chief Boatswain E. Burnett, United States Navy, executive officer, ship's material officer. Handle all matters pertaining to seamanship forward. To habitually remain on deck while ship is in moorings.

Chief Boatswain R. E. Hawes, United States Navy, commissary and communication officer, boat officer. Available for call at all times.

Gunner F. E. Church, United States Navy, air control. Will see plant started daily at 0500. Air routed through the system as ordered by the commanding officer. Secure the plant when diving is suspended. Make

Officers attached to *Falcon* during salvage operations.

FIG. 21.—Standing, left to right: Chief Machinist E. A. Healy, engineer officer; Gunner F. G. Church, gunnery officer; Lieut. Henry Hartley, commanding U. S. S. *Falcon;* Chief Gunner F. J. Kaiss, assistant diving supervisor; Lieut. Commander G. H. Mankin, medical officer; Chief Gunner W. F. Loughman, assistant diving supervisor. Seated at right: Chief Gunner C. L. Tibbals, diving supervisor. Kneeling, left to right: Gunner John Nicol, diver; Chief Boatswain R. E. Hawes, boatswain; Chief Boatswain E. Burnett, executive officer

no change in the routing of the air unless ordered by the commanding officer (except in case of emergency, in which case, act first and report afterwards). Aide to salvage officer for control of air temperatures. Will habitually remain on deck while diving is in progress.

Chief Machinist E. A. Healy, United States Navy, chief engineer and electrical officer. Will keep plant as a whole in operating condition at all times. Steam on both boilers, while in moorings, ready to move on bell; at anchor, ready to get under way on 15 minutes or one-half hour notice as ordered. In charge of all portions of air plant below main deck. Will see that valves of diving-air compressor are removed, cleaned, and wiped off with oil rag (*castor oil only*) each 48 hours, i. e., overhaul one compressor each night. When divers are down will alternate on watch over diving compressor with chief machinist mate; that is, either the chief engineer or chief machinist mate will be in fireroom or fireroom uptakes and within hearing distance of compressor

Chief Gunner C. L. Tibbals, United States Navy, diving supervisor. Will habitually remain on deck while diving operations are going on.

Chief Gunner W. L. Loughman, United States Navy.

Chief Gunner F. A. Kaiss, United States Navy.

Assistants, diving supervisor, will habitually remain on deck during diving operations. One must always be on duty in actual supervision over divers on bottom.

(NOTE.—In addition to the above Lieut. Commander G. H. Mankin (M. C.), United States Navy, was attached to the *Falcon* as diving medical officer. Figure 21 is a photograph of these officers.)

DIVERS

First section:	Second section:	Third section:
Eadie, T., C. G. M.	Eiben, J., C. T. M.	Crilley, F. W., C. G. M.
Carr, W. J., C. B. M.	Wilson, R. C., C. T. M.	Wickwire, W. C., C. G. M.
Scott, C. W., B. M. 2c.	Grube, A. C., T. M. 1c.	Baker, J. E., Cox.
Burd, D. E., T. M. 1c.	Kelley, J. R., C. T. M.	Applegate, C. E., Cox.
Mattox, E. A., C. T. M.	Miller, F. B., T. M. 1c.	Harris, H. P., C. G. M.
Michels, F. G., C. T. M.	Von der Wall, F. G., C. T. M.	McMullen, J. F., Sea. 1c.
Kallinoski, E., T. M. 1c.	Schmidt, C. J., C. T. M.	Stanley, J. (C. G.), Mo. M. M. 2c.
Johnson, W. C., C. T. M.	Sherwood, H., C. T. M.	Dewberry, T., C. G. M.

NOTE.—Divers will be given one week's leave in three; i. e., work two weeks, go on leave one week. The period of leave will begin and end on board the *Falcon* each Sunday. Men who are on the diving list *must* be sent down in their turn, until such time as they may be disqualified or new men prove themselves better divers. In other words, it is desired to have available for work at all times 16 divers who can take their regular turn at work when 17 are available. The most incompetent divers on the list will be removed from the diving crew and put on one of the dressing and tending crews, preferably in the section that the latest diver added to the diving list came from, so that one list of men does not deplete another.

It is not the intention to actually restrict the number of divers to the 24 or 16 available, but we have a limited number of men to work with, and can't afford all corporals and no privates. Divers will not be allowed to exchange leave period. They do not have to go on leave, but if they wish to take advantage of this leave system they must go with their section.

FIRST DRESSING AND TENDING CREW		SECOND DRESSING AND TENDING CREW	
Holden, G. F., C. T. M.	First section, dress, tend, undress first diver, tend, light, hose.	Deady, C. A., C. T. M.	First section same as first section, first crew, or take third diver.
Witters, T. S., T. M. 2c.		Joy, E. S., T. M. 1c.	
Bierer, J. T., T. M. 1c.		Johnson, I., Sea. 2c.	
Smith, A. M., G. M. 3c.		Poston, J. T., G. M. 1c.	
Winter, F. A., C. T. M.	Second section, take care of second diver, as first section does first diver.	Bedford, H. H., C. M. M.	Second section, same as second section, first crew; or take third or fourth diver.
Schuchman, L. L., T M. 3c.		Brown, H. L., C. T. M.	
Engle, F., T. M. 1c.		Anderson, J., T. M. 1c.	
Evans, G. L., Sea. 1c.		Duckett, R. G., Sea. 2c.	
McNulty, P. C., G. M. 2c.			

NOTE.—When but two divers are down one dressing and tending crew may go below. Crew will relieve each other for meals.

HOSE TENDERS

First crew: Doherty, C. F., C. T. M., plus working party from *Bushnell.* See that this detail of men are divided equally on hose, etc.

Second crew: Plus working party from *Bushnell.*

Men on diving list, but who are not actually diving, will assist dressing and tending crew. These men to date are:

Dewberry, T., C. G. M.	Von Der Wall, J. H., C. T. M.
Stanley, J., Mo. M. M. 2c. (CG).	Johnson, W. C., C. T. M.
Sherwood, H., C. T. M.	Bedford, H. H., C. T. M.
Schmidt, C. J., C. T. M.	Skumautz, V. J., Sea. 1c.

LOCK TENDERS

Syphax, R. H., C. B. M.
Frazer, J. W., C. T. M.
David, H. R., Ph. M. 1c.
Bailey, H., C. G. M.

Gairing, A. A., C. T. M.
Lehr, F. J., G. M. 1c.
Parker, V. G., T. M. 3c.

TELEPHONE MEN

Casabella, J. C., T. M. 1c.
Svoboda, C., F. C. 1c.
Stahlheber, R. C., F. C. 1c.

Collier, J. E., Sea. 2c.
McCone, J., E. M. 1c., also repair man.

DIVING HOSE, HELMETS—UPKEEP AND REPAIR

Sanders, S. E., C. T. M.

Clemens, H. R., Cox.

FLOOD AND SEARCH AND WATER LIGHTS

McCone, J., E. M. 1c.

Williams, D., E. M. 2c.

C. & R. GANG (PONTOONS, HOSE AND FITTINGS, TOOLS, ETC.)

Weaver, A. W., C. S. F., towing engine.
Badders, W., C. M. M., winches as required.
Pasternacki, P., S. F. 1c., anchor engine.
Warner, M., C. M. 3c., capstan.

Hammett, J. H., C. M. M., deck winches; also burning and cutting torches.
Moore, W. O., C. M. M., air compressors.

MEN REGULARLY ATTACHED TO VESSEL

Carr, William J., C. B. M.	Diving.	Blumberg, E. R., C. R. M.	Radiomen.
Whittliff, C. A., B. M. 1c.	Deck forward.	O'Neil, L. A., R. M. 1c.	
Brouillette, J. P., B. M. 1c.	Deck aft.	Mulligan, V. M., Sea. 2c.	
Rogers, C. A., B. M. 2c.	Surfboat (coxswain).	Weaver, A. W., C. S. F.	C. & R. salvage, blowing hose, etc.
Burton, G. E., Cox.	Surfboat and deck winch.	Hammett, J. H., C. M. M.	
Gallons, J. E., Cox.	Captain hold; storekeeper.	Pasternacki, P., S. F. 1c.	
Lehr, F. J., G. M. 1c.	Recompression chamber.	Moore, W. O., C. M. M.	Air compressors.
Parker, V. G., T. M. 3c.	Do.	Cauffield, R. C., F. 1c.	Surfboat (engineer).
Snyder, S. L., C. Q. M.	Temperatures and report to salvage officer.	Varano, P. N., M. M. 2c.	On full steaming watch continuously.
Canady, L. C., Q. M. 1c.	Quartermaster and signal watch.	Flowers, H. H., Eng. 1c.	
Wardrop, R., Q. M. 3c.		Simms, D. D., Eng. 1c.	
Hebert, J. H.,S . M. 2c.		Corbett, J. J., Eng. 2c.	
Collier, M. H., S. M. 3c.		Camp, L. R., Eng. 2c.	
Williams, G. B., Sea. 1c.	Winchman.	Ottinger, D. P., C. W. T.	
Waltz, N. E., Sea. 1c.	Do.	Shicosky, J. L., W. T. 1c.	
Soignier, A., Sea. 1c.	Surfboat.	Grant, R. H., W. T. 2c.	
Bond, H. J., Cox.	Winchman.	Cox, E. A., F. 1c.	
Roberts, Abe W., Sea. 1c.	Do.	Fort, W. H., F. 2c.	
Deverle, H. W., Cox.	Do.	Dunfee, J. A., F. 2c.	
Thompson, H. B., Cox.	Do.	Randall, R. H., F. 2c.	
Bentz, J. H., Sea. 2c.	Deck.	Hansen, C. J., F. 3c.	
Berard, G. N., Sea. 2c.	Compartment cleaner.	Humphries, M. L., F. 3c.	
Collier, J. E., Sea. 2c.	Telephone, diver.	David, H. R., Ph. M. 1c.	Recompression chamber.
Frogge, L. L., Sea. 2c.	Mess cook.	Borron, J. P., Yeo. 1c.	
Gervais, Hubert J., Sea. 2c.	Dec.	Stephenson, O. G., C. Std.	
Grant, O., Sea. 2c.	Mess cook.	Nesgoda, W. J., Bkr. 1c.	
Gruszanski, J. C., Sea. 2c.	Winchman.	Selfridge, J. O., S. C. 1c.	
Guillory, R. R., Sea. 2c.	Deck.	Flynn, B. J., S. C. 1c.	
Helms, J. B., Sea. 2c.	Mess cook.	Desjardins, A. J., S. C. 3c.	
Johnson, T. B., Sea. 2c.	Do.	Pico, J., O. C. 3c.	
Williams, D., E. M. 3c.	Telephones and lights.	Lalata, C., O. S. 3c.	
		Wilhelm, G., M. Att. 1c.	
		Abellon, P., M. Att. 2c.	

HENRY HARTLEY,
Lieutenant, U. S. Navy, Commanding.

Part VI.—Section 2A. Salvage Hatches.

The salvage hatches used by the *Falcon* for the *S–51* job and subsequently made a regular part of the equipment of the rescue vessel, were modified somewhat and were used on the *S–4*. (See figs. 62 and 63.) Certain changes had of course to be made to suit local conditions on the latter vessel, and in addition the type of auxiliary strongback and the method of slinging the hatch for lowering and placing (fig. 61) were improved and developed.

The arrangement of salvage hatches and spill pipes has already been quite fully described in Bureau of Construction and Repair Technical Bulletin No. 2–27, containing the report on salvage operations, submarine *S–51*, pages 18, 20, and 38, and the details are believed to be quite generally known. However, the descriptive data previously available is supplemented by photographs in this report, showing—

(1) The manner of making up and attaching the slings to cause the hatch and spill pipe to rest level when lowering. (Fig. 63.)
(2) The auxiliary strongback of sheet steel (fig. 61) which was placed over the lugs in the sides of the engine-room hatch trunk to hold the upper end of the kingbolt accurately in the center of the trunk and hatch opening.
(3) Painting of the strainer a white color (fig. 58) to facilitate watching and guiding it into place in the bilges when lowering the hatch.
(4) The manner of conducting air through the hatch to an air line within the compartment by means of a separate hose connection and an auxiliary air hose underneath as shown in Figure 125.
(5) One and one-fourth-inch globe valves provided on top of each salvage hatch for flooding the respective compartments.
(6) Suitable arrows and markings painted on the hatches to indicate the portion which was to point forward, the location of special valves, and so forth. (See fig. 59.)
(7) The guides for entering the hatch in the trunk are shown in the photographs (figs. 58 and 125) on the under side of the hatch plates.

These salvage hatches as now regularly carried by the *Falcon* are useful for S-class submarines and are of satisfactory and adequate design except that the lead washers which were used on the *S–4* under the securing nuts became deformed and torn as shown in Figure 127. For subsequent work there should be used a rather narrow close-fitting lead washer lying under a steel washer, upon which the nut would bear. Sufficient pressure could then be exerted by the nut to flatten the washer inward against the threads, making it act as a grommet.

The spill pipes on the *Falcon* salvage hatches placed in the engine and motor rooms were originally built as suction pipes, since they had a foot or check valve at the bottom, built into the strainer. This gear served very well, but there is some advantage in the arrangement adopted in the torpedo room of having the flooding valve directly on the spill pipe with the check valve above it, as by this means any deliberate flooding of the compartment after the first blowing operation (as was customary on *S–51* and *S–4*) serves to wash all rags and débris away from the strainer and clear it, an operation which is not possible when there is a foot valve or check valve at the bottom of the spill pipe.

Part VI.—Section 2B. Miniature Salvage Hatch or Air Connection.

The miniature salvage hatch shown in Figures 22, 23, and 24, was designed and fabricated to serve as an air-blowing connection in locations where it was not feasible or where time did not permit the laborious drilling and tapping of a hole and where a rough hole could be burned instead. The idea was supplied by Chief Gunner C. L. Tibbals and this fitting was sketched and manufactured overnight on the *Bushnell* for possible use in the bottom of normal fuel-oil

tank No. 6 on the *S–4*, to be inserted in a rough hole burned into the outer hull plating by the air torch. The device shown is not a particularly fancy piece of work, although it serves the purpose and has now been made a part of the regular equipment of the *Falcon*.

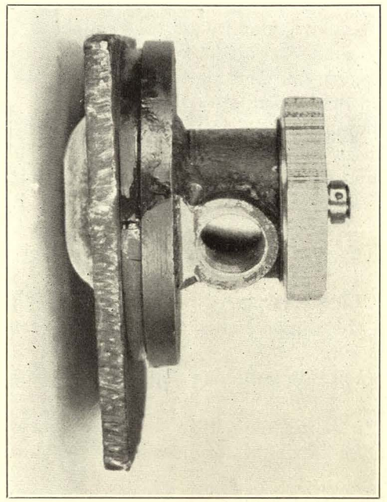


FIG. 22.—Miniature "salvage hatch" or toggle-type air connection. The plate with burned edges represents the boundary of the hull or of a tank. The toggle is shown at the extreme left with the securing nut and air connection at the right

A plate fitted with a gasket of square section on one side and a chamber on the other side is clamped to the outside of the compartment or tank boundary by a toggle and bolt inserted through the burned hole. The plate is held against the hole with one hand and the nut and toggle-bolt assembly inserted through the chamber and the hole in the plate with the other, the toggle being placed parallel to the bolt for this purpose. A slight backward and hooking motion engages the toggle, whereupon the nut is set up and screwed home, a ring washer making a tight joint against the chamber. The air connection is made directly to the side of the chamber by a nipple and the male half of a union screwed in beforehand. The nut is made with a long recess and with the threads toward the end of the cone in order to give the greatest "reach" on the toggle bolt and to prevent the toggle bolt from projecting when the device is in place. The whole operation of placing, attaching, and securing this miniature salvage hatch can be performed in a few minutes.

Part VI.—Section 2C. Combination Drill, Tap, and Stopcock, Description and Use.

There was developed by the navy yard, Boston, an ingenious contrivance for making an air connection through the boundary of a compartment or tank in a single operation. The photographs (figs. 25 and 26) will perhaps be found self-explanatory but the following description is furnished, together with the method of operation.

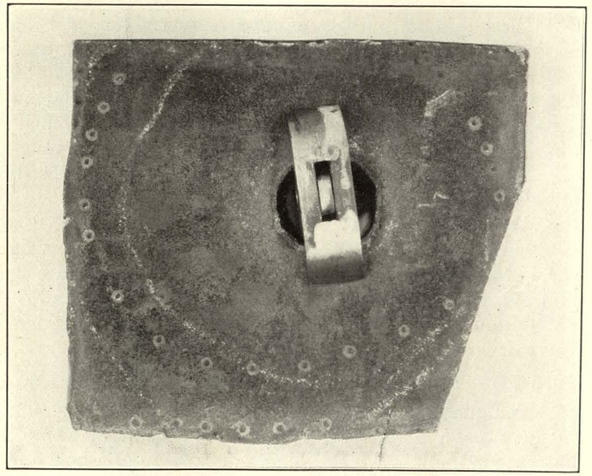


FIG. 23.—Toggle-type air connection looking from inside showing toggle engaged and secured and space for passage of air

This device is made up of tool steel and comprises a pilot drill, ⅜-inch pipe drill, standard pipe tap and ⅜-inch cock made in one piece. The ⅜-inch pipe drill makes a 9/16-inch hole. The outlet end of the cock has a standard ⅜-inch pipe connection. A ⅜-inch hole runs through the cock, down the shank of the tap and drill, with 3/16-inch side outlets. The adapter has a standard ⅜-inch pipe coupling thread on one end for connecting to the outlet

end of the cock, and at the other end is a standard No. 2 Morse taper shank for fitting in the chuck of an air drill.

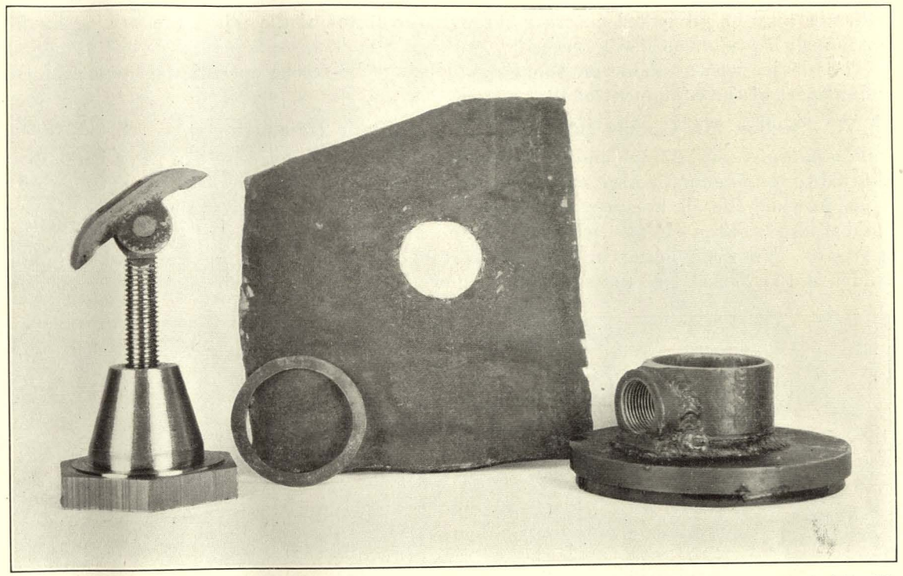


FIG. 24.—Toggle-type air connection, disassembled. Toggle, toggle bolt, and securing nut at left. Washer for nut and plate with rough-burned hole in center. Faceplate with chamber, air connection, and gasket at right

The method of use is as follows: The adapter is screwed to the end of the stopcock and the whole device inserted in the drilled chuck. The end of the drill is then pressed against

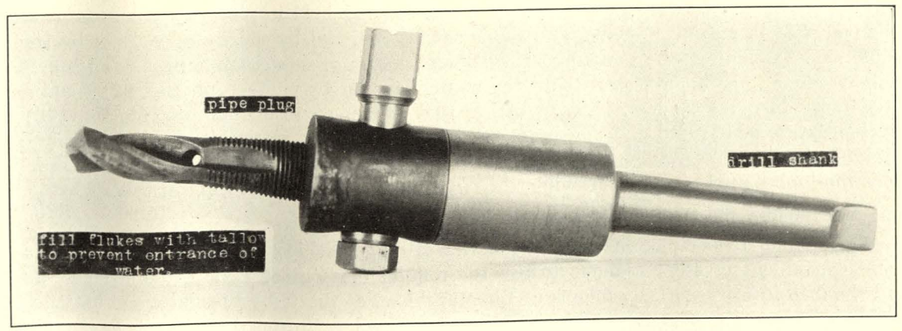


FIG. 25.—Combination drill, tap, and pipe connection assembled ready for drilling

the surface to be tapped and the air drill started. Caution should be exercised to stop the air drill as soon as the tap has entered the surface; the threaded portion should be screwed in by hand to prevent breaking. As soon as the cock is screwed home the air drill is reversed, unscrew-

ing the adapter and leaving the standard ⅜-inch pipe connection ready for air or oxygen hose connections. Care should be exercised to see that the stopcock is closed before uncoupling the adapter.

Water may be prevented entering through the flutes of the tap while drilling by filling these flutes with tallow or hard grease.

This device was available on the *Falcon* during the rescue operations and now forms a standard part of the equipment of that vessel.

Part VI.—Section 2D. Clamps and Tools for Pneumatic Hammers.

Photographs (figs. 27, 28, and 29) illustrate a device developed by the navy yard, Boston, and fitted to the pneumatic air hammers on the *Falcon* for retaining in place the cutting tool and the piston while the air hammer is being operated by the diver. A shallow groove is turned around the body of the hammer near the end, and a split collet is fitted with a tongue which enters this groove. The collet has an internal recess at its outer end about 1 inch long which holds the shoulder of the tool and at the same time allows about one-half inch longitudinal movement

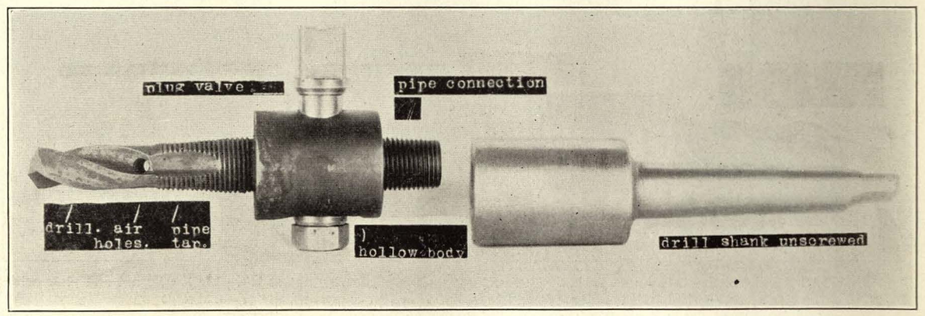


FIG. 26.—Combination drill, tap, and pipe connection disassembled

of the tool, sufficient to insure full travel of the piston and full impact on the tool. The two halves of the collet are threaded on the outside and are held in place by a knurled band or collar screwed in place by hand. Dull tools can be replaced by sharpened ones or by tools of a different shape in less than one minute without the use of special appliances. The operation of the pneumatic hammer assembly in the manner shown by photograph (fig. 27) is eminently satisfactory in every respect. The splitting tool shown at 10 on photograph (fig. 148) was developed to enable rapid and continuous cutting of the thin plating encountered around the topsides of submarines. The long round tongue enters a hole or nick previously made and holds the tool securely in position while the cutting edge splits the plating in two.

Part VI. Section 2E. Drilling Machines and Pneumatic Tools.

Concerning the employment of pneumatic drilling machines, it was in no case on the *S–4* found convenient or advantageous to use the regular or modified style of "old man" and to feed the drill into its work by means of the star wheel at the top. Special wood battens were made up, about 2 by 4 inches in cross section and of a length from 4 to 6 feet, having clips or hooks at one end for catching under the adjacent structure. The middle of the batten was placed over the point at the top of the drilling machine and the free end was held down by a second diver, who in almost every case had to lock his feet or his knees under some part of the vessel in order to apply the necessary downward force, since in his suit he was almost buoyant.

While this method seems somewhat archaic and crude, it was found to be quite rapid and satisfactory and was in almost every case the one preferred by the divers.

Pneumatic hammers, size 60, and pneumatic drilling machines Nos. 2 and 3, were carried as regular equipment and were used to advantage at depths up to 100 feet. Air was supplied through 250 feet of diving hose with the usual 3-foot leader attached to the pneumatic tool itself. These tools were for a time operated by air supplied from the diving air main at 100 pounds per square inch, giving an effective pressure at the tool of not more than 50 pounds, as the lines rapidly froze up if air were taken in the usual manner from the salvage main. Their operation was much more satisfactory of course when arrangements were later made to take their air from the diving air main at 150 pounds per square inch, giving an effective pressure under water of from 80 to 90 pounds, equal to that obtaining in most navy yards. For satisfactory continued operation of these tools, it was imperative that conditioned air be used to prevent freezing of the air lines; this air was finally taken off the diving air main beyond the heater but ahead of the reducing valve.

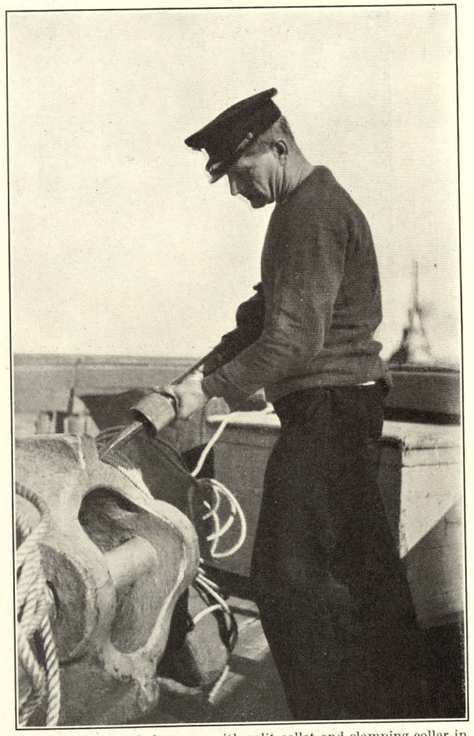


FIG. 27.—Pneumatic hammer with split collet and clamping collar in place, ready for use by diver. This device prevents loss of the tool under water in case the cutting edge slips off the work

Part VI.—Section 2F. Cutting Hooks.

Hooks of forged and tempered steel, fitted with knife edges on the inside, as shown in Figure 31, formed a part of the equipment of the *Falcon* for use in the hooking, cutting, and clearing away of rigging, rails, and other relatively light structures.

These hooks are easily set by a diver, can be engaged in a locality where only a small opening is available, and, on the end of a stout wire hauling line, form highly efficient cutting and clearing tools. One of the hooks illustrated was used for cutting away all the sections of clearing lines, antenna wires, etc., on *S–4*.

Part VI.—Section 2G. Underwater Gas Cutting Torch.

The oxyhydrogen air underwater cutting torch as developed and perfected up to and including the period of the salvage operations on the *S–51*, and as described in the salvage report on that vessel, Bureau of Construction and Repair, Technical Bulletin No. 2–27, pages 24, 28, and 52, was available on the *Falcon* from the start of the rescue and salvage operations of the *S–4*.

The flasks for carrying the gas with which to supply this torch were at first laid out horizontally in rows on the port side of the superstructure deck where they were in the way and had to be walked over continually. They were connected together in banks by the use of a short manifold of heavy pipe. The flasks comprising these banks were later stowed vertically along

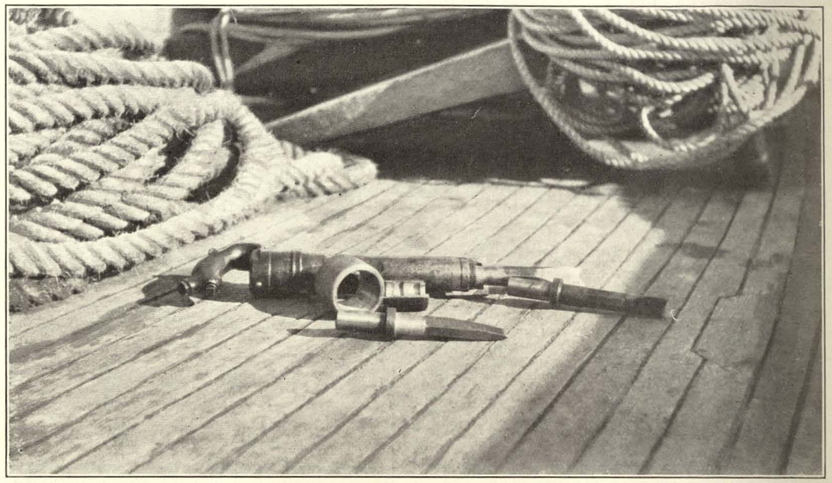


FIG. 28.—Pneumatic hammer with split collet for holding shouldered tools in place when used by a diver. Note groove cut in body of standard hammer and ½-inch longitudinal clearance for tool

FIG. 29.—Same as Figure 28. The tool in the hammer was used on the *S-4* for ripping a hole in ⅛-inch fairwater plating

the port side of the main air receiver on the superstructure deck as will be seen from the photograph. (Fig. 32.) The air supply for this torch was taken from the diving air main.

One practice dive to test out the torch was made by Kelley on December 21 at the scene of the wreck. After this one trial with the latest model of torch, the salvage force resorted to the older 1920 model torch which was used on every succeeding dive. (See fig. 33.) A second practice dive was made by Kelley on January 15 to a depth of 90 feet, during which dive he succeeded in cutting a clean hole through the double-thickness (two times seven-sixteenths inch) test plate representing the inner hull of the *S-4* in way of the torpedo room and in making a number of other cuts through three thicknesses of metal. The work that he performed on this dive is shown in Figure 34 and the template that he used is shown also in Figure 162.

The gas underwater cutting torch was used by Kelley on January 13 and again on January 28 in an endeavor to prepare for and burn a hole through the top of the torpedo room in order to

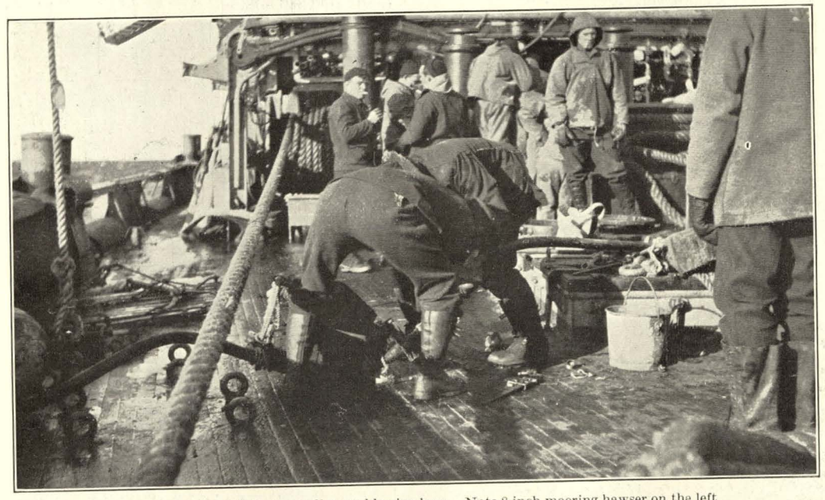


FIG. 30.—After deck of *Falcon*, coupling up blowing hose. Note 8-inch mooring hawser on the left

fit the spill pipe to that compartment. On the latter date great difficulty was experienced in maintaining the proper pressures at the torch so as to make it operative; it was quite obvious then, and it is almost certain, now that these difficulties were primarily due to freezing of the air line to the torch, and secondarily to freezing of the oxygen line to the torch.

Even in the hands of Kelley, who had the greatest experience with it, and later in the hands of Carr, who actually did some burning on the vessel with it, the gas torch was a very tricky piece of mechanism, necessitating the most careful adjustment of pressures in order to keep it burning and continual tinkering with the igniter, to say nothing of replacing tips when these were burned out due to excess oxygen. (See fig. 35.) In one case the guard or distance piece unscrewed from the torch as the latter was being moved around inside the hole in the steel template. The igniters were found to work fairly well on the deck of the rescue vessel, but when taken below by the diver the operation of the igniter with the diving gloves was a rather awkward job, generally resulting in the two braided copper wire contact arms being bent so

that the contact tips remained together. In this condition the igniter would obviously not strike an arc and the heavy current flowing continuously would soon cause the connections to burn up in the handle of the igniter. It was the practice later to turn off the current in the igniter within at least one minute after the diver telephoned to have the current turned on so as to save wear and tear on the igniter and on the resistance units on the salvage vessel. If the diver did not succeed in lighting the torch under water during that minute he was required to

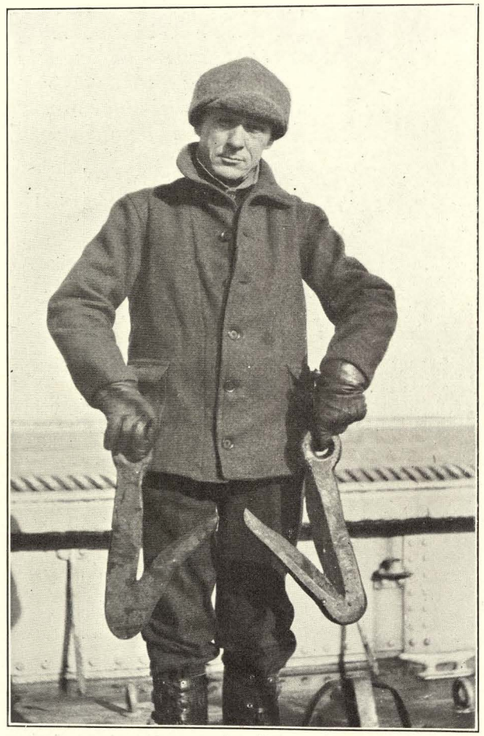


FIG. 31.—Cutting hooks attached to hauling lines on surface vessel for severing rigging and ripping up light structures

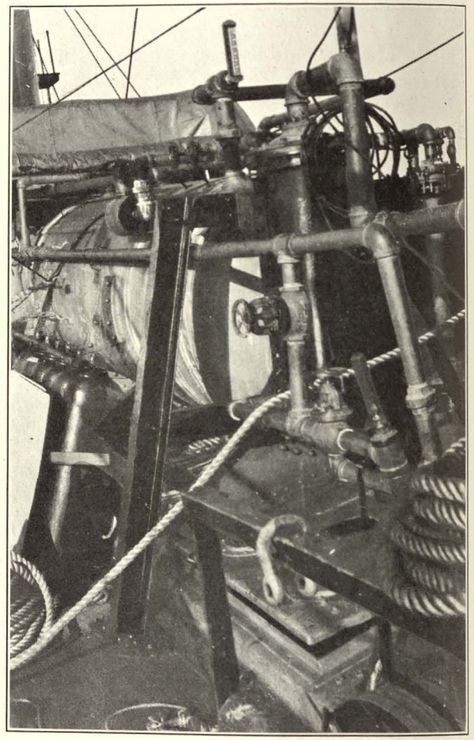


FIG. 32.—General view on superstructure of *Falcon*, showing banks of cylinders for gas torch at left; special air cooler in center and calcium chloride dehydrating unit at right. Pressure-proof cylindrical chamber for hygrometer is just behind upper corner of foundation for cooler. Main air receiver in the background

telephone again for current on the igniter. Resistance units and switches for the igniter circuit were not as rugged as they should have been for the service performed.

An inspection of the photograph (fig. 33) will show the old model torch actually used on the *S–4*, the igniter, the hose and the wire, and the method of lashing the three hoses and the wire together for a distance back from the torch in order to facilitate keeping these hoses clear when working in and around the submarine.

It is unquestionably true that, given reasonable working conditions where hoses will not clog, and pressures which will not vary when once set, the gas underwater cutting torch in the hands of an experienced operator is capable of rapid and efficient work, as evidenced by the

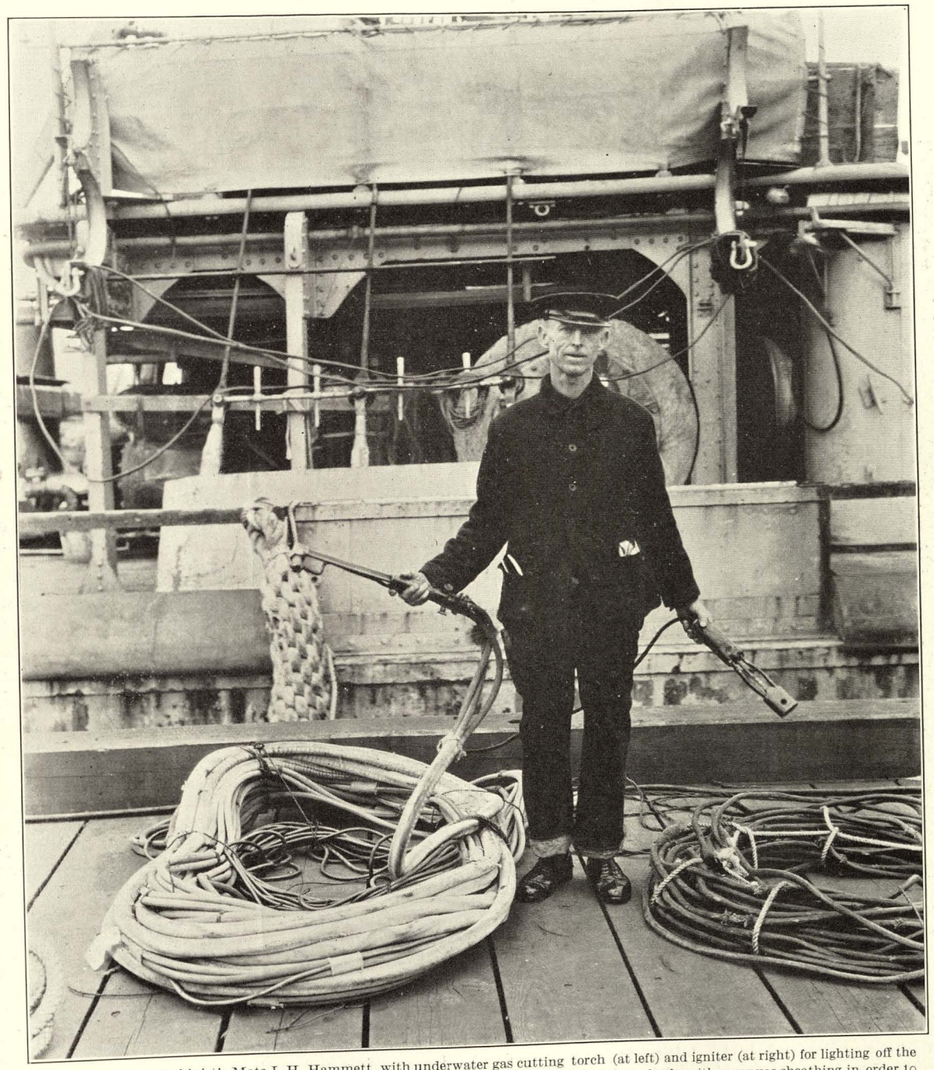


FIG. 33.—Chief Machinist's Mate J. H. Hammett, with underwater gas cutting torch (at left) and igniter (at right) for lighting off the torch under water, showing method of lashing together the three hoses and the igniter leads with a canvas sheathing in order to prevent fouling when working in and around the submarine

work which was done upon the sample plate representing the top of the torpedo room of the *S–4* and shown in photograph (fig. 34). However, under conditions as they were encountered on the *S–4* salvage and in the hands of such divers as were available, whether fully experienced or not, the effectiveness of the gas torch was reduced almost to the vanishing point, as evidenced by the fact that it required the services of at least 10 divers with a total diving time of over nine hours, including the services of 4 divers who worked with a pneumatic hammer, extending over the period January 27 to February 9, inclusive, to make sufficient cuts through the upper course of the double $\frac{7}{16}$-inch inner hull plating of the *S–4* to effect the removal of the piece of metal (about 3½ inches in diameter) shown in the photograph (fig. 36). Two more dives were spent chipping on the lower course, with very little progress. Finally Carr, in not more than 20 minutes, cut the complete hole in the lower course with the arc torch.

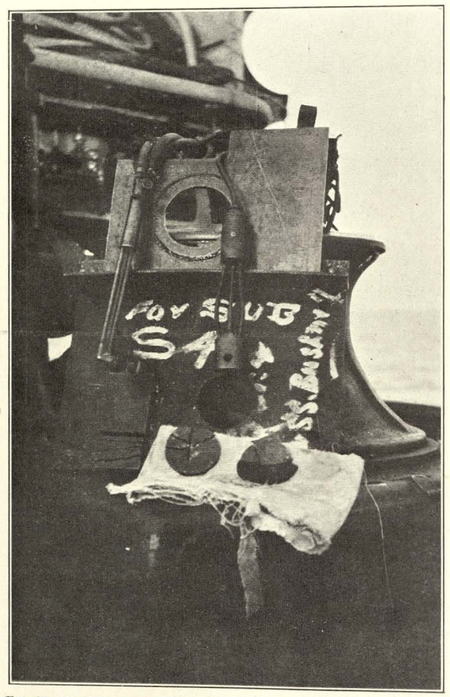


FIG. 34.—Underwater gas cutting torch with igniter. Plate marked "For Sub. *S–4*" was a sample representing inner shell of double 17½-pound plate over torpedo room in way of spill pipe. Hole cut for experimental purposes by the use of the steel template in upper part of photograph

Part VI.—Section 2H. Underwater Arc Cutting Torch.

This torch was developed by private individuals and commercial firms and was first used on submarine salvage work to open the motor-room hatch of submarine *S–48* when sunk off Bridgeport, Conn., in December, 1921. This torch had been used by some of the personnel on the *Falcon* previous to the *S–4* operations and was considered to be a proved piece of apparatus, positive in its action, although slower than the gas torch. Although this torch has been in general use for underwater work for some years, its operation and its capabilities are not generally understood. The following is quoted from the Marine News of March, 1925, the remarks in parentheses being added for purposes of this report:

One lead (the positive) from the generator is connected to the plate to be cut (or to any portion of the structure metallically connected to it). The other (negative) lead through the necessary circuit breakers and resistances terminates in a manifold (or valve) at the upper end of the cutting hose. The oxygen hose from the tank gauge valve also terminates in this manifold. Both the oxygen and the electric current then are conducted to the torch through this hose, which contains a copper wire conductor. This wire terminates in a brass coupling into which the electrode holder fits.

A carbon electrode 12 inches long, and containing several (two) small holes drilled lengthwise through it (and through which brass tubes of small bore are inserted) is clamped in the brass electrode holder, the holes making an air-tight connection with the holder at the inner end. This electrode holder is then screwed into the hose coupling and the torch is ready for use. (The holder, coupling, and electrode may then be wound with rubber tape to prevent accidental burning or fusing of the parts should they touch the metal structure when in the hands of the diver.)

The diver descends with the torch and when in position and prepared to burn, signals his attendant. The current and the oxygen are turned on (on the *S–4* job, oxygen at low pressure was turned on as soon as the torch entered the water), the diver strikes an arc upon the metal and the blast of oxygen is directed through the electrode toward that spot on the metal where the arc is playing.

No protection of the arc from the surrounding water is necessary, as the intense heat of the arc immediately transforms the adjacent water into steam and the arc continues to function enveloped in a constantly forming bubble or blanket of steam. The oxygen under pressure directed on the metal heated by this arc both oxidizes and blows the molten metal out of the cut.

In view of the continued difficulties with the gas torch, steps were taken by the *S–4* salvage force about the middle of January, 1928, to rent or acquire an outfit for cutting under water by electricity. The need for this equipment increased at such a rapid rate after its use was first considered that a set of apparatus was eventually purchased and installed more or less permanently on the *Falcon*, the work being completed in record time on February 10. The torch equipment is shown in arrangement and detail on Figures 37 and 38. Some preliminary instruction in cutting steel plates on the deck of the *Falcon* was given to a number of the divers and the arc torch was first used under water on the *S–4* by Carr and Eadie on February 11, 1928. In a single dive Carr succeeded in burning the hole for the torpedo-room spill pipe, work which had been attempted with the underwater gas cutting torch and pneumatic tools off and on since January 28, and in cutting partly through a 6-inch copper pipe forming a part of the outboard ventilation line. (See photograph, fig. 39.) In the next dive Eadie succeeded in finishing the cut, removing the section of pipe, and blanking the line. (See fig. 72.) The work done during these two dives represented the labors of at least two days by the older methods previously in use. The arc cutting torch was subsequently used under water, even in the most awkward locations, by divers who had never seen it before and had never been formally instructed in its use. In almost every case they were able to accomplish some cut-

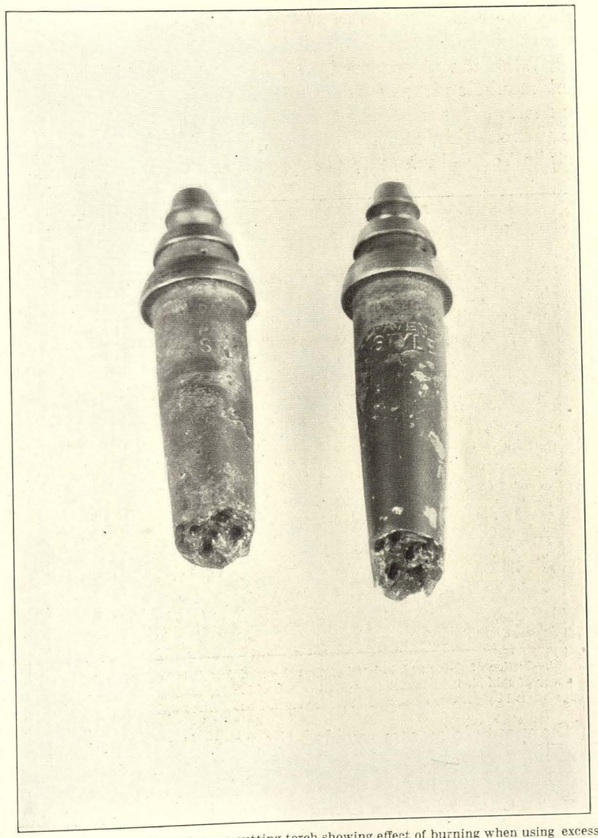


FIG. 35.—Tips for underwater gas cutting torch showing effect of burning when using excess of oxygen

ting, although admittedly at a slow rate. As examples of what may be done, attention is invited to the following.

Photograph (fig. 73) shows blowing holes cut by Wickwire and Carr in the *S-4* outer hull plating, 7/16 inch thick, forming the bottom of the forward trimming tank. This work was done in a tunnel where the working space was restricted and where the visibility was zero. Photograph (fig. 68) shows the results obtained by Carr in burning "a hole" through the 7/16 inch thick outer hull at frame 37½ under fuel tank No. 2; this was also done in a tunnel where everything had to be accomplished by "feel."

When it was proposed later to burn a hole with the arc torch through the outside fuel-oil tank manhole plate at frame 70½ for the insertion of the miniature salvage hatch or air-blowing connection it was manifest that the burning of more than one hole could not be permitted. To prevent this, and to assist the diver in picking up his location when in the tunnel, a wide "stake" of 3/16-inch template wood was made, about 4 feet long and 8 inches wide. One end of the stake was pointed and was to be pushed along between the bottom plating of the ship and the mud to hold it in position. The other end was covered with a sheet of insulating fiber about 1/16 inch thick and through the fiber and the wood was cut a hole about 2½ or 3 inches in diameter. The diver was to push the stake along between the ship and the mud until the hole in the free end of the stake was over the middle of the manhole plate. Then, using the hole in the stake as a guide for feeling, he was to insert the torch electrode inside the hole and burn an opening through the outer shell plating.

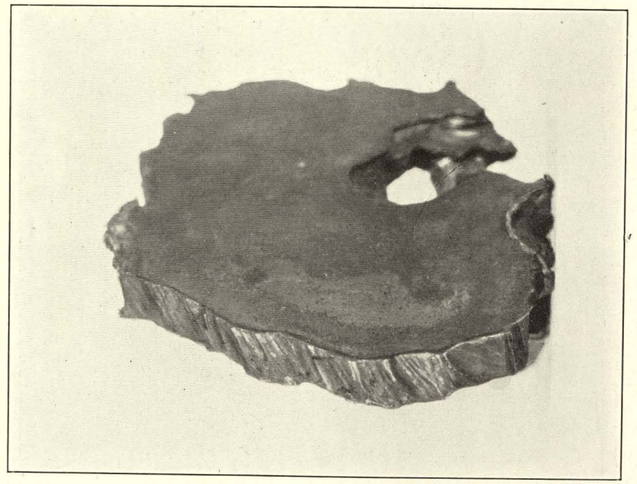


FIG. 36.—Section of 7/16-inch plate forming upper layer of double inner hull over torpedo room in way of spill pipe. The face shown is the one which lay against the lower plate. Note edge burned by gas torch and hole in center burned out between plates

Success in removing one of the manhole screws avoided the necessity for performing this work, so that its success as a working method has still to be demonstrated.

Photograph (fig. 66) illustrates the holes cut through the ¼-inch thick outer hull in three dives by Carr, Eiben, and Crilley to locate the source of certain air bubbles and Figure 129 is a photograph of the plate cut from the outer hull, illustrating the type of work performed. The most outstanding work of all was the cutting away of foundations and floor-plate supports in the port forward bilge of the engine room as accomplished by Carr and Wickwire. This work was performed under the most adverse conditions imaginable. Photograph (fig. 67) shows three different cuts in heavy angle irons and a fourth cut which was only partially completed. The photograph (fig. 39) of the 6-inch copper line previously referred to indicates what can be done with nonferrous metals.

The great advantages of the arc-cutting torch are its ability to cut any material which will conduct electricity and to accomplish this cutting at a certain, although perhaps slow, rate, even

in the hands of divers who have had no previous experience with it. It is much more economical of oxygen than the gas torch and it requires no adjustments or special manipulations whatever by the diver.

The long 12-inch carbon electrodes as furnished with the equipment were designed for continuous work extending over a period of three or four hours. These electrodes, even though

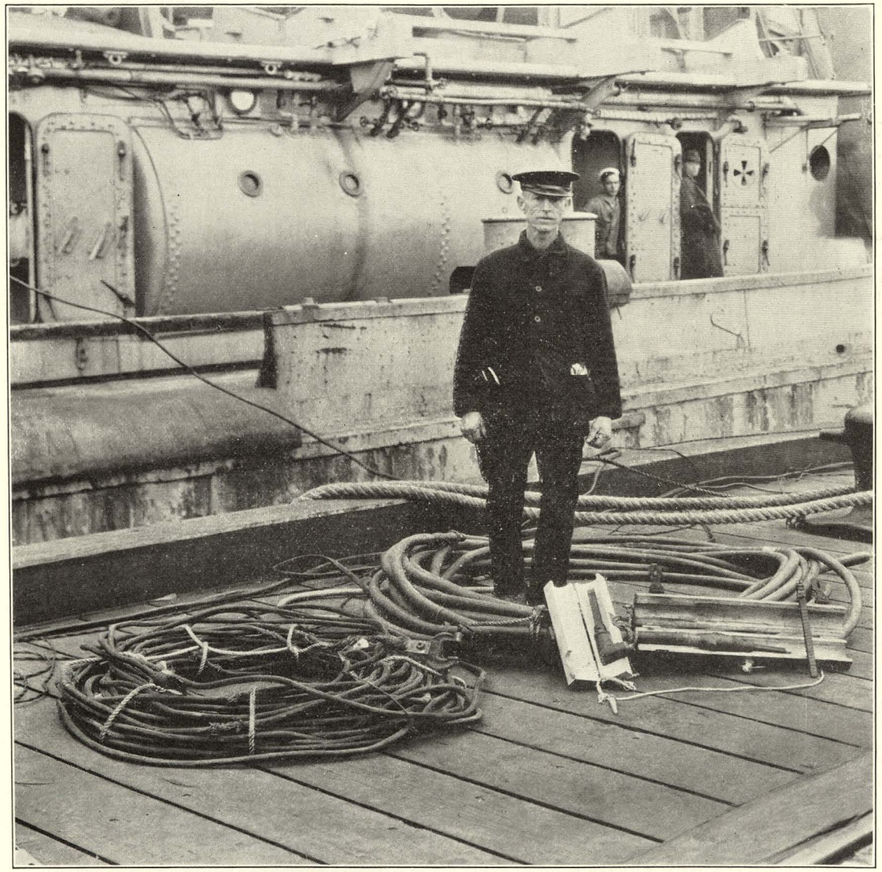


FIG. 37.—General view of oxygen hose, ground wire, and other parts pertaining to the underwater arc-cutting torch. Decompression chamber on *Falcon* in the background

protected by a wooden box, were fragile and easily broken at the base should the diver accidentally bump the tip of the electrode up against any solid structure. (See fig. 40.) The carbon electrodes were subsequently sawed off to a working length of about 6 inches, as shown on Figure 38. This alteration very materially reduced the breakage and the resulting length of carbon was found sufficient for the work of several divers in succession. The 90° angle fitting

shown in the photograph (fig. 38) was used to advantage by Carr in burning the hole underneath the ship at frame 37½, since this work had to be done in a tunnel of limited depth.

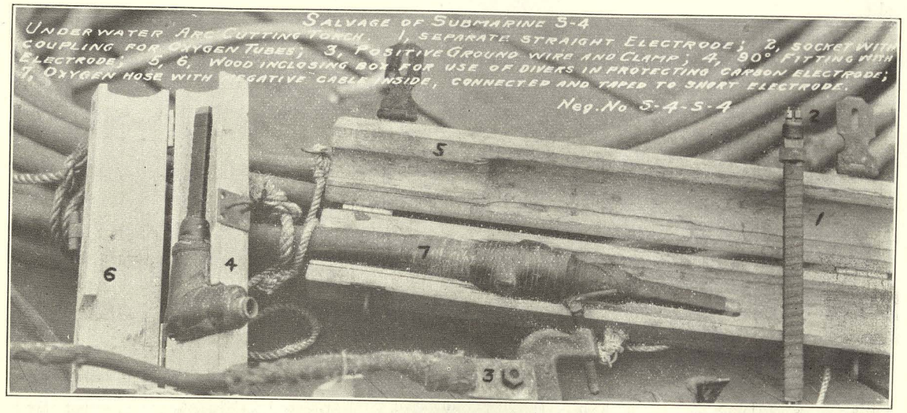


FIG. 38

FIG. 39.—Six-inch copper outboard ventilation line cut through with arc torch in hands of Carr and Eadie. V section was first cut out in order to use torch on inside of pipe, as the latter was accessible only from the top

Although the taping of the electrode and its socket with gum rubber tape was not absolutely necessary, it prevented the formation of arcs and the burning of nicks into or through the electrode whenever the torch touched any intermediate structure which would conduct electricity.

The ground wire and its clamp shown on photographs (figs. 37 and 38) and as actually used on the *S–4* operations were improvised affairs, but they functioned satisfactorily. The ground

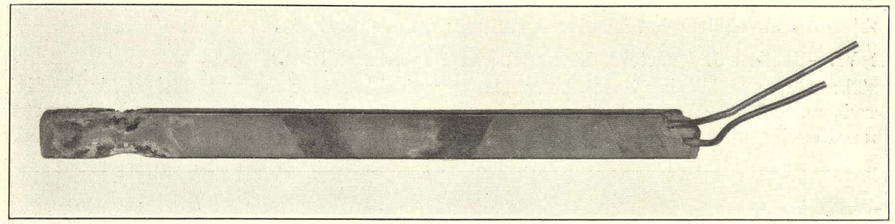


FIG. 40.—Broken electrode for underwater arc cutting torch. Nicks due to side cutting at left; bent oxygen tubes at right

wire was secured to the most convenient location in the vicinity of the cutting operations and the only precautions taken were to scrape the paint off the vessel's structure before screwing the

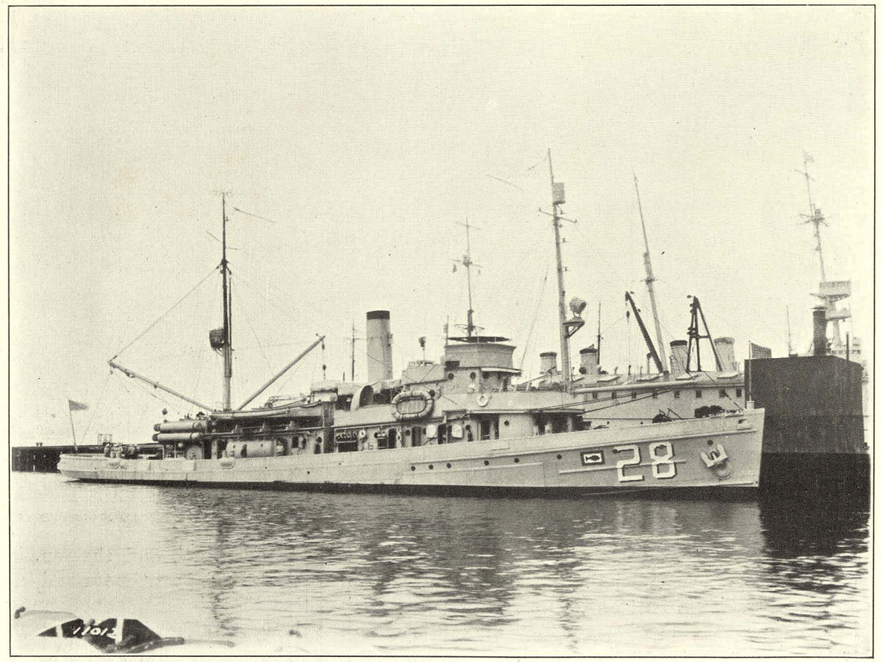


FIG. 41A.—General view of *Falcon*, August, 1928, at completion of overhaul, during which much work recommended by *S–4* salvage force was accomplished

clamp in place. The ground wire, when secured to a step on the after end of the *S–4* conning tower fairwater, served perfectly well when cutting the angle irons down in the engine room.

The 1-inch oxygen hose furnished with this equipment, containing the negative conductor within the hose, is very easily handled; the ground wire, since it does not need to be fully insulated throughout its entire length and since it can be attached to any convenient point, does not form an objectionable obstruction for divers working on the submarine.

Part VI.—Section 3. Quarters, Stowage, and Repair Facilities.

The salvage and diving vessel, *Falcon*, lacked suitable officer accommodations for the diving supervisors, the diving medical officer, and for the salvage officer, all of whom should be quartered on board during extensive operations. The salvage officer and one of the diving supervisors on

FIG. 41B.—Stern of *Falcon*, with new bitts and new pontooning chocks installed. Note low freeboard when ready for rescue or salvage work

the *S–4* operation had to travel back and forth every day to the *Bushnell*, and the remaining two diving supervisors and the diving medical officer had to bunk in the wardroom and in the sick bay of the *Falcon*, on transoms and on cots. The fact that these inconveniences and discomforts were not a hindrance was due almost wholly to the thoughtfulness of the commanding officer and ship's officers on the *Falcon*.

The facilities of the *Falcon* were greatly taxed for the stowage and repair of such material as was required to be on hand for diving operations or for use in the salvage work proper upon short notice. A space had to be provided for the repair and overhaul of diving dresses and gear and all the extra diving gear had to be stored without encroaching upon the living quarters. A dozen or more diving dresses, all those in use for a day, were kept stored in the engine-room

hatch, where they were placed upside down on wooden X frames and left standing against the hatch bulkheads over the engine to dry out. The gangways were cluttered up with at least eight sets of diving hose and telephone cable, each 600 feet in length, as shown in Figure 42, to say nothing of the three or four 7-inch and 8-inch mooring hawsers forward which had to be flaked on deck and the extra hawsers aft which had to be coiled on the fantail. (See figs. 83 and 162.) The remaining miscellaneous cordage and gear, blowing hose, torch hose, buoys, and whatnot had to go on top of the deck house; part of it is shown in Figures 17, 32, 44, and 47.

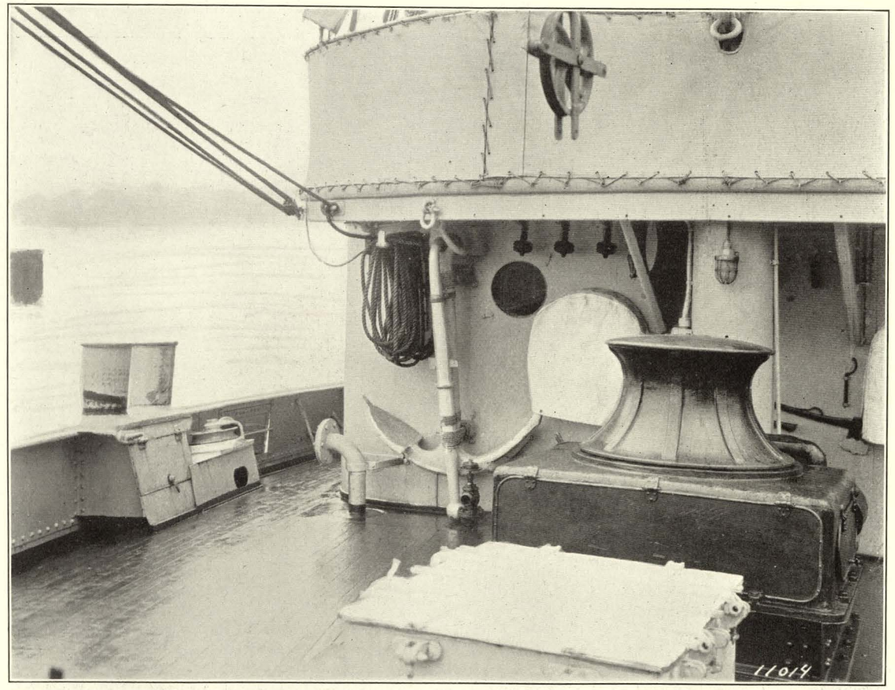


FIG. 41C.—Forecastle of *Falcon*, with new steam capstan in foreground and new roller sheave for reeving wires installed just abaft bitts

Had not the surfboat been in the water all the time and the motor launch left at Boston on January 25, there is no telling where this gear would have had to be stowed.

The deck-force workshop was in a cubby-hole off the main deck on the port side of the deck house. It was fitted only with a vise and with lockers and hooks for the stowage of gear. Any pipe cutting or threading or any work on long material had to be done aft on the port side, at the vise shown in the extreme left of the photograph. (Fig. 167.)

The engineer's workshop was in the port side of the forward fireroom, where there were a lathe, a drill press and grinder, and some smaller tools. This shop was very useful and in it were performed many "hurry-up" jobs of machining, thread cutting, and so forth.

Part VI.—Section 4. Flood Lights.

The *Falcon* was fairly well equipped with flood lights for night work when the *S–4* salvage operations were begun, but as the work progressed there became a need for more careful lighting and a more systematic arrangement of switches and outlets for flood lights and for diving lamps as well. With the aid of material and labor supplied by the navy yard, Boston, there was installed during March, 1928, while salvage operations were in progress, a very complete and convenient set of outlets and switches at the port and starboard after corners of the deck-house upper coaming, abreast the stowage positions for the mooring buoys.

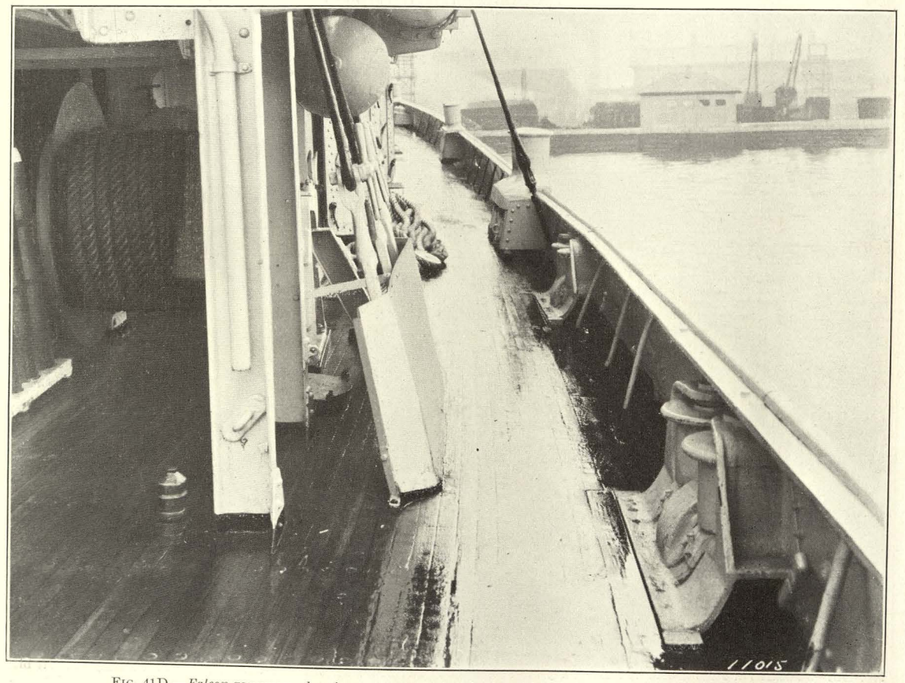


FIG. 41D.—*Falcon* gangway, showing new pontooning chocks with rail closing and fairing pieces in place

Part VI.—Section 5. Lifting Gear.

The hoisting and lifting gear, consisting of several winches and a multitude of booms, seemed adequate at the beginning of operations, and, as a matter of fact, served very well throughout, save that the four supplementary booms added abreast the mainmast after the *S–51* operations, two on each side, were found to be somewhat too short, in that they did not provide sufficient clearance over the side when hoisting divers' stages in and out. The light supplementary booms as proposed after the salvage operations on the *S–51* are shown on plan of superstructure deck at the top of Plate No. 10 of the salvage report on that vessel and as actually rigged on the *Falcon* in Figure 19.

The installation of the best possible type of winch for use in handling divers' stages can not be too strongly emphasized and the performance of the Meade-Morrison winch used for the

greater part of the *S–4* diving operations can not be too eloquently praised. Continuous and easy motion on the whip, free from jumps, jerks, slips, etc., is manifestly necessary when the stage on the end of the whip carries one or two divers in their heavy gear.

Part VI.—Section 6. Diving Air Plant.

Following the experience on the *S–51*, where in the early part of December, 1925, freezing and clogging of divers' air lines took place, requiring suspension of operations until April of the following spring, a careful investigation of the causes leading up to this freezing was conducted. The recommended remedy was to cool the divers' air to a point at least as low as it would reach

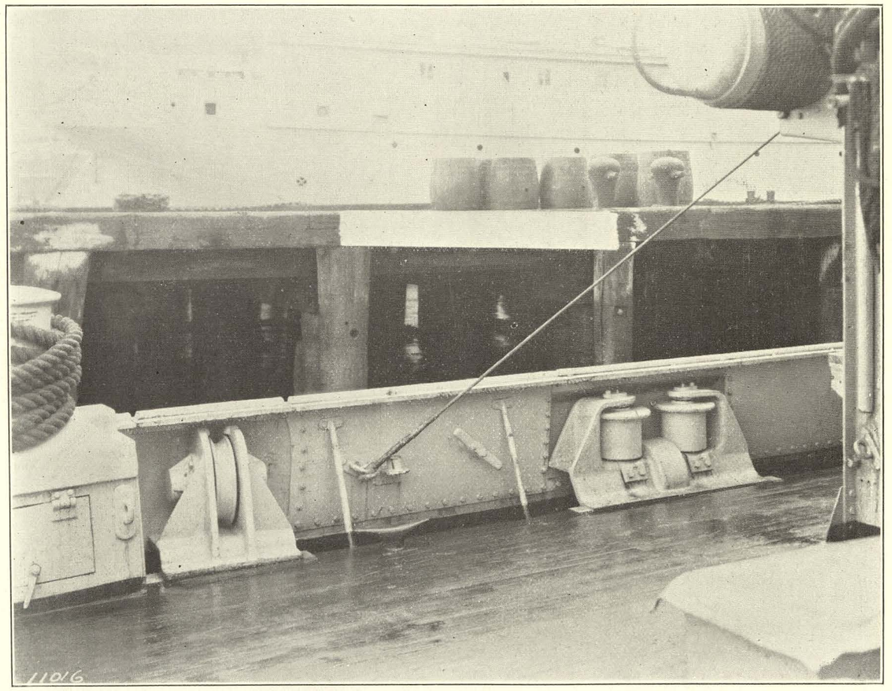


FIG. 41E.—New roller sheave opposite after capstan on *Falcon* for taking direct pull from under water. New pontooning chock at right. Fairing and closing pieces in place

on its way to the diver, thus causing the deposition of suspended moisture and lowering of the dew point. Following these recommendations, some changes were made to the diving air system on the *Falcon* whereby the air under pressure was stored in a large air receiver in the open on the superstructure deck and the air was cooled by the aid of cooling coils inside the receiver through which sea water circulated. These alterations were not as extensive as might have been desired, on account of lack of funds, but the fact that diving was conducted successfully throughout the *S–4* rescue operations, under much lower air and sea-water temperatures than had obtained during the *S–51* operations, indicated that the problem might have been satisfactorily solved.

However, on January 3, 1928, under a combination of air temperatures of 20° to 21° F. and sea-water temperatures of 35° to 37°, freezing and clogging of the hoses again took place, followed by similar experiences on January 4, January 9, and January 13, 1928. For a week or more following diving operations were practically at a standstill, while the *S–4* salvage force, with the assistance of officers from the navy yard, Boston, was striving to find a solution for the problem. (See fig. 43.) The unfavorable conditions encountered during the remainder of the winter were finally mastered by a further and more intensive development of the principle

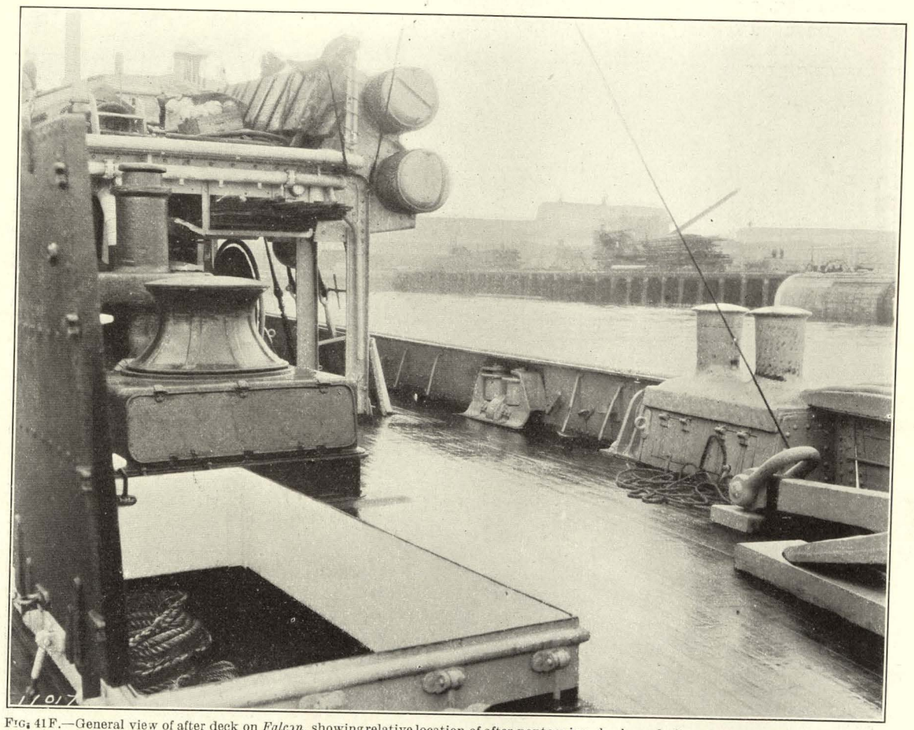


FIG. 41 F.—General view of after deck on *Falcon*, showing relative location of after pontooning chocks and after steam capstan. New vertical roller sheave is just forward of bitts, directly opposite capstan. Note new type bitts with integral bolster. Hatch to after hold at left and two of the four mooring anchors at right

of mechanical deposition of the moisture in the diving air, as inaugurated originally during the *S–51* operations.

The navy yard, Boston, designed and built a special air cooler (fig. 44) for removing moisture from the diving air. The yard also provided an air heater for heating the dried air and an air-reducing valve for reducing the relative humidity of the air by increasing its volume without an increase in absolute moisture content. Subsequently a calcium chloride dehydrating unit (fig. 45) was designed, built, and installed on the *Falcon* at the suggestion of Mr. W. L. Shively, of the laboratory engineering division, the Koppers Co., Pittsburgh, Pa., and the Bureau of Construction and Repair, but its services were not called into play and it was not used.

Without entering too much into theoretical considerations and details of design, there is given herewith a brief technical description of the units forming the principal parts of the *Falcon* diving air plant at the conclusion of salvage operations on the *S–4*, together with a brief statement of the manner in which they operated. Certain details of routine and procedure concerning the operation of the diving air plant were set forth previously under Part V, section 9. Changes proposed for diving air plants on submarine rescue vessels to be fitted up in the future are set forth under Part XVII, section 3, hereunder.

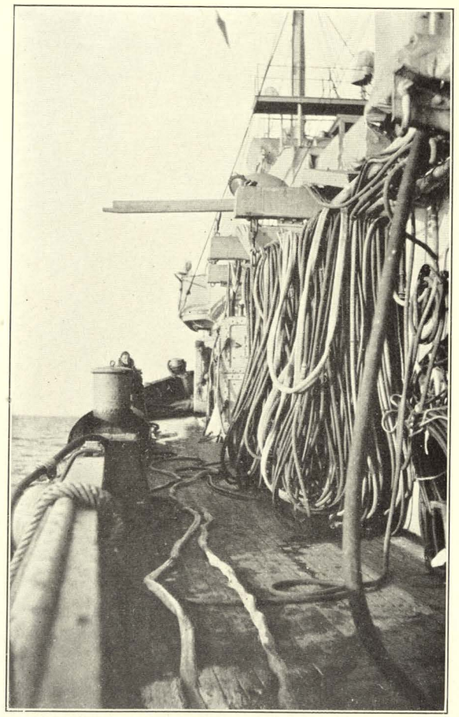


FIG. 42.—Diving air hose and combined life line and telephone cable in 600-foot lengths coiled on hangers in port gangway of *Falcon*. Note manner of lashing air hose and life line together with canvas for 50 or 75 feet back from helmet, to insure keeping hose clear when working around obstructions or when inside of submarine

AIR-COMPRESSING APPARATUS

Two Ingersoll-Rand Imperial steam-driven duplex air compressors, two-stage, each having a capacity of 150 cubic feet of free air per minute at 150 pounds per square inch. The air compressors took their suction from screened openings in the side of the deck house. There were intercoolers between the first and second stages, but no after coolers. A large separator (which very rarely collected any water or oil) and a large volume tank were fitted in the discharge line adjacent to each compressor, the latter serving as a sort of "flywheel" to improve the governing. A group of valves forming a sort of manifold in a deck-house recess on the port side made it possible to connect the diving compressors, the salvage compressors, and the air mains in various combinations.

AIR-CONDITIONING APPARATUS

A *cooler* in the combined discharge line from the two diving air compressors was located in the open air on top of the deck house. (Fig. 44.) Circulating water from the sea was supplied by a separate steam pump to the bottom head of this cooler, whence it passed upward through the tubes, out through the top head and overboard. The air under a pressure of 150 pounds per square inch was delivered to the cooler body at the top and taken off at the bottom, in addition to which there was a drain at the bottom for drawing off the moisture extracted from the diving air and precipitated on the tubes. The fact that the tubes and the bottom tube sheet were maintained at a temperature slightly above 32° F. prevented the deposited moisture from forming frost on the tubes or ice in the bottom, under which circumstances it could not have been removed from the cooler. The circulating water entered at a temperature of from 32° to 35° F. and was discharged at a temperature of 36° to 37° F. The compressed air entered

at temperatures varying from 60° to 100° F., was lowered to about 35° F. in the cooler, and then further cooled by passage through exposed piping on the superstructure, so that on cold days the air-discharge thermometer almost invariably read lower than the temperature of the entering circulating water.

The *moisture separator* or *eliminator*, fitted inside the engine-room hatch just under the cooler, where the temperature of the surrounding air was always well above freezing, contained a series of labyrinth passages (in fact, this eliminator was copied from a similar device on a low-

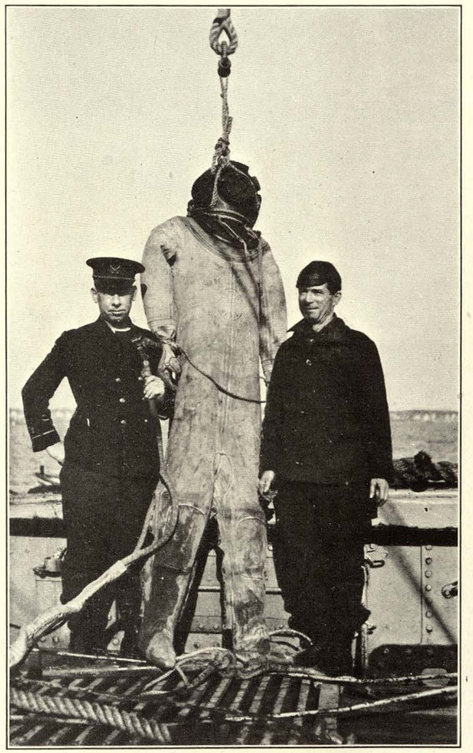


FIG. 43.—"Jake," the dummy diver, used in the January experiments to determine whether or not diving air lines would freeze under existing temperature conditions. A maximum and minimum thermometer was placed inside the helmet

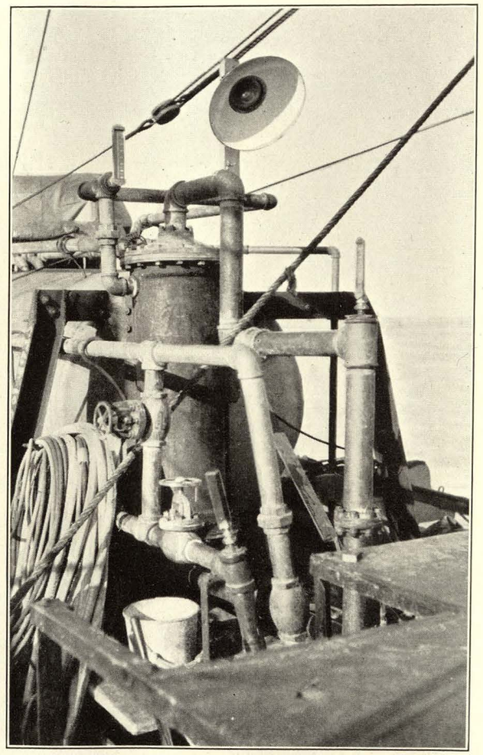


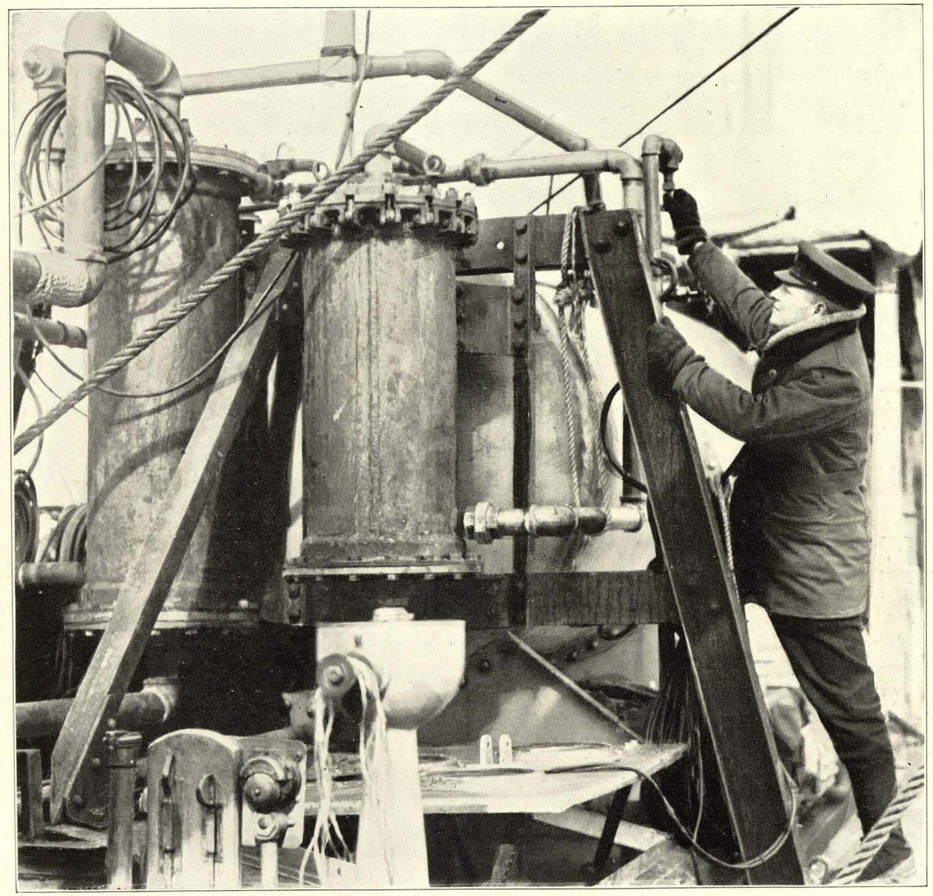
FIG. 44.—Special cooler for condensing moisture from diving air as manufactured and installed by navy yard, Boston, on *Falcon* during January 24–25, 1928. Note position of thermometers and exposed air piping which furnished additional cooling for diving air when atmospheric air temperatures were below 32° F.

pressure evaporating system) in which any moisture carried over by the air from the cooler was to be deposited. Actually, the rate of flow of air through the cooler was relatively low, resulting in the deposition of practically all the moisture in the cooler, with little or none to be collected by the eliminator.

The *main air receiver* was a large volume tank (see fig. 32) on top of the superstructure, which acted partly as a storage tank for diving air and partly as additional cooling surface, since its sides were exposed to the atmosphere and, like the exposed air piping adjacent to it,

it became more and more effective with the cooler atmospheric air temperatures. This receiver had a volume of 300 cubic feet.

A *heater* consisting of a rebuilt-fuel oil heater was installed in the discharge line from the main air receiver with the idea of heating the diving air to such a point that after its travel through the manifold and the diving hose its temperature would still be above the dew point



International Newsreel Photo.

Fig. 45.—Air-conditioning apparatus on diving air plant of *Falcon*. Air cooler on left, calcium chloride dehydrating uniton right, and air receiver in background. Photograph shows air-supply branch to decompression chamber being opened by Gunner Church

for air carrying that particular amount of water vapor. With steam taken from the ship's heating system, it was possible to raise the temperature of the diving air to 190° or 200° F.; the heater was installed overhead on the bulkhead between the two firerooms so as to reduce the amount of additional heat which had to be supplied to it. Unfortunately, time and means

were not available during the salvage operations to determine and record the air temperatures at various points in the diving air systems. However, on the coldest days the air discharge piping to the diving air main loop around the deck house was too hot for the touch. The individual diving hose branches and strainers felt hot and the diving hose itself, up to a point 100 feet from the diving air main, was susceptibly warm.

A *reducing valve* in the discharge line from the heater lowered the air pressure from 150 to about 100 pounds per square inch gauge and correspondingly increased the air volume, an operation which automatically reduced the relative humidity. Assuming that 1 cubic foot of air at 100 per cent saturation carried 2.279 grains of water vapor, leaving the cooler at 34° F. and entering the reducing valve at an absolute pressure of 165 pounds per square inch, this amount of air would leave the reducing valve at an absolute pressure of 115 pounds per square inch with a volume of 1.43 cubic feet. Since the amount of water vapor in the 1.43 cubic feet of air would be exactly the same as in the original 1 cubic foot of air, the relative humidity of the air at reduced pressure would be lowered to about 70 per cent, and 1 cubic foot of air at this pressure would carry only 1.59 grains of moisture. In this manner the dew point of the diving air would be reduced to about 25½° F. when discharged from the reducing valve. The reduction of pressure in the diving air main served also to reduce the amount of expansion at the divers' air-control valve. Whereas, on the *S–4* salvage operations, air was originally reduced in pressure at the control valve from 135 pounds per square inch gauge (figuring a drop in the hose of 15 pounds per square inch) to 45 pounds per square inch gauge, with the reducing valve in operation the expansion was from only 90 pounds per square inch to 45 pounds per square inch, lowering the original ratio of 3 to 1 down to a new ratio of 2 to 1 with the air conditioning plant in operation.

The *diving air main* was split into two parts, forward and after sections, by cut-out valves and a direct supply from the reducing valve was provided to both sides of the diving air main loop. In this manner warm air was supplied to both sides of the loop and to the after portion only, when using the after diving connections. The diving air main, which ran around the outside of the deck house, was lagged with hair felt and canvas and a U-shaped loop with a drain at its lowest point was provided aft for collecting any moisture which condensed in the external main.

The *diving hose and fittings*, while of standard type and construction, were modified as follows in an attempt to improve the efficiency of the plant:

(1) Hose couplings of rolled copper-nickel alloy, having larger internal passages to prevent wire-drawing of the air every 50 feet, were manufactured by the New York yard, as explained in Appendix III, section 1, following and were fitted in one 600-foot length of diving hose.

(2) The air-hose couplings and clamps on three sets of hose (including the 600-foot length with improved couplings) were lagged in an endeavor to reduce the radiation from the metal couplings to the atmosphere. The diving hose, for about 4 or 6 inches each side of the coupling, was wrapped with four or five layers of muslin, each layer being impregnated by dipping the hose coupling in a bucket of melted paraffin before the next layer of cloth was applied. Unfortunately, there was neither time nor opportunity to make a careful investigation of the actual or relative value of the heated air, the improved couplings, or the lagged couplings. Even with a considerable portion of the diving hose hung up inside the engine-room hatch in order to decrease radiation, the writer is inclined to believe that the radiation to the cold air and the cold water in the remainder of the 600-foot length was sufficient to reduce the air temperature at the divers' air-control valve to practically the temperature of the water.

Even after the improved air-conditioning apparatus was installed by the navy yard, Boston, in the latter part of January, the salvage force was still confronted with the thought of waking

up some morning and finding that the atmospheric and sea-water conditions were again too severe for the equipment available. There appeared to be no means of lowering the dew point of the compressed air below about 34° F. with any degree of certainty, save by the use of a refrigerating system, the installation of which appeared to be impracticable under the circumstances. Suggestions made by Mr. W. L. Shively, of the Koppers Co. Laboratories, in reply to inquiries by the Bureau of Construction and Repair, led to the design and fabrication of a *calcium chloride dehydrating unit* along the lines suggested and as shown in the photograph (fig. 45). This dehydrating unit acted, of course, upon the principle of chemical absorption of moisture, whereas the remainder of the air-conditioning apparatus provided for mechanical deposition of the moisture. This steel pressure-proof chamber or tank shown in the photographs contained a number of baskets for holding calcium chloride, all the baskets being mounted on one frame similar to the food carriers on naval vessels. At least every 24 hours it was intended to take the pressure off the plant, come up the top bolts and remove the upper cover, lift out the carrier, remove and dispose of the wet calcium chloride in the lower basket, place each of the remaining baskets one level lower in the carrier, and fill the basket just emptied with fresh calcium chloride, placing it on top of the carrier.

The use of this chemical unit would have involved a considerable amount of experimentation in order to obtain the proper degree of drying, since the air supplied to the divers had to contain a certain minimum quantity of moisture to prevent drying of internal membranes. The smallest allowable amount of moisture was supposed to be 15 per cent, but the exact figure would have had to be determined by much experimenting, basing the results upon the comfort of the divers. To insure delivery of air having the proper humidity, it would then have been necessary to place a hydrograph or hydrometer in the discharge line from the chemical unit. A pressure-proof chamber for an indicating hydrometer was actually manufactured by Boston and installed on the *Falcon* (see fig. 32), but the design would have required extensive modifications to make it wholly satisfactory.

The calcium chloride dehydrating unit was, like all other units of air-conditioning apparatus, fitted with cut-out valves and a by-pass. The air was by-passed through this unit during the *S–4* operations and the chemical drying process was not used at any time, since the conditions encountered could be adequately met by the mechanical deposition apparatus.

A silica gel dehydrating unit No. 35, pressure type, was purchased by the Bureau of Construction and Repair on contract 6592 during the salvage operations and sent to Boston, but was not installed or used. The great objection of the salvage force to the use of these chemical units lay in the excessive amount of supervision and care which they felt would be necessary in order to make them function properly—supervision which might better be spent on the salvage work proper.

The data on air and water temperatures and on operation of the air-conditioning apparatus which was taken by the salvage force during the latter part of January, 1928, was not sufficiently systematic or extensive to be generally conclusive. However, for the information of those who may desire to pursue this subject further, it may be stated that all the data in question as relating to the operation of the air-conditioning apparatus on the *Falcon* during the *S–4* salvage operations may be found in Bu. C. & R. File AM 28/S94, Serial No. 38567.

Part VI.—Section 7. Salvage Air Plant.

The *Falcon* was fitted with a 2½-inch salvage air main in the form of a loop, running around her deck house. In the transverse section at the after end of the house were six connections, each consisting of a 1¼-inch blow valve, a vent valve of the same size under it, and an individual

pressure gauge. On the superstructure deck, forward of the pilot house, were two 12-valve manifolds. The latter are clearly shown in photographs (figs. 102 and 103), and the layout of the salvage main is shown in diagrammatic form on the plan of main deck, forming a part of Plate No. 10 of the salvage report on the *S–51*, C. & R. Technical Bulletin No. 2–27.

There were available on the *Falcon* three independent sources of supply for salvage air, each feeding into the salvage main.

First. *Falcon* salvage compressors, five in all, consisting of two cross-compound steam-driven Westinghouse compressors each having a capacity of 150 cubic feet of free air per minute, compressed to 150 pounds per square inch, and three simple steam-driven Westinghouse compressors each having a capcaity of 33 cubic feet of free air per minute compressed to 80 pounds per square inch. All these machines were air-cooled and of a type similar to those used for air service on surface vessels and on locomotives.

The Westinghouse cross-compound air compressors had the following characteristics:

Air end:
- Low-pressure cylinder: 14½ inches diameter, 12 inches stroke.
- Displacement: 165.13 by 12=1,961.5 cubic inches per single stroke.
- Rated speed: (100 per cent volumetric efficiency) 131 single strokes per minute.
- Actual displaced volume: 178.4 cubic feet per minute.
- Rated volume at actual volumetric efficiency—150 cubic feet per minute.
- Delivery pressure, maximum: 150 pounds per square inch.
- Cooling: Air (radiation).

Second. *Falcon* diving compressors, two in number, two-stage steam-driven Ingersoll-Rand machines capable of compressing 150 cubic feet of free air per minute to 150 pounds per square inch. The full volume of both diving compressors was available at intervals for discharging into the salvage air main whenever there were no divers down and when air was not required for the recompression chamber.

Third. *Falcon* high-pressure air banks of 103 cubic feet capacity, which were charged to a pressure of 2,500 pounds per square inch by a steam-driven four-stage Platt air compressor with a capacity of 20 cubic feet per hour at a pressure of 2,800 pounds per square inch.

Part VI.—Section 8. Mooring Gear and Moorings.

The equipment for mooring the *Falcon* consisted of her own two bower anchors and of two stockless anchors of about 5,000 pounds each and two of about 4,000 pounds each, carried regularly in portable chocks and lashed to eyes on her afterdeck. Four log buoys, each about 16 inches in diameter and 20 feet long, two of which are shown in Figure 6, were carried in chocks on the deck house aft. These buoys are of white pine or spruce, to give the necessary buoyancy, and have a bail of 1½-inch steel at either end.

Two additional buoys, made of spruce logs padded on the outside with spruce strips to give the necessary buoyancy, were made up by the Boston yard on December 18–19 and carried back to Provincetown on December 19 for use with two additional stockless anchors of about 6,000 pounds each. Later two more buoys, making eight in all, were prepared by the Boston yard, one of which was planted on February 3 to eastward of the *S–4* with the 7,400-pound stockless anchor shown in Figure 27, and one of which was planted as a mooring and position buoy for the *Mallard* during the raising of the *S–4*. The latter buoys had to be made up of four spruce logs each to obtain the necessary volume. The permanent moorings for the *Falcon*, planted around the *S–4* on December 25, 1927, resembled closely those previously used for the *S–51* and described at length on pages 10 and 12 of the report of salvage operations on that vessel.

The detailed arrangement and layout of the six anchors and six buoys used as regular moorings for the *Falcon* over the *S–4* are shown in Plate 2, which will be found largely self-explanatory.

The 7-inch and 8-inch manila hawsers used for mooring lines on the *Falcon*, after lying in the water all day, froze solid when hauled in after the end of the day's work and left on deck all through a cold night. (See figs. 12 and 162.) To have attempted to take them around bitts or around a capstan, even had such an operation been possible, would have parted the fibers and very quickly ruined the line.

It was thought at first that by making up the hawsers with an excess of fish oil or some other compound the hawser would become more or less impervious to water and would not freeze up solidly. Inquiries to the navy yard, Boston, where all manila rope is made for the Navy, brought forth no satisfactory replies. That yard made some experiments, not with impregnated hawsers but with hawsers which had been coated with grease or other substances, and one of these hawsers of 8-inch size was sent to the *Falcon* for trial. In this case the prevention was worse than the trouble, for the hawser was so slippery that it could not be handled, either thawed out or frozen.

Finally, on February 2, Chief Boatswain Hawes was sent ashore to make inquiries among the Provincetown fishermen as to the methods which they used during the winter. He found, in the first place, that they used chain or wire whenever possible, neither of which would freeze and carry away. In the second place, when they had to use manila or similar lines, they trailed them over the side or doused them with sea water to thaw them out.

On subsequent days, therefore, the *Falcon* adopted the practice of coming into the moorings, anchoring to hold the vessel in position, then throwing overboard the mooring hawsers, just as they were flaked or coiled down on deck. After 15 or 20 minutes in the water, even at water temperatures as low as 32° or 33°, they would thaw out and become flexible, whereupon they were hauled aboard and the vessel moored before they could freeze up again.

Part VI.—Section 9. Pontooning Gear.

The *Falcon* had not been fitted with permanent pontooning chocks in the interval between the *S–51* and the *S–4* salvage operations. The old openings in the rail serving as the temporary chocks for the *S–51* job had been plated up and the bolsters removed. However, the old chafing plates had been sent on from New York via the *Sagamore*, together with some of the wood bolsters. The remaining parts were fabricated at Boston and the temporary pontooning chocks replaced during the stay of the *Falcon* at that yard on January 24–25, in the manner shown in Figure 46. The chafing plates and bolsters for the four pairs of after bitts, shown in Figures 86 and 87, were brought on from New York with the first consignment of gear and installed by the ship's force on the *Falcon*.

These temporary rigs were made to serve the purpose when working on the *S–4*, although at the expense of much wear on the hauling lines and a great loss in efficiency due to the enormous friction of the lines sliding at right angles over the chafing plates and the consequent loss of hauling power on the line, since the determining load which could be put on the line was inboard of the chock, where the winches were pulling against friction as well as hauling useful load.

New cast-steel roller-type pontooning chocks and new bitts, with fair-lead and hauling rollers, have been fitted to the *Falcon* during her recent overhaul at Boston (May–June, 1928). These are shown in photographs. (Figs. 41D, 41E, and 41F.)

Part VII.—Plan of Attack for Salvage Work. Section 1. Condition of "S–4."

Laying out the salvage work on the *S–4* necessitated a careful study of all the reports made by the divers during the rescue operations and of all the data which had been obtained through the medium of messages from the vessel itself, collecting and analyzing all the information obtained from first-hand reports of eye witnesses to the casualty, from officers and men on the *S–6* who had served on the *S–4* or who were familiar with the exact manner in which that vessel was

handled, and it involved much careful thought as to the condition of the various valves, doors, fittings, etc., which must have been necessary to bring about the effects observed.

Since the vessels of this division were not in all respects similar, as they had been in commission for some eight years and various alterations had been made to some vessels and not to others, it was necessary to check up on installation features from the home yard—in this case also the building yard, the navy yard, Portsmouth. Fortunately, the officer (naval constructor) who had acted as ship superintendent on the *S–4* during an overhaul which was finished just prior to the casualty was available on the scene as assistant to the salvage officer for material.

FIG. 46.—U. S. S. *Falcon*. Broadside view showing position and extent of wood sheathing on sides and location of pontooning chocks abreast after end of deck house. Vessel was 2 or 3 feet lower in the water during salvage operations

Of the condition of compartments, doors, hatches, valves, etc., on the *S–4* not much was *definitely* known except that all access hatches were closed and that the door between the battery room and the torpedo room was closed. The principal damage was known to be in way of the battery room on the starboard side, with possible incidental damage in way of the conning tower on the port side. It was assumed that the door between the control room and battery room was closed or that an attempt had been made to close it, and it was probable that the doors between the engine room and control room and between the engine room and motor room might not be tightly closed on account of the presence of electric cables for special counter gear which ran through them. It was probable also that all outboard ventilation and induction valves were

closed, and it was assumed that all inboard flapper valves at the inner hull were closed, since it is the general practice on submarines to secure these valves when diving. The center Kingstons of the main ballast tanks were undoubtedly open—the side Kingstons probably closed. The main ballast vents were undoubtedly closed, save for No. 1 vent, which was reported to be leaking a small stream of air bubbles. Of the condition and position of ventilation and voice tube bulkhead valves nothing was known.

Part VII.—Section 2. General Plan of Gaining Buoyancy.

Under the conditions described, it appeared entirely practicable to enter the *S–4* through the engine-room hatch, close the water-tight doors at both ends of the control room, engine room, and motor room, and free those compartments of water by the use of pipe lines already installed or by fitting salvage hatches. The torpedo room was known to be partially flooded through the breaking of the SC tube terminal, and access through the hatch was known to be practically out of the question for a diver; however, the problem of fitting a special spill pipe and freeing this compartment of water appeared entirely reasonable. It was not certain that No. 1 main ballast tank was actually ruptured (the air which escaped when attempting to blow main ballast tanks on December 18 might have come from a damaged blow line), but, granting the worst, it was still possible to shut off the air line to No. 1 main ballast tank when the divers entered the control room and to blow the remaining tanks.

Part VII.—Section 3. Preliminary Estimate and Buoyancy Calculations.

The navy yard, Portsmouth, supplied the salvage force with the following data concerning the net or free air capacity of the various compartments, and it was upon this data that all preliminary estimates were based. Corresponding capacities in tons of salt water are given.

	Cubic feet	Tons
Torpedo room	3, 000	85. 8
Battery room	5, 000	143. 0
Control room	2, 600	74. 3
Engine room	3, 800	108. 5
Motor room	3, 100	88. 5
Steering-gear room	200	5. 7
	17, 700	505. 8

Based on the above assumptions and data, the problem resolved itself generally into the raising of a submarine with one compartment and one group of main ballast tanks flooded and with incidental water here and there throughout the remaining compartments. A rough and rapid calculation indicated that one pair of 80-ton pontoons attached to the vessel in way of the flooded compartment (battery room) might supply very nearly the proper amount of external buoyancy and moment. However, there had to be faced the emergency condition of losing the buoyancy in one compartment, as on the *S–51*, and there remained, as always, the necessity for providing an adequate working margin.

The decision which had been made during the rescue operations, to prepare for rigging three pairs of pontoons, two at the bow and one at the stern, was therefore adhered to for the salvage operations. The only difficult operation in providing external buoyancy would be the rigging of the middle pontoons, which pair would be necessary in any event. It was known in advance that rigging the bow pair and the stern pair of pontoons would be a relatively simple matter; hence the additional buoyancy to be gained by the use of these pontoons was considered entirely justified.

Part VII.—Section 4. Tentative Program of Salvage Work and Rules Governing Its Adoption.

Upon the conclusion of the rescue operations, during which a tunnel had been dug and reeving lines passed at frame 19, and the inauguration of regular salvage operations, there was prepared, on December 27, 1927, a tentative program of salvage operations, listing the major operations in the order in which they were to be undertaken.

Pass reeving lines under stern for after set of pontoons.

Dig tunnel at frame 46 and pass reeving lines for middle pontoons.

Fit salvage hatch over engine room on *S–6*. Make strongbacks for torpedo-room and motor-room hatches and fit on *S–6*.

Cast loose and clear *S–4* towing pendant for permanent marker buoy.

Slew gun fore and aft. Rig life line on starboard side over cut.

Clear engine-room hatch and open.

Clear torpedo-room hatch and motor-room hatch and fit strongbacks.

Fit air-blowing connections in torpedo room and motor room.

Clear (1) engine room, (2) motor room, (3) control room.

Close forward control-room door and ventilation valves over door.

Arrange valves and piping for blowing-control room.

Arrange valves and piping for blowing-motor room.

Remove section of 6-inch outboard ventilation line in way of cut and blank ends.

Remove section of 10-inch outboard ventilation, starboard side, and blank. (This line was originally thought to be ruptured.)

Close hull ventilation valves (main induction, battery exhaust, etc.) in conning-tower fair water.

Fit strongbacks over conning-tower hatch.

Blow main ballast tanks Nos. 2 and 3.

Close motor room and blow.

Close control room and blow.

Fit salvage hatch over engine room.

Close engine room and blow.

Sink pontoons in following order (not then settled).

Fit towing bridles.

Raise ship.

This tentative salvage program was based upon the general use of air under pressure as a means of unwatering tanks and compartments in order to obtain self-buoyancy. The vessel having sunk in a submerged condition, with halves and hatches closed, having no extensive damage to compartments other than those damaged in the collision and having only recently been overhauled at the navy yard, Portsmouth, and subjected to complete tightness tests throughout, led to but one conclusion as to the most efficient means of freeing the compartments of water.

As a check, however, the control room, engine and motor rooms on the *S–6* were sealed by the ship's force and given an air test, as a result of which it was determined that the hatc es, valves, doors, etc., even when subjected to pressure tending to unseat them, would hold just about 10 pounds per square inch without any external assistance.

Unless entirely impracticable, the buoyancy gained in any one compartment or tank was to be entirely independent of the buoyancy gained elsewhere; in other words, the compartments and tanks were to be sealed and blown as individual units, so that the attainment of the requisite buoyancy in one was not necessarily dependent upon the others.

The program also involved the completion of all measures toward self-buoyancy and all work upon the ship herself before any tunneling was to be done or any pontooning attempted. This was to insure that the tunnels would not fill in before they were used and that the pontoons would be under water, attached to the submarine, for the minimum time possible.

The general principle adhered to was to obtain every ton of buoyancy practicable.

The first estimated date of completion of all the work set forth in the tentative program was May 1, 1928. The favorable weather in January and in early February enabled this date to be advanced first to April 15 and then to April 1, following which the expeditious pontooning enabled the ship to be raised on March 17, 1928.

Part VII.—Section 5. Available Plans and Data.

For handling details of the work there was available the *S–6*, upon which all gear intended for fitting on the *S–4* could be tried. Many plans of the *S–4*, such as booklets of general plans and of general information, including inclining experiment data, air salvage lines and fittings, access hatches, outboard valves and pipe lines, inboard or hull valves, bulkhead valves, ventilation system, air systems, water systems, etc., were brought to the scene by officers from the Portsmouth yard on December 17, 1927, but additional plans had to be sent for and a regular plan file, with index, was subsequently set up in the chart house of the *Falcon*.

For rescue or salvage work of this character it is practically essential that the following plans and data be at hand:

Booklet of general information, containing, among other things, capacities and centers of gravity of tanks; free air capacities of compartments, with approximate centers of gravity; diagrams of all piping systems.

Booklet of general plans.

Inclining experiment data, with detail list of useful weights and data on weight of hull and fixed weights.

Salvage system, outboard fittings, details.

Escape system.

Air salvage systems, piping arrangements.

Superstructure deck, details (for use in definitely locating various fittings, etc.).

Compartment and access plan.

Main ballast tanks, flood and vent valves.

Outboard ventilator trunks and lines, arrangement and details.

Access and escape hatches, arrangement and details.

Ventilation system.

Drainage system, piping diagrams and arrangements.

Trimming system, piping diagrams and arrangements.

Shell expansions, outer and inner hulls.

Body plans, outer and inner hulls.

Bulkhead valves, arrangement and details.

Bulkhead water-tight doors, arrangement and details.

Air system, piping arrangements.

Fuel-oil system, piping arrangements.

Part VIII.—Preparation of Wreck for Self-Buoyancy.

The actual salvage work under the heading of self-buoyancy resolved itself into a number of fairly distinct operations or projects, which will be noted briefly hereunder and which will be used as a basis for describing the salvage work in detail.

Access to and work inside the vessel, including recovery of bodies and clearing up and removal of wreckage.
Torpedo room, sealing and fitting of spill pipes and blowing connections.
Battery room, blowing connections.
Control room, including conning tower, sealing and fitting of spill pipes and blowing connections.
Engine room, sealing and fitting of spill pipes and blowing connections.
Motor room, including tiller room, sealing and fitting of spill pipes and blowing connections.
Main ballast tanks, blowing connections and blowing.
Fuel-oil tanks, blowing connections.
Outboard ventilation line, blanking of.
Miscellaneous buoyancy, preparations and blowing.
Blowing hoses to compartments and tanks.
Preliminary unwatering and check blowing of compartments.
Towing bridles and arrangements, while not having to do directly with buoyancy, is included here because the work was done simultaneously.

Of these, the work involved in sealing the control room and in preparing the fuel-oil tanks for blowing were by far the most laborious and tedious. The amount of work spent on each phase, as an indication of their relative difficulties, is set down in tabular form in Part XVI, section 4. Added to the normal difficulties were those which came about due to differences in construction and in arrangement of wheels, piping, and fittings between the *S–4* and her sister vessel, the *S–6*, which was used as a model.

Part VIII.—Section 1. Access To and Work Inside the Vessel.

Before any of the salvage work on the *S–4* was attempted the vessel was cleared as carefully as possible of all lines and top hamper which would interfere with work on and around the vessel.

Eiben, Eadie, Crilley, and Campbell went down on December 26, the first day that the *Falcon* was in her regular moorings, and by the use of the hook shown in Figure 31 and by numerous hauling lines succeeded in clearing away enough of the wreckage to prevent fouling of hoses and lines. It was thought then that the clearing lines had been cut loose and thrown into the mud, but Ingram, on January 12, reported parts of the loop antenna and clearing lines draped over the side. Crilley went down on January 27, hooked a wire hauling line to the wires and, by using the after capstan, the *Falcon* finally succeeded in untangling and hauling up about three-quarters of the whole clearing line assembly, with the loop antenna cable, flat-top antenna, insulators, etc., including the forward stub mast and anchor light.

On February 1, Harris went down and secured a chain strap on the end of a wire hauling line to the bridge-awning frame, preparatory to hauling it up so as to clear the open bridge and the conning-tower hatch. The frame, as recovered, is shown in Figure 47.

From time to time subsequently it became necessary to clear up loose lines and gear which had accumulated during the operation.

Although not strictly a matter of clearing up the ship, it became necessary to clear the bottom alongside the *S–4* of numerous obstructions which would have interfered with work in and around the tunnels. The section of *Paulding* bow shown in Figure 48 was removed by

Crilley from the starboard side of the *S–4* on February 28. Curiously enough, it was Michels, the only diver to be fouled on the whole job, who was privileged to bring up the largest collection of "junk." The haul made by Michels from the port side of the *S–4* comprised the following all of which hung from a single hauling line:

(*a*) Section of starboard side of superstructure of *S–4*, with section of rail.
(*b*) One grapnel with long length of 4-inch manila.
(*c*) Blowing hose for compartment salvage line which Michels took down on December 18, 1927.
(*d*) Kingpost at frame 49 from *S–4*.
(*e*) Section of flat top antenna wire.

Unfortunately, it was too late in the day for photographs. Michels, on the latter dive, reported more wreckage over the port side, about abreast the gun, but clear of the tunnel at

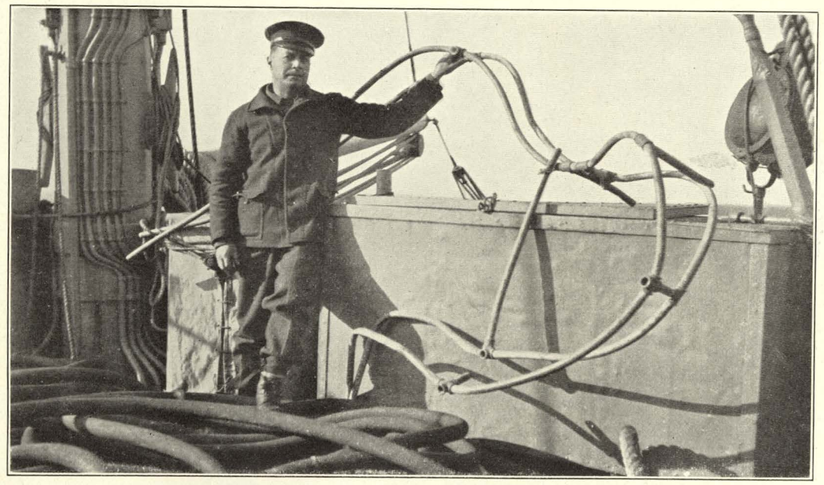


FIG. 47.—Bridge-awning frame, removed in clearing up the vessel by Diver Harris

frames 70 to 71. Additional wreckage in frame 46 tunnel, reported by Wilson, Crilley, and others as foul of the pontoon chains, is shown in Figure 92.

In order to seal up the compartments which were to be used for self-buoyancy, access to the interior of the vessel was necessary, and it was planned to gain it through the engine-room hatch, as being the handiest and the one offering the greatest convenience to the diver. Mattox, in a diving suit less a helmet, made his way laboriously through the engine-room hatch and through the water-tight doors of the *S–6*, while the rest of the divers looked on and took note of the precautions to be observed when working in each locality. It is of interest to note that when Eadie and Eiben were working in the forward battery room at frame 71, just through the door leading from the control room, in order to reach that place they had to descend a ladder 10 feet long, turn around at the bottom of the ladder, and walk forward along a narrow platform 6 feet in length to the after control-room door, pass sideways through this door and between the bulkhead stiffeners, which were only 19 inches apart, then forward 7 feet through the narrow passage (23 inches wide) between the radio room and the galley, walk forward 17 feet through the control room, then for 7 feet through another narrow passage at the forward end,

with a second squeeze sideways through another pair of bulkhead stiffeners and a water-tight door, a total distance of nearly 50 feet from the top of the engine-room hatch trunk.

The air hoses and life lines of all divers who were required to do this were lashed together in a canvas sheath for 75 feet, as shown in Figure 42, to prevent possible fouling on projecting objects.

On December 31, 1927, after some preliminary work of stripping off the teak deck strips on top of the engine-room hatch cover, Campbell and Baker, by the use of a 7-foot wrench and a sledge, started and unscrewed the 1¼-inch nut on top of the kingbolt. Upon backing

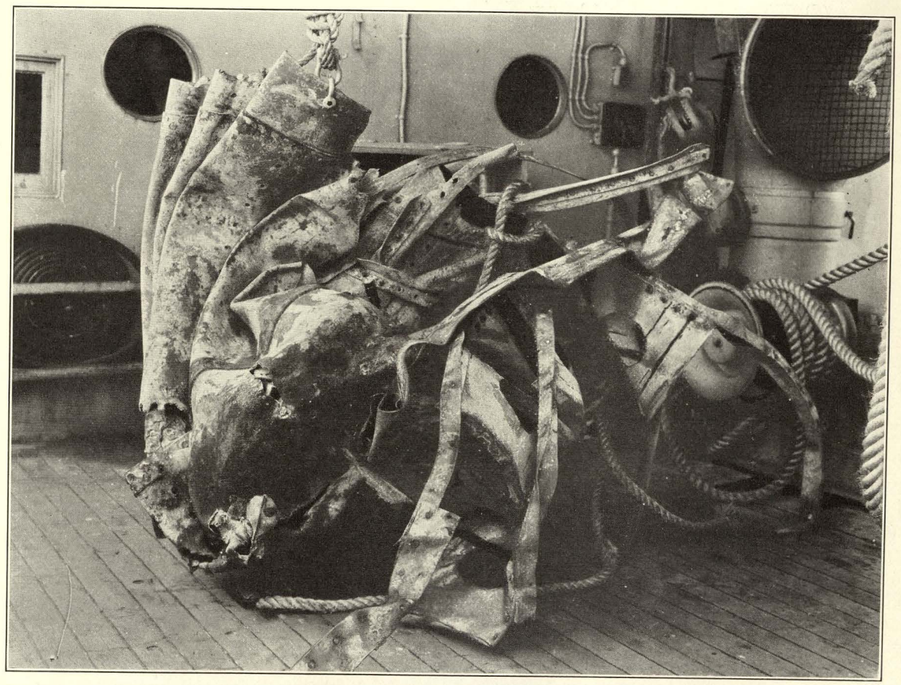


FIG. 48.—At left, section of keel and bow of *Paulding* which was torn off and dropped on starboard side of *S-4*, later to be recovered by Diver Crilley. At right, section of superstructure of *S-4* torn off and thrown to port of vessel, later recovered by Diver Michels

out the bolt they found, to their great astonishment and to the subsequent amazement of all on the surface, that water rushed into the engine room through the hole, indicating an internal pressure considerably less than sea pressure and showing that the engine room was not fully flooded.

The hole was plugged temporarily while a conference was held as to the advisability of flooding a compartment which might then be nearly dry. Upon second thought, it was realized that the engine room must be entered in order to perform the inside work, and it became almost immediately obvious that the engine room must be allowed to flood so that the access hatch could be opened.

Kelley went down at 1.20 p. m. on December 31 to remove the plug, and when Eadie came up at about 4 p. m. the engine room was still flooding briskly. Unfortunately, no further diving was possible on account of gales and freezing air hoses until January 4, nor was it possible in that time for the *Falcon* to moor over the *S-4;* hence it is not known just how long the engine room (and motor room, since the door between them was later found open) continued to flood before the pressure was equalized and air escaped from the bolt hole in the hatch. Eiben and Wilson were the first to enter the engine room, at about 2 p. m. on January 4; incidentally, they were the first divers to wear and use the new batteryless telephone equipment, and the first service test of the gear was made on this dive. They found the forward engine-room door closed and three bodies under the hatch, in the wells alongside the control stations for the engines, at the foot of the ladder. These were identified later as the bodies of Lieutenant Commander Jones (the commanding officer), Lieutenant McGinley, and Lieutenant Commander Callaway. After a considerable amount of difficulty on this dive in passing the bodies up the hatch and in securing them to a hauling line, the divers doing this work subsequently were provided with a short line which they could secure at the top and pass down the hatch for hauling the bodies on deck. With one or two hauling lines, or "body lines," as they came later to be called, each of which had three tails secured to the end, three bodies could be lashed to each line. The bodies when brought to the surface were not taken aboard the *Falcon,* but were left in the water until they could be taken aboard a *Bushnell* sailing launch by a medical party and transported to that vessel.

On January 6, when diving again became possible, Ingram and Scott, Kelley and Wickwire recovered 4 more bodies from the engine room, all lying down between the engines. The following day 10 bodies were recovered, 9 of them from between the engines, clearing the engine room, and 1 from the extreme forward end of the motor room.

On this day, January 7, Ingram opened the door leading from the engine room to the control room and made his way forward in that compartment to the wardroom without any difficulty. This indicated, much to the surprise of everyone, that there were apparently no bodies in the control room nor was that compartment cluttered up with wreckage. These operations made it possible to begin the first real work toward sealing up the control room on January 8, as will be described subsequently.

Campbell, Crilley, and Baker were sent down at about 2 p. m. on January 8 to examine and clear the motor room and begin preparing it for self-buoyancy. It was almost certain by this time that there were other bodies in the motor room which would have to be removed before work could proceed in it without interference, and it was obvious that to avoid the long haul through the engine room the bodies should be removed through the motor-room hatch. Following instructions, Campbell attempted to open the motor-room hatch from below, in the usual manner, but he found the ladder missing. Endeavoring to climb up to the hatch, he emerged partially into the air bubble at the top of the motor room, acquiring so much negative buoyancy and instability due to top weight that he could not reach the hatch strongback.

After having the teak stripped off the motor-room hatch, Campbell and Crilley went down at 1 p. m. on January 9 and opened the motor-room hatch in the same manner that the engine-room hatch had been opened, and Campbell entered the motor room.

On January 11, after placing in the motor-room hatch a temporary ladder (fig. 49), the motor room was entered and cleared. Fifteen bodies were recovered and of these Eadie and Carr recovered eight on one dive. Taking into consideration the six known to be in the torpedo room, this left two unaccounted for. As one body had been recovered from the platform behind the port engine, Kelley was instructed to look carefully behind the starboard engine, but he found nothing. It is apparent that he did not recover the body which was later found there

because it was down over the clutch, level with the floor plates. It is small wonder that Eiben and Grube did not recover the one body found in the motor room when the vessel was entered at Boston, since it was over behind the port high-pressure air compressor, lying against the shell.

No attempt was made to enter the battery room on account of the very narrow passageway just forward of the door leading to the control room and just under the hatch. It was almost a foregone conclusion, judging from previous casualties, that the battery room was a mass of wreckage and a very dangerous place for a diver to work.

FIG. 49.—Grube, with temporary ladder made on *Bushnell* and used in motor-room hatch

Actual trial on the *S–6* demonstrated that a diver fully dressed could not work his way with safety down into the torpedo room between the hull opening and the hatch strut, even had it been possible to open the torpedo-room hatch itself without spending an excessive amount of time on the job. All work of preparing the torpedo and battery rooms for self-buoyancy had therefore to be done from outside the vessel.

Part VIII.—Section 2. Torpedo Room.

The original plan of unwatering the torpedo room involved the fitting of a strongback over the torpedo hatch to hold the necessary excess internal pressure, the sealing of the SC tube openings, the insertion of a blowing pipe in the top of the compartment, and the cutting of a hole in the outer shell by gas torch in the lower port after corner of the torpedo room, just forward of bulkhead 38, for the escape of the water. A sea chest and the old oscillator patch plate made very convenient landmarks for locating and burning the hole from the outside, but the salvage party soon questioned the wisdom of an open hole through the side of the ship where there would be no control over the flow of water or air, in addition to which much buoyancy would be lost by having this opening at the after end if the ship were to be raised first by the stern.

The use of a regular spill pipe leading to the bottom of the compartment was decided upon and a careful search revealed a spot between frames 33 and 34, just to starboard of the center line, where there were no external or internal interferences. There was, however, a rather restricted pocket in the superstructure in which to work, which might possibly be enlarged somewhat by burning. There was also a doubler fitted on the inner shell in way of the proposed spill-pipe opening, but the practicability of burning through the double thickness of $\frac{7}{16}$-inch plate was proved by having a sample plate made up at Boston and having Kelley burn a hole through it under water. Figure 34 illustrates the test plate and the pieces cut out of the hole. The inner edges of the hole were so clean and regular as to leave nothing to be desired.

To keep the hole clear of rivets and the like, its location was definitely fixed for the divers by cutting out a hole in a ¼-inch steel plate, which was in turn notched on one corner to fit against the starboard side of a cleat on the center line just abreast the hole. (See fig. 53.)

A second template, painted white in Figure 163, was drilled with twenty-three ½-inch holes for use as a guide or bushing plate should the salvage force not succeed in cutting the hole with the torch. A ring of holes was to be drilled and the plug punched and chiseled out with pneumatic tools. Eventually a third template was made of asbestos lumber (fig. 163), by means of which the hole in the lower course of plating was burned through with the arc torch.

In the meantime the deck grating over the torpedo hatch was opened and the locker in way of the torpedo-room spill pipe cleared of all lines. A double-channel strongback (fig. 50) was made up for the torpedo hatch, with an oak center block fitting snugly over the center boss and ribs. Two holes had been drilled at the navy yard in a stiffening flange on the hatch casting for clamping a strongback on the hatch during compartment tests, but straight tie-rods could not be fitted through these holes, as they did not lie opposite the center of the hatch. The tie-rods were accordingly made with loose eyes under the strongback, but when Eadie and Carr went down on January 12 to set up on the strongback they had no end of trouble in holding the tie-rods in the restricted space while they set up on the nuts. The tie-rods should have been made with a simple universal joint block so that, while permitted to swing, they would not turn. Although fitted in place on the *S–6*, the tie-rods were found too long when the gear was placed on the *S–4*.

Campbell and Crilley went down on January 12 and 13 and drilled and tapped a hole in the torpedo-hatch casting into which they inserted an elbow and a ¾-inch globe valve to serve as the blowing connection. Into the globe valve was screwed the male half of the union which was later to be used for attaching the No. 1 blowing hose; the female half was tagged and hung up in the workshop.

On February 3, Michels and McNulty, with the aid of the 7-foot Stillson wrench that had been used on the hatches aft, succeeded in unscrewing the cross arm from the SC tube. Fortunately, the acoustic tubes twisted up, carried away, and came out with the cross arm, so that by screwing on the cap which had been supplied them they sealed up the vertical stem of the tube. The cross arm was removed to avoid damage by tow lines and pontoons as well as to permit sealing; that the tube did not escape the former fate is clearly illustrated in Figure 132, but it was not cracked nor did it leak.

It was known that the compartment salvage air outlet in the torpedo room was closed and it was certain that bulkhead 38 was intact. While the salvage party had no means of knowing how hard the torpedo-room ventilation valve was screwed on its seat, since it closed with external pressure, the locking gear was so rugged as to indicate that it might hold the necessary internal pressure.

Kelley and Wickwire went down on January 13 to burn away some of the superstructure and give better access around the spill-pipe hole, but all that they succeeded in burning were two tips on the gas torch.

Part VI, section 2G, describes the difficulties experienced in putting this hole through the inner shell into the torpedo room. After burning the hole in the test plate on January 15, Kelley went down on January 27 to tackle the torpedo room itself. There was trouble with igniters that day and he burned up tips the next day. While waiting for Kelley to return from leave, Carr attempted the burning on February 7 and he succeeded in burning a small hole all the way through, permitting entrapped air in the upper part of the torpedo room to escape. The presence of the 1-inch cork sheathing inside the shell plating seemed not to inter-

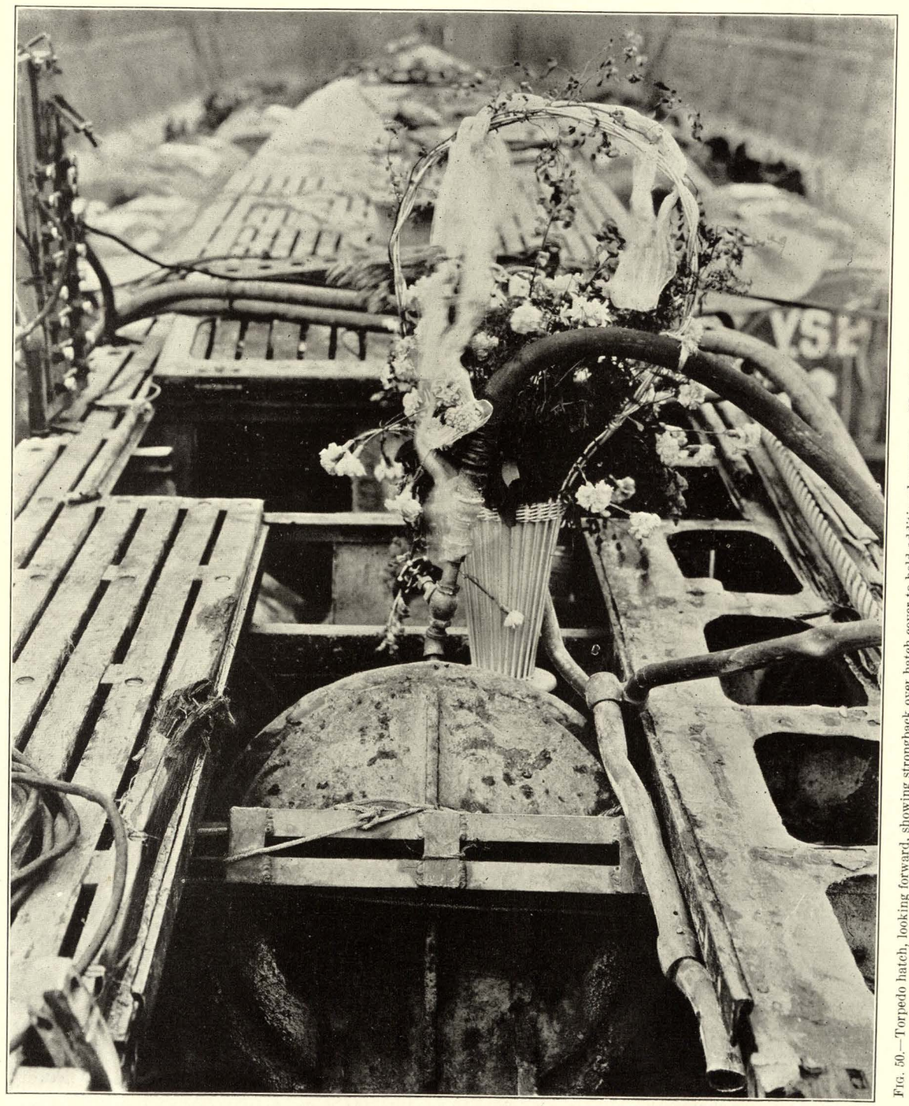


FIG. 50.—Torpedo hatch, looking forward, showing strongback over hatch cover to hold additional pressure. The blowing connection was made by Grube on the afternoon of March 18 to replace the regular connection carried away by the pontoons during towing

fere with the burning. Crilley followed Carr, but could not make the gas torch work. On February 8 Carr got the torch going and burned about two-thirds of the way around the hole—a none too regular cut, as he described it. Harris and Baker, following him, could not get the torch lit off, but Carr, making a third attempt on February 9, succeeded in burning through all but a small distance, leaving three "holidays" of about one-half inch each.

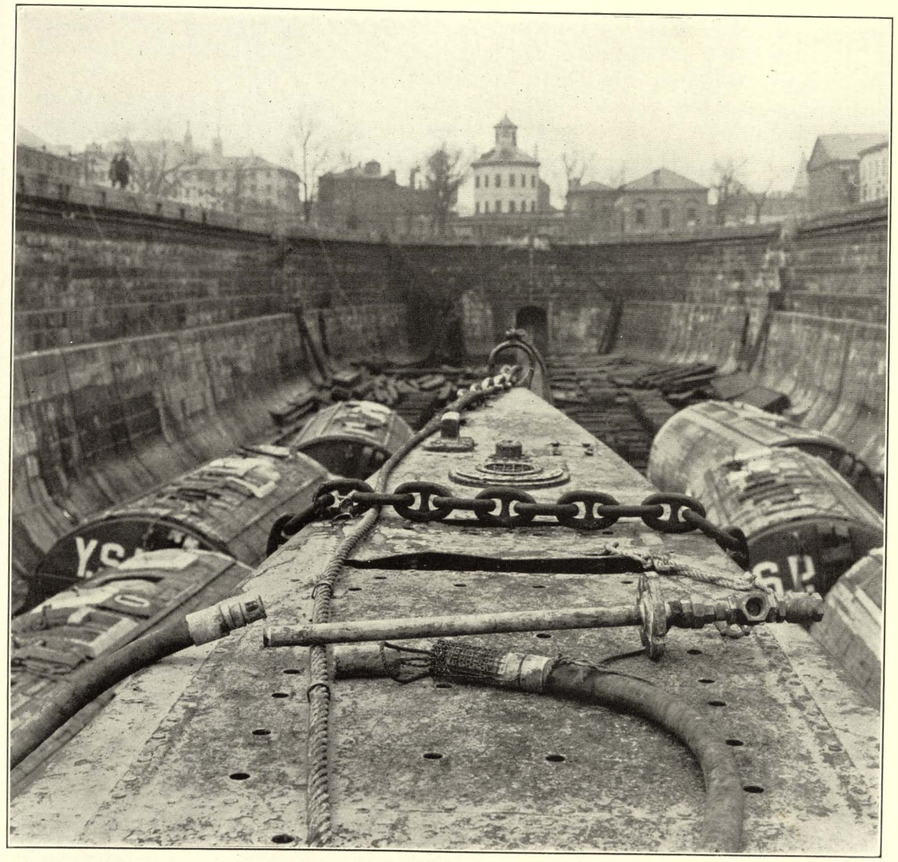


FIG. 51.—Torpedo-room spill pipe with check valve, flood valve, hull flange, drop pipe, suction hose, and double strainer. Note lead weight for carrying strainer to bottom of compartment and for sliding it to forward end when vessel was raised, stern first

On February 10, three strong-arm squads, made up of Carr and Applegate, Wickwire and Mattox, Harris and Baker, tackled the hole with the pneumatic hammer and they succeeded in cutting out and bringing up the section of plate cut out of the upper course of shell plating. (See fig. 36.) The divers would have been fighting it out on this line all winter had not the arc torch, like the old *Monitor*, come to the rescue at just the right time.

Carr succeeded in burning the full hole in the lower course in the matter of a few minutes, although this was the first time that he had used the arc torch under water.

Crilley and Mattox drilled two of the flange bolt holes through the template (fig. 162) on February 11. Harris and Baker, Wickwire and Burd, completed drilling the holes and then tapped them, screwing the taps all the way through until they fell down into the torpedo room.

Plenty of clearance was provided in the flange for insertion of the bolts should the holes not be exactly true. The flange was made large enough to provide plenty of gasket area around the hole, although with one bolt hole drilled double and the spill-pipe hole of ragged contour, the gasket surface, as illustrated in Figure 52, was none too large.

A wood plug, shown in Figure 163, was made up of a diameter just in excess of the over-all diameter of the strainer to try in the hole and insure that it was large enough for the spill pipe.

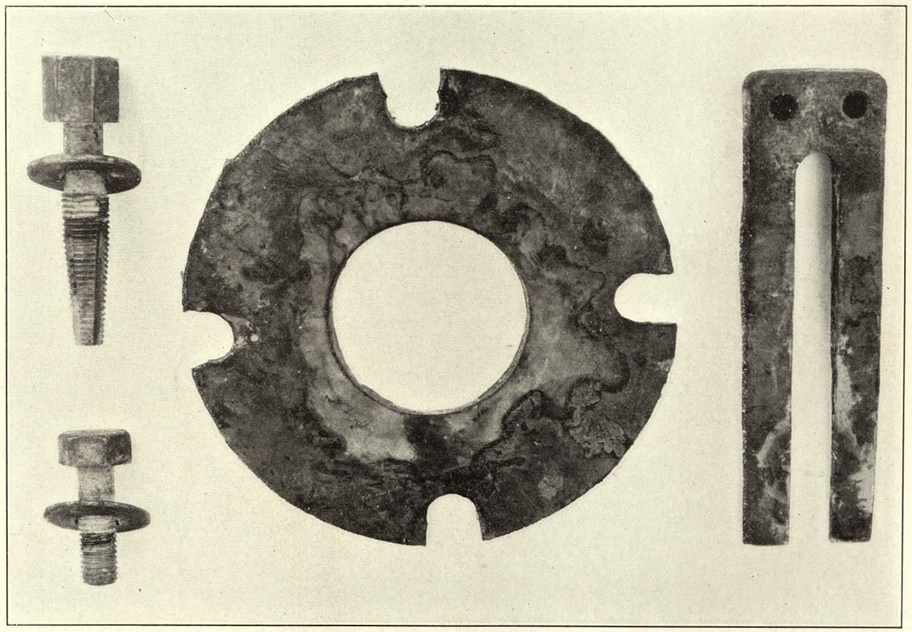


FIG. 52.—Gasket from flange on torpedo-room spill pipe, showing irregular gasket surface. Only the area outside the wavy line was effective. Special oversize tap bolt at upper left; tightening wedge for use under bolthead at right

A sounding lead was rigged, with a marked line just long enough to reach from the hole in the shell to the bottom of the compartment, to determine whether there was any débris under the hole upon which the spill-pipe hose would catch.

The spill-pipe strainer was provided with an outer protecting basket of heavy wire, as shown in Figure 51, and on the lower end was fastened a lead weight to carry the strainer to the bottom when lowering the spill pipe and then to carry it to the forward end of the compartment when the vessel rose by the stern.

On February 12, all holes having been tapped for the attachment of the spill pipe and everything else being ready, the torpedo-room spill pipe was lowered into position and secured in one dive by Eadie and McMullen. It was found on this dive that the forward starboard hole, as

shown on Figure 162, had somehow been drilled "double," so that when tapped it was not a neat fit for the flange bolt. Two special tap bolts (fig. 52), combining a tapered fluted portion, a parallel threaded portion, and a small neck, were made up on the *Bushnell* of hardened tool steel. They had the same threads per inch as the original ⅝-inch taps, but one was one-sixteenth inch larger and the other one-eighth inch larger than the regular bolts. Eadie and McMullen went down the next day, put in the smaller tap, and found that air leaked by when the *Falcon* turned it on. They then put in the larger bolt, but could not screw it home, so the special wedge (fig. 52), made up previously for use on the flapper valves at bulkhead 72, was driven under the head to hold the flange down. (See fig. 53.) Some air still leaked out, but in minor quantities.

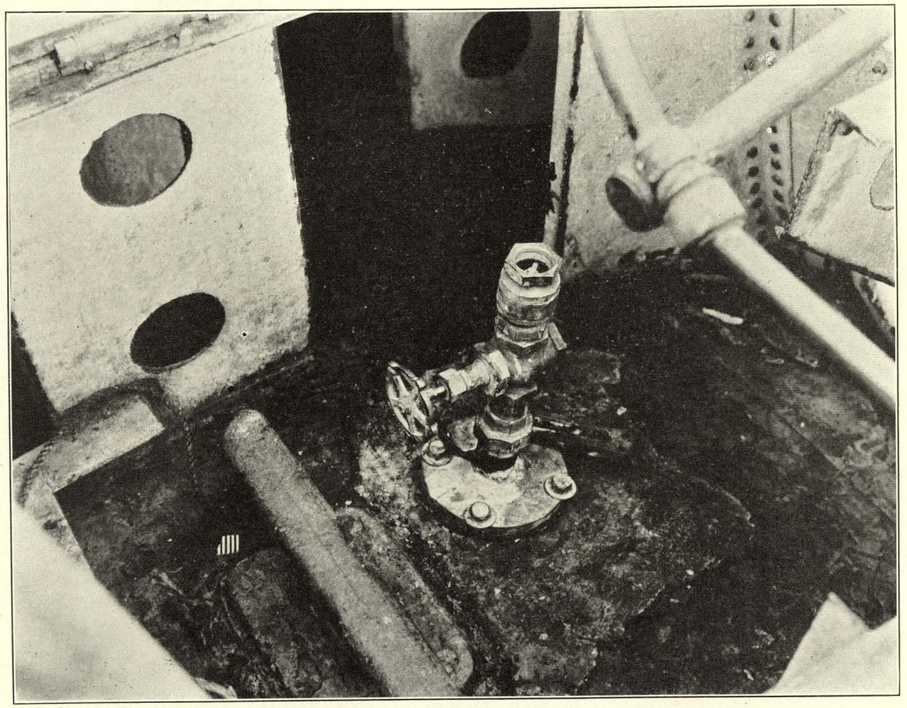


FIG. 53.—Torpedo-room spill pipe connection between frames 33 and 34. Cross valve at middle of spill pipe for flooding and check valve at top of spill pipe. Note special wedge used under head of starboard forward bolt to obtain tightness of flange, also bituminous composition chipped away before spill-pipe hole was burned

Part VIII.—Section 3. Battery Room.

When it was learned on January 31 that the vessel lay about 2½ or 3° by the head and it was discovered on February 6 that the hole in the vessel was apparently in the side rather than in the top of the battery room, it was realized that it might be possible to obtain a very considerable amount of buoyancy in the battery room itself if air could be blown in. A much larger amount of buoyancy would be available when the stern lifted, just at the time that buoyancy forward would be most needed.

At the suggestion of Crilley, a long piece of ½-inch brass pipe was prepared, with a 1¼-inch union at its upper end. After one unsuccessful attempt, due to lack of information as to the

exact shape of the hole, Crilley on February 13, with the assistance of Eiben, succeeded in ramming about 7 feet of this pipe into the side of the *S–4*, so that the end had apparently entered the battery room. The outer end was bent up and secured to the starboard cleat just forward of the gun, ready for connection of the No. 7 blowing hose, in the manner shown in Figure 126.

Part VIII.—Section 4. Control Room and Conning Tower.

For a considerable time the salvage force endeavored to find a way in which a salvage hatch might be fitted in the conning tower by means of which the control room could be unwatered. The difficulty there lay in opening the upper conning tower hatch which was held closed by a toggle device with a gravity latch, all on the inside. Breaking out an eye port in the conning tower to reach it with a special tool appeared not practicable, on account of the necessity of simultaneously lifting the latch to unlock the toggle. Burning out the latch was later considered, either by burning a piece out of the toggle side, in which case the conning tower top casting, with the gasket seat, would almost certainly have been damaged, or by burning off the hinges, in which case the toggle would still have been engaged. When the air test of the *S–6* indicated that the conning tower upper hatch would hold a pressure of 10 pounds per square inch without assistance, the plans were definitely made to reinforce the hatch and to blow the water out through some of the existing piping on the ship. As the conning tower was later found to be open to the control room, the unwatering of the latter would automatically unwater the former.

It was a great relief when Ingram first entered the control room (via the engine room) on January 7 to find that the passage through it was apparently all clear to the forward end; Eadie and Carr the next day confirmed this.

Having in mind the great number of operations involved to close and check all openings bounding the control room, the job was tackled without delay, the first crew being Eadie, Carr, and Nicol on January 8. Eadie made his way forward to the water-tight door leading into the battery room and found it closed, but with only two or three dogs on the starboard side turned down loosely; in other words, it was closed but not dogged. He had been instructed to open the door and close the battery exhaust ventilation flapper valve and the wash-room drain valve on the forward side of the bulkhead, but seeing the door closed and knowing that the crew had found their way out of the control room, he reasoned that water had come in somewhere else than through the door in large quantities, so he dogged down the door without first opening it. He closed the voice-tube bulkhead valve in the wash room on the starboard side, which he found half open and closed the wash-room drain valve down at the lower left-hand forward corner of the passageway—a very difficult operation in view of the narrow passage. He could not find the lever to the ventilation flapper valve over the door.

After receiving a full report from Eadie in the decompression chamber, the salvage officer took the next six divers to the *S–6* for additional instructions before sending them down. The delay involved was considered warranted in cases of this kind—and it was for just such occasions as these that the *S–6* was anchored as close to the *Falcon* as possible.

With the work of Eiben, Wilson, and Mattox on the next dive began a struggle which extended over 24 days and required the work of nine divers exclusively to close and secure the two flap valves in the ventilation line over the forward control-room door at bulkhead 72. The gear on the after side was different from the *S–6*, so that the special tools made to fit the handles, levers, and nuts, two of which are shown at "1" and "3" on Figure 148, had to be by direction of the divers rather than by measurement on the sister vessel. Eadie, on January 14, had to reopen the forward control-room door to close the flapper valve on the forward side of the bulkhead, the one which would seal the control room when excess pressure was applied to it, but he could not close the valve. Eiben, with Wilson helping him, spent the next dive on it without

much accomplished, whereupon work inside the vessel was suspended until January 30, on account of freezing of the divers' air lines. Armed with more special tools made up in the meantime, Eadie and Carr, Eiben and Wilson, made another attempt, this time succeeding in ap-

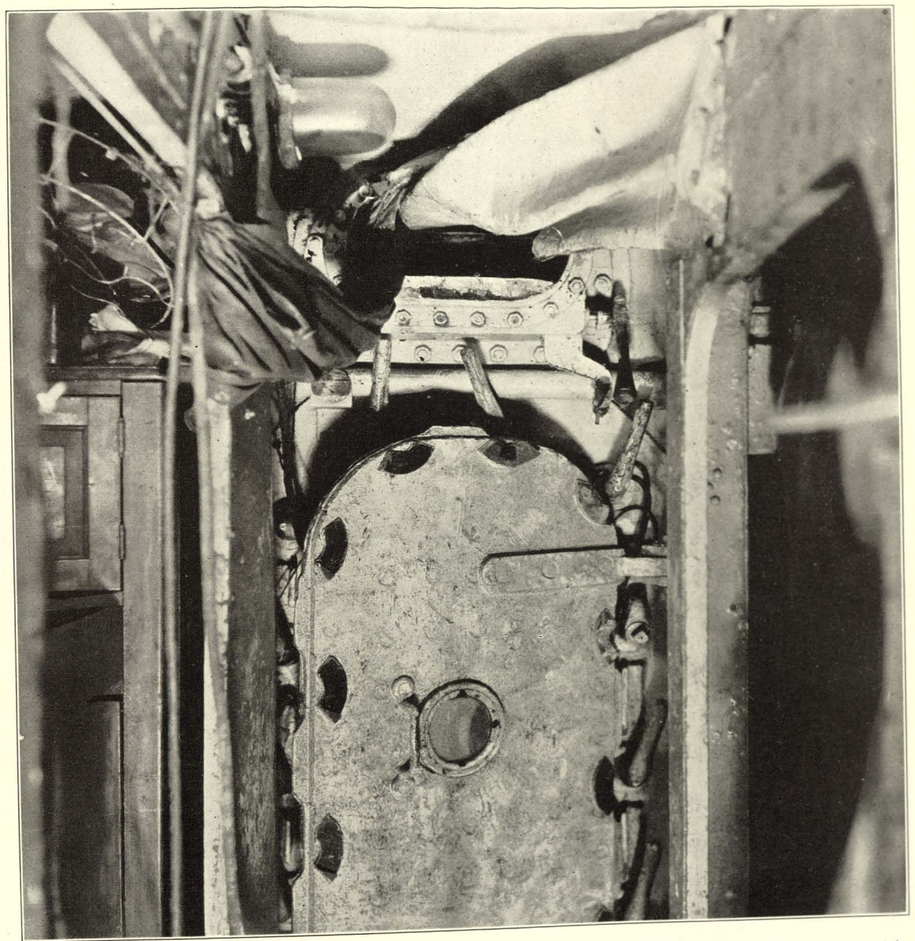


FIG. 54.—Passageway in wardroom country at after end of battery room leading to door into control room. The wardroom curtain floated back through both flap valves in the ventilation line when the duct collapsed and was carried away, thus preventing the valves from being tightly closed

parently closing both valves but not securing them. Again, with new tools made overnight, Eadie went through the control-room door on January 31, and after some more careful work in the passageway which was then more workable by reason of the clearer water and the air bubbles at the top of the compartment formed by the accumulation of divers' air, he discovered that the

exhaust ventilation duct had been torn away from the casting on the forward side and that the valves were clogged with foreign matter. On the next dive Eiben unlatched both flapper valves and removed some blue prints and some heavy cloth (unquestionably the curtain of the starboard stateroom door (see fig. 54)) which had lodged inside the valve box. He succeeded in closing both valves quite readily but could not secure them. However, Eadie the next day, taking along the tools and a special double wedge to place under the butterfly nut on the forward valve, which could not be set up tightly, succeeded in securing both flapper valves. On the same dive he closed the forward control-room door, thus terminating work begun by him at this point on January 8.

The following valves were thought to be closed in the control room, but each had to be checked carefully for closure and tightness in order to insure sealing of the compartment. This work was carried along concurrently with other work described in this section. The location of the principal valves is shown on Plate 16.

(*a*) Voice tube bulkhead valve, bulkhead 72, in wash room on starboard side. Closed by Eadie, as above described.

(*b*) Washbasin drain valve in passage at bulkhead 72. Closed by Eadie, as above described.

(*c*) Main induction valve lever. Tightened and secured by Eiben.

(*d*) Control-room supply ventilation hull valve (flapper). Tightened and secured by Eiben.

(*e*) Drain valve for this valve box. Checked closed by Eiben.

(*f*) Voice-tube bulkhead valve, bulkhead 93, forward side. Closed by Wilson.

(*g*) Control-room exhaust ventilation outboard valve on top of trunk. Checked closed by Kelley.

(*h*) Drain valve for this trunk. Checked closed by Campbell.

(*i*) Control-room exhaust ventilation hull valve (flapper). Checked closed by Kelley.

(*j*) Drain valve for this valve box. Closed by Campbell.

(*k*) Compartment salvage valve. Checked closed by Campbell.

(*l*) Battery exhaust outboard valve on top of trunk. Checked closed by Kelley.

(*m*) Battery exhaust hull valve (flapper). Checked closed by Kelley.

(*n*) Drain valve from this valve box. Checked closed by Crilley.

(*o*) Radio trunk lower flap valve. Checked closed by Wilson.

(*p*) Bulkhead valve for battery exhaust ventilation at bulkhead 93. Forward valve in radio room. Could not be reached by diver. After valve found closed but slightly loose by Wilson. Secured by him.

(*q*) Main induction trunk drain valve. This was a 3-inch valve in the superstructure, with a very small handwheel, and four attempts by Eiben to close this valve by hand were unsuccessful. It was finally closed by Campbell and Crilley, using the wrench shown at "5" on Figure 148.

Due to the inability of the salvage force to reach the forward flap valve on the battery exhaust line at bulkhead 93, it was known that pressure could not be held in the engine room in excess of that in the control room, else the after flapper would spring open. However, since the control room was to be blown dry first, since the pressure required to blow down either compartment was about the same, and since the spill pipe from the control room was small, it appeared that no great harm would be done if air did leak in from the engine room to the control room. At some stage of the proceedings, however, perhaps while attempting to vent down the control room on March 17, the after flapper valve carried away and dropped open, thus placing the control room and the engine room in communication with each other.

Eiben, Wilson, and Campbell, on January 4, when first entering the engine room, reported two or three dogs loose on the port side of the water-tight door at bulkhead 93 leading from the engine room to the control room. This was confirmed by Ingram, who on January 7 brought up a piece of 2–inch stage plank which he said had been lashed across the door, presumably to help hold it closed. As one loose dog on the engine-room door of the *S–6* had been discovered during the air test on that vessel, the presence of loose dogs on the *S–4* door was not surprising. However, when Wilson went down on February 6 to close and dog the after control-room door, he found four or five wedges on the door entirely missing. Whether these were sheared off by the ship's force on December 17 or by Ingram in his zeal in opening the door on January 7, could not be determined. New steel wedges of varying thicknesses were made up, five of which Wilson inserted under the dogs on February 12 when the control room was finally sealed.

It was calculated that the upper conning-tower hatch would be subjected to a static pressure on the underside of 9½ pounds per square inch when the compartment was blown down to the spill-pipe strainer, in addition to which at least 5 and preferably 7 pounds per square inch excess pressure would be required to expel the water at a reasonable rate. It was at first proposed to reinforce this hatch by the use of clamps or strongbacks, but no suitable location or fastenings could be found for such a device, and the final decision was to load up the hatch with lead in the same manner as when making a compartment or ship air test at a navy yard. One hundred-pound pigs were to be piled on the hatch, held in place by a bin, and the whole cemented in place.

A wooden bin of collapsible construction was made, so arranged that it could be set up piece by piece in the bridge, around the hatch, and held together by loose-fitting bolts. Inside the bin was to be placed a canvas lining, to hold the liquid cement, then on the canvas were to be placed two iron bars 1 by 4 by 36 inches, so as to insure that the pigs of lead resting on these bars would all exert their effective weight on the hatch cover.

Harris and Wickwire, on February 5, took down a new descending line to the bridge, received the bin, set it up, placed the inside lining, laid in it the two steel bars, and placed on the bars 10 pigs of lead, each weighing 100 pounds, all in 50 minutes. The pigs were attached by a becket to a combined ring and shackle forming a runner on the descending line, so that when the pigs reached the bridge the divers cut the becket with a knife and laid the pigs in place. (See fig. 55.) Michels and Bailey followed and placed 30 more 100–pound pigs in 42 minutes.

On February 5, 400 pounds of cement was shot into the bin containing the lead. In the meantime, blowing of the control room having indicated that air was leaking from one side of the conning-tower hatch, and Michels, upon examination, having reported that more pigs of lead could be placed on the upper conning-tower hatch, he was sent down with Von der Wall on February 14 and in 16 minutes they placed 10 additional 100–pound pigs. Michels also rearranged the existing lead, so that with a total excess pressure of 17 pounds per square inch under the conning-tower hatch it was sufficiently tight for all practical purposes. Assuming that the 4,000 pounds of lead and the 400 pounds of cement were all effective, the calculated excess pressure per square inch due to the reinforcement adopted would be 11.6 pounds: actually it was about 7 pounds.

The method of sealing the main induction outboard valve by cement is described subsequently in Appendix VI, section 3.

The hole in the periscope fair-water plating for the insertion of the cement hose in the top of the spray-tight trunk above the main induction valve, as cut by Wickwire on February 1, 1928, with the tools shown in Figures 27, 28, and 29, can be seen just under the rail for the signalman on Figure 107 or just under the starboard A frame on Figure 120.

The method of sealing the outboard ventilation line to shut off air leaking from the control room through the hull valve for the control-room ventilation supply which was designed to seat with pressure from outside and upon which a very weak securing device was fitted is described subsequently in section 9.

The original plan was to unwater the control room through a hose suction valve in the bilge of this compartment, and this plan was carried through almost without a change, save for the later decision to place the spill-pipe hose and strainer down in the magazine instead of in the ice-machine well, as in the former case more water could be expelled from the control room.

Wilson, on January 8, opened a stop valve on the bilge suction line, a stop valve to the trimming manifold, and three valves on that manifold, checking the remainder to insure that

FIG. 55.—Looking down and slightly aft into chariot bridge, showing pig lead over upper conning-tower hatch to hold additional air pressure under this hatch. The afterside of the bin has broken loose and extends toward the upper left-hand corner of the photograph. Forty 100-pound pigs were placed in this bin

they were closed. He could not find the sea valve to the trimming manifold, to open it, nor could he find it on subsequent dives made on January 14, January 30, January 31, and February 1, and Crilley was not able to find it on the latter two days. No one could be found on the *S–6* who remembered just where the handwheel was located on the *S–4*. As it was the usual procedure to run the *S–4* with the sea valve open to the manifold and the stop valve closed, salvage work proceeded on the assumption that the sea valve was open. (The operating handwheel, with its extension stem, was later found to point upward and aft instead of directly inboard on the *S–6*).

Eadie and Carr, on February 3, took up the flooring in the control room to port of No. 1 periscope and found that the hose suction valve in the bilge pointed inboard against No. 1 periscope well instead of directly upward, as on the *S–4*—and once again members of the force said things.

Wilson, Eiben and Burd were sent down with a short length of hose to place between the suction valve and the spill-pipe fitting, but they could not get the old hose disconnected from the valve.

The next day Eiben and Wilson cut the old suction hose near the end and succeeded in removing it, but they could not bend the new hose to a sharp enough radius to engage the hose threads on the valve. They brought up the length of old hose as a sample and brought back the spill-pipe fitting, which was altered on the *Falcon* between dives so as to make a sort of short return bend in place of the straight connection, the general shape of which is illustrated in Figure 56. The topmost fitting on this assembly is the check valve, as there were no other check valves in the line.

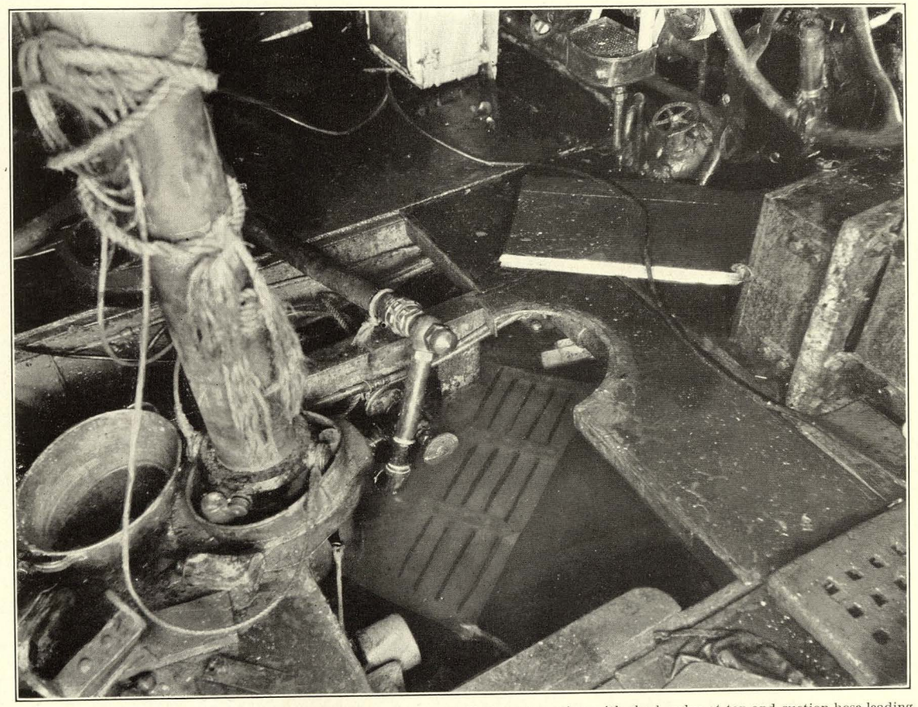


FIG. 56.—Control-room bilge, port side, showing hose valve and spill-pipe connection with check valve at top and suction hose leading aft to magazine. This hose valve on the *S–6* pointed directly upward; hence the alterations to the spill-pipe connection as shown. Note jamming of No. 1 periscope in well due to failure to telescope the handles

Carr and Baker took down the altered spill-pipe fitting and, after working almost the whole dive, managed to engage the threads and to secure it to the hose valve, whereupon they opened the bilge suction valve and the pipe line was all ready. This made a total of seven valves between the spill pipe and the sea, not including the check valve.

On the check valve had been screwed a special fitting, and Carr and Baker had taken with them a diving hose, so when they were all set they screwed the diving hose to the special spill-pipe fitting and, upon signal from them, the *Falcon* turned on the air. The divers reported air passing, it was evident from the manifold that air was going in and very soon a new stream

of bubbles appeared at the surface. Turning the air off and on several times, asking the divers to listen for air going through and watching bubbles, was ample proof that the spill-pipe fitting was properly connected and that all valves were open.

Crilley, Wickwire, and Applegate, following, removed the diving hose and special fitting from the spill pipe and connected the regular spill-pipe suction hose to it. They lifted the gratings and flooring between galley and radio room and pushed the spill-pipe strainer down to the bottom of the magazine through the open manhole in the bilge. The final sealing of the control room and the blowing operations are described else-where.

The problem of providing an air supply to the control room was comparatively simple, as the compartment salvage line, with external connection on the starboard side of the conning-

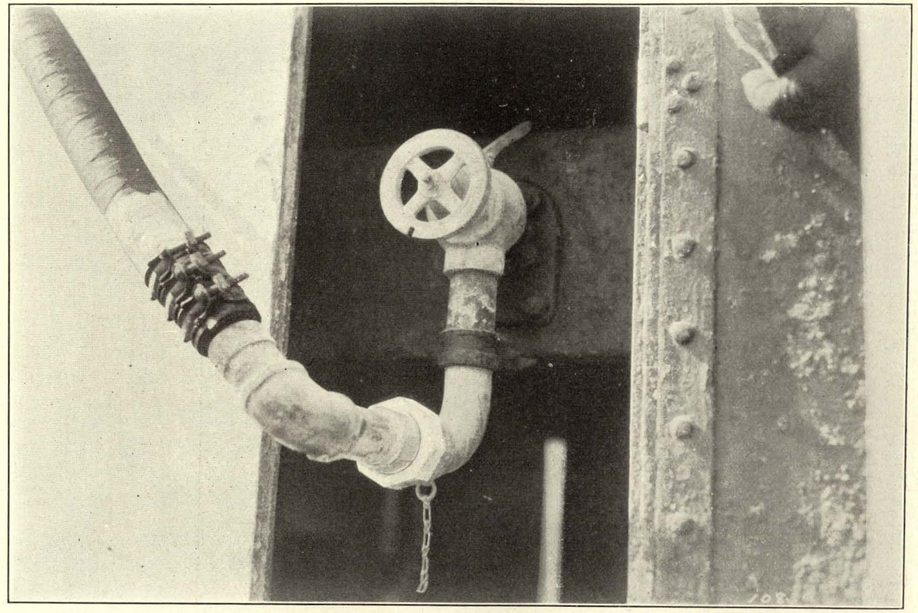


FIG. 57.—Blowing hose No. 2, for control room, connected to salvage-air fitting on starboard side of fair water, normally used for supplying air to compartments

tower fair water, led down into the top of the control room with a flange just before it entered the for e-and-aft line through a T fitting.

On January 30 Campbell, Crilley, and Grube took out two bolts on this flange, slacked off the third, but could not start the fourth, even with the special wrenches supplied them. The next day Campbell, Crilley, and Baker, by prying the 1-inch copper line down from the shell overhead, managed to disconnect the flange and to blank the T connection leading to the fore-and aft line, so as to shut off the control room from other compartments via this line.

On January 31 Wickwire and Harris removed cap from compartment salvage connection in starboard side of fair water. Upon opening the valve they found air to escape, thus indicating that the air bubble in the upper part of the control room was in direct communication with the valve, as desired. They screwed the male half of the union for the No. 2 blow-

ing hose to the salvage valve; the female half was set aside for attachment to the hose. The control-room blowing connection, as completed, is illustrated in Figure 57.

Part VIII.—Section 5. Engine Room.

Since the engine-room hatch had been opened for access to the vessel, it was planned from the first to close it with a salvage hatch and to unwater the compartment by means of blowing connections and a spill pipe on that hatch.

On January 14, Wilson checked closed the main induction hull flapper valve and the drain for this valve box, as well as the voice-tube bulkhead valve on the aft side of bulkhead 93. On

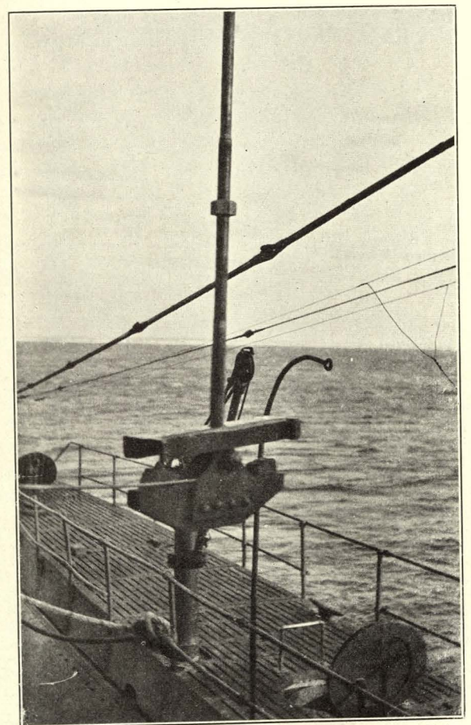


FIG. 58.—View of underside of hatch, showing short length, of diving air hose to be attached to blowing hose already in place in engine room. Strainer painted white to improve visibility when guiding it into bilge

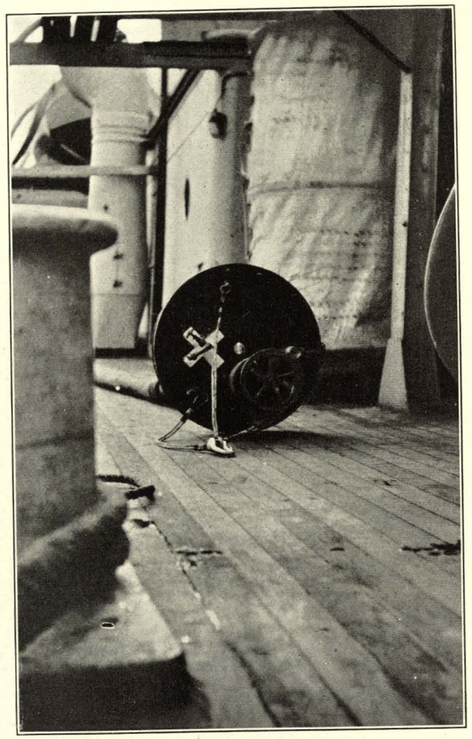


FIG. 59.—Engine-room salvage hatch assembled on *Bushnell*. Valve and fitting over white-painted cross were for blowing normal fuel-oil tanks from the engine room

January 30, Campbell checked closed the breathing-air valve abaft the port engine. The compartment salvage valve was supposed to be checked closed on this dive, but as it was over behind the port engine, with a rather inaccessible valve wheel, instead of directly over the port engine, it is doubtful whether it was reached. The engine exhaust valves were certainly left closed by the ship's force; hence they were not touched.

On February 16, after the final effort by Crilley to set the fuel-oil valves in the engine room and after an unsuccessful attempt to blow the forward fuel-oil tanks through the 1-inch blow line and the outboard filling connection, there was no more work left to be done inside the

S–4. The control roo m and the motor room had both been sealed and blown and the sealing of the engine room was next undertaken. Baker, Grube, and Applegate on this day took a short length of divers' hose into the engine room and connected the lower end of it to the special flange which had been bolted to the forward fuel-oil tank blow line. The upper end of this hose was left on deck, above the hatch, to be connected to the special blowing hose *through* the engine-room salvage hatch shown in Figure 125. This crew cleared away the floor plates in the starboard engine-room bilge to make room for dropping the spill-pipe strainer all the way to the bottom of the compartment. Just before coming up from their dive they opened the flood valve on the motor-room salvage hatch so as to flood the motor room and prevent the stern from lifting when blowing the engine room.

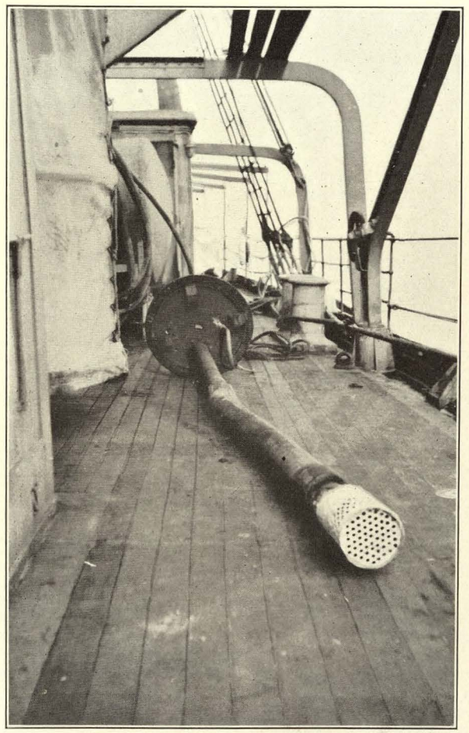


FIG. 60.—Sheet-metal trough secured to engine-room hatch ladder for guiding strainer of engine-room spill pipe into the bilges

Although the engine-room salvage hatch had been assembled on the *Bushnell* (figs. 58 and 59) and had been tried on the *S–6* (see figs. 61 and 62), on February 2 in the presence of all the divers, a second and final rehearsal and placing of this hatch was conducted on the *S–6* on February 15, the day before it was placed on the *S–4*. At the same time the galvanized-steel trough which had been made up for securing to the engine-room hatch ladder and for guiding the strainer into the bilge was fitted in the *S–4* and its features described to all the divers.

Even then the trough was the next day placed in the wrong part of the bilge on the *S–4*, so that it could not be secured to the ladder in the regular way. (See fig. 60.) However, it served its purpose and the final result was the same. This incident serves to emphasize the necessity for having the salvage officer endeavor to visualize the various things that may go wrong and the different ways in which a job may be done improperly, so that if the divers report trouble he may ask them if so and so is not the trouble or he may tell them to do things which will tend to correct the missteps which *may* have been made.

On the afternoon of February 16, everything possible having been done inside the vessel to blow the fuel-oil tanks and the adjacent compartments being sealed, it was decided to seal up the engine room and close the vessel. At 4.03 p. m. Eiben and Von der Wall put the trough for the engine-room spill pipe in place and secured it to the ladder. They then placed the main strongback, the kingbolt, and the auxiliary strongback, everything going smoothly and exactly as per plan, although all their work had to be done by the aid of a lamp. The white paint which had previously been applied to all these parts thus served its purpose excellently.

It was now after dark, but everything was ready, and Kelley and Kallinoski were anxious to show what they could do with the engine room salvage hatch, even by lamplight. They were sent down at 5.57 p. m. with one lamp and another was hung in the water over them, so as

to give general illumination. From the time that the engine-room salvage hatch left the deck of the *Falcon* until the spill pipe had been entered in the engine-room hatch, the strainer guided into the trough, the diving hose for the fuel-oil tank blows connected to the short length of hose on the underside of the hatch (fig. 125), and the hatch cover threaded over the kingbolt, lowered into place and clamped home with the nut, only 21 minutes elapsed—a truly remarkable performance, even under the most favorable conditions.

Part VIII.—Section 6. Motor Room.

It had been found possible on the *S–51* to blow the water out through the motor room via the engine room, through a drainage pipe that led between the two compartments. Some such means was looked for on the *S–4*, and it was discovered that by the opening of certain valves on the bilge suction manifold and certain other valves on the high-pressure ballast pump lines,

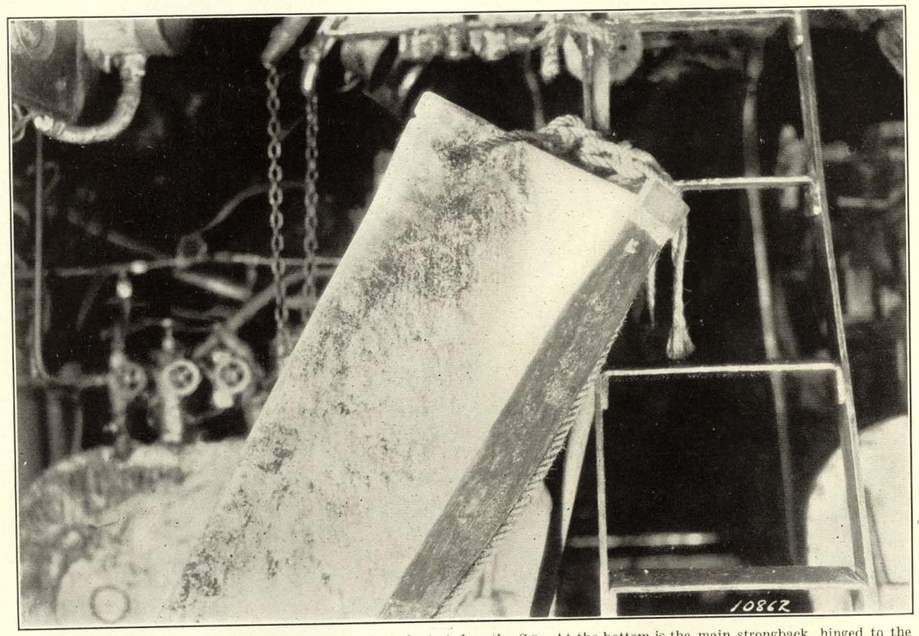


FIG. 61.—Kingbolt for engine-room salvage hatch, ready to be tested on the *S-6*. At the bottom is the main strongback, hinged to the kingbolt. Above it is the auxiliary strongback or spreader for holding the kingbolt central in the hatch trunk. The relative position of the auxiliary strongback is just underneath the nut on the kingbolt

water could be forced out through the compartment suction and the pump to the sea. There was even a check valve conveniently provided in the line. Although some of the valves were quite out of the way, the divers maintained, after study on the *S–6*, that they could reach them.

Accordingly, a double-channel strongback was prepared, the section of wood deck grating was removed from around the motor-room hatch by Eadie on December 31 and steps taken to secure the strongback to four of the coaming bolts on the motor-room hatch. Further consideration of the matter, thinking of the wreckage and débris that might be cluttering up the motor room, and the awkwardness of the operations required to reach all the valves, led to the decision on January 5 to fit a regular salvage hatch in the motor room as was to be fitted in the engine room. Another salvage hatch was broken out of the *Falcon's* hold and immediate

preparations made to fit it to the motor room. This hatch was to carry a blowing connection for the motor room and a flooding valve, as well as the spill pipe.

Sealing up the motor room after the compartment had been entered and cleared was a comparatively simple matter. Campbell and Crilley on January 11 checked closing of ventilation flapper valve, compartment salvage valve, and bulkhead voice-tube ventilation valve. On this dive and on a subsequent dive Campbell attempted, without success, to reach and check for closure the drain valve from the ventilation flapper valve. Since there was no particular reason for this valve to be open, the salvage force took it for granted that it was closed.

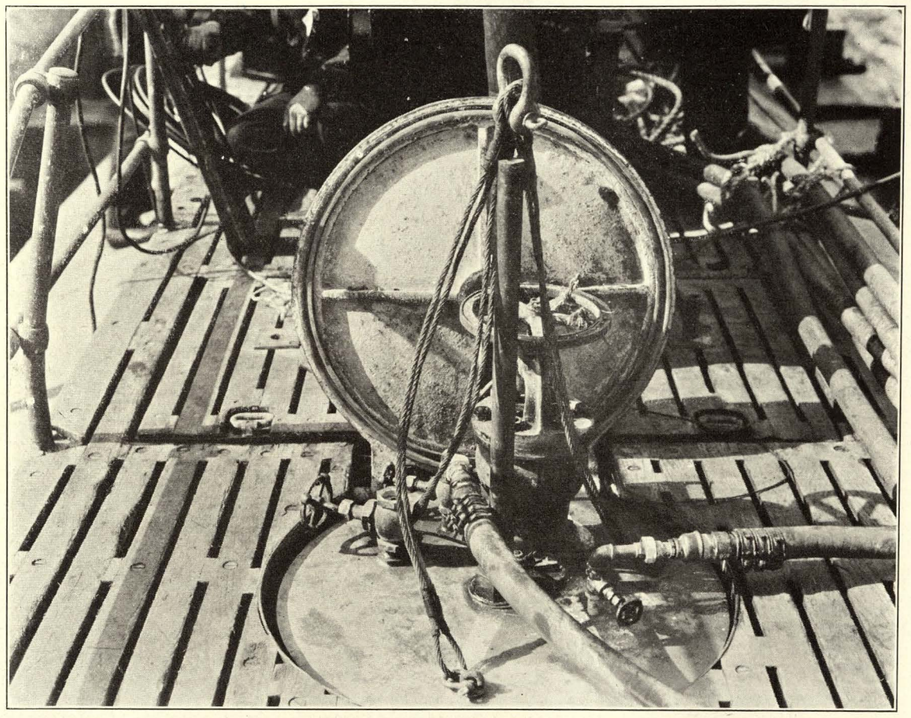


FIG. 62.—Engine-room salvage hatch in place; 1¼-inch flood valve at left, ¾-inch blow connection and blowing hose; spill-pipe valve and ½-inch blow to normal fuel-oil tanks on right. The unions marked in white were the ones which were connected by the divers when attaching the air-blowing hoses

The tiller-room door was thought to be open, in which case the water in that compartment would run out into the motor room automatically.

It was almost certain that the bulkhead shaft stuffing boxes between the engine and motor rooms would leak, but in view of their extreme unaccessibility, there was nothing that could be done about it. At any rate, leakage of water or air would take place only back and forth between two compartments, both of which were to be blown dry.

Grube and Mattox on February 1 searched the motor room again for the two missing members of the crew, then lifted the floor plates preparatory to lowering the spill-pipe suction hose through the hole, and sent up the temporary ladder in the motor-room hatch.

Everything being ready, a crew of four divers were instructed and drilled and on February 3 were sent down to the motor room to place the salvage hatch, the *Falcon* moving over in the meantime so as to plumb the hatch with the boom whip. Wickwire and Applegate were on deck to enter the hatch and place it; Crilley was inside, at the motor-room door, to guide the spill

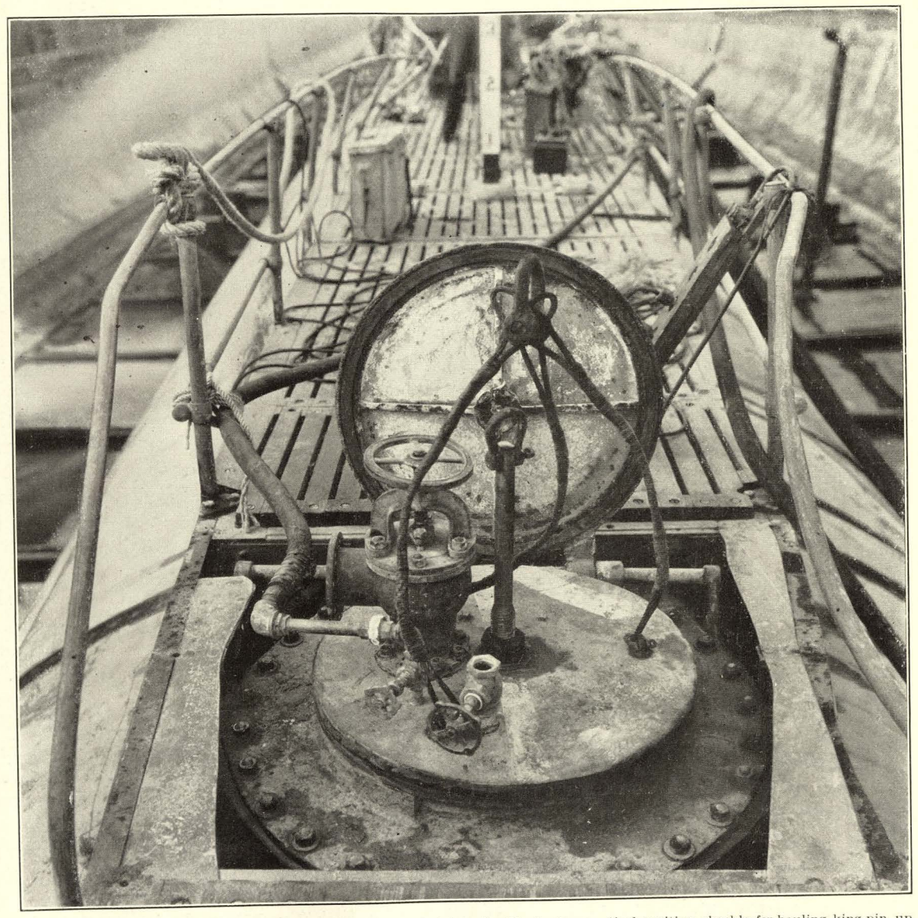


FIG. 63.—Motor-room salvage hatch with sling for suspending hatch and spill pipe in a vertical position, shackle for hauling king-pin up tight preparatory to bolting and blowing hose No. 4 lashed securely to nearest fixed point. Stop valve on spill pipe at rear left, blowing hose and blow valve at left, and flood valve in front

pipe and strainer into the bilge, while Baker was tending him on deck at the engine-room hatch. The salvage hatch, complete with strongback, kingbolt, spill pipe, suction hose, etc. (fig. 63), was lowered at once, with the strainer secured to a shackle which slid down a special descending line made fast to the rail near the motor-room hatch. The spill pipe was passed down the

hatch by Wickwire and Applegate, then guided down into the bilge by Crilley. The strongback slipped easily into position, the hatch was landed, the securing nut set up, and the job was done, all in one dive. Crilley closed the motor-room door leading into the engine room, but could not start the dogs to secure it. Wickwire went back into the engine room the next day and dogged the door with the use of a pipe wrench and a heavy sledge, although even then he could not engage all the dogs. Blowing of the motor room was begun on February 5, as related elsewhere.

Part VIII.—Section 7. Main Ballast Tanks.

Very early in the operations it became evident that the starboard forward main ballast tank was damaged to such an extent that it could not be used for buoyancy. Even had the use of the forward ballast tanks group been contemplated, air in the port tank would have given the ship a decided list. The practicability of making either of the forward tanks hold air was questionable, since the No. 1 main vent ("A" vent) leaked bubbles almost continuously and it was evident that the valve had become damaged in the collision.

There was, however, nothing to prevent the use of the remaining ballast tanks for buoyancy, even though it was known that the location of the Kingstons at the after ends of the middle main ballast and safety tanks would permit much of the air in those tanks to escape when the vessel rose, stern first. A check in the control room on January 8 and another on January 30 indicated that all main ballast tank Kingstons were open and that divers could reach the air-blowing manifold with little difficulty. The side flood valves, according to practice, were undoubtedly closed. It was proposed to supply air to the main ballast tanks first from the *S–4's* own air flasks—using what high-pressure air was left in them—then from the *Falcon*, via the high-pressure external charging connection in the port forward corner of the superstructure.

A number of the divers, notably Eadie, Carr, Eiben, Wilson, and Crilley, were rehearsed and instructed at the *S–6* air-blowing manifold. The salvage officer was to man the telephone on the *Falcon* with a chart of the complete manifold in front of him, while the diver doing the work was to stand in front of the *S–4* manifold, shown in Figure 64. The scheme worked very well, and in all the blowing and checking that was performed in the course of the next six days only one slip was made and that was soon discovered.

Following the above plan, Carr went to the manifold on January 31 and observed and checked the position of all valves and had them recorded. He found the No. 1 and No. 2 high-pressure air banks connected to the high-pressure manifold and the remaining valves set for blowing *all* main ballast tanks through the high-pressure by-pass. The air had naturally all escaped from these banks through the hole in the side of No. 1 starboard main ballast tank. The gauges could not very well be read in the murky water, but that on No. 4 bank appeared to show some pressure. When Carr opened the high-pressure valve to No. 4 bank, he heard air coming through and the *Falcon* observed large bubbles coming to the surface, which continued until the blow valve for No. 1 main ballast tank could be shut off. Wilson, on the next dive, set the valves to blow the middle and after main ballast tanks and the safety tank from the external connection, but after Wickwire and Harris, Grube and Applegate, had finally succeeded in connecting No. 5 blowing hose on deck of the *S–4* (fig. 65), and air was turned on, the salvage air pressure rose immediately and did not drop, indicating that no air was passing through. The rapid venting and lowering of pressure showed that only the volume of the hose was open to the salvage air manifold on the *Falcon*.

Salvage air at pressures up to 100 and 150 pounds was kept on until midnight of January 31 and all day on February 1, thinking that the line had perhaps become frozen or clogged with sediment through unuse and that the line would eventually blow through. Valves and lines wer checked over again on the *S–6* and the high-pressure external charging line blown through

on that vessel. Carr, on February 1, checked over all the valves in the control room for the second time but could get no air out of the manifold, so it was decided that high-pressure air would have to be supplied direct to the *S–4* manifold in order to blow through the lines and empty the tanks.

A special high-pressure fitting with stop valve was made to screw onto the *S–4* high-pressure manifold after the removal of one of the bonnets belonging to a valve on a gauge line. The force was fortunate in discovering on the *Bushnell* a number of lengths of flexible high-pressure metal hose taken from an ex-German submarine which, with the flexible copper tubing available,

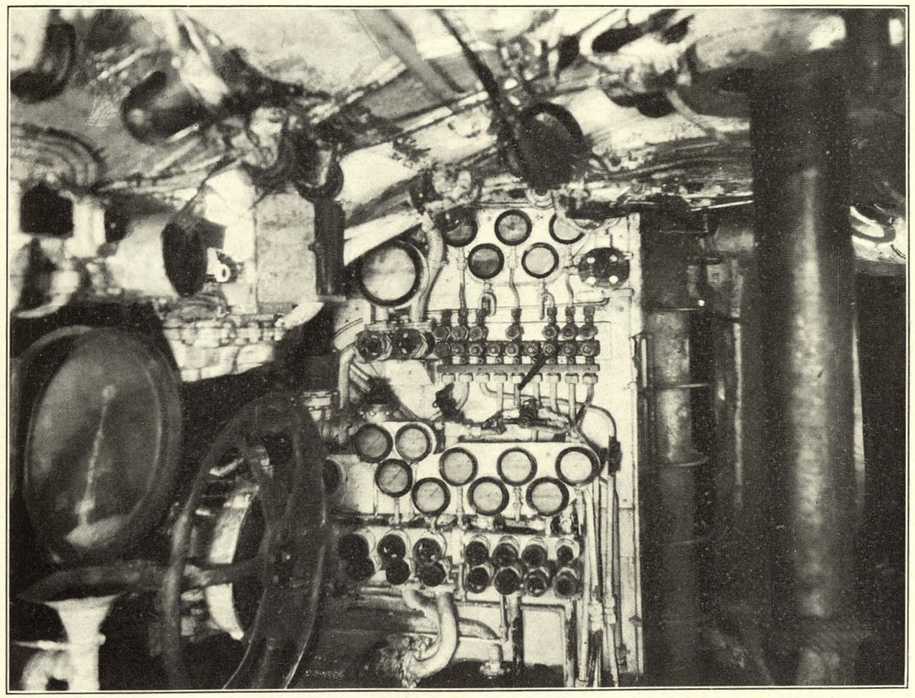


FIG. 64.—Air-blowing manifold in port forward corner of control room of *S–4*. Every valve on this manifold was set or checked at least once by the divers in the course of the salvage operations

made up a total length of over 200 feet. This hose and all its fittings were overhauled, assembled, tried on the *S–6* and tested out with air under pressure—a very creditable performance for one day's work on the part of those handling material in the force.

While this gear was being prepared, Lieutenant Commander Withers, executive officer of the *Bushnell* and a qualified submarine commanding officer, suggested that there might be a stop or hull valve on the external charging line on the *S–4*, as he had had one put in on his vessel, one of the *S–10* to *S–13* class. Accordingly, when Eadie, Carr, and Scott went down on February 3 with the high-pressure fittings and the flexible metal hose, dragging the latter after them down through the engine room hatch and into the control room, they searched for a stop valve in the charging line. A blast of air and spray from the vent valve at the No. 5 blowing hose on

the *Falcon* soon after the divers reached the control room told the story—that there had been such a stop valve on the *S–4* and that Eadie had found and opened it. The *Falcon* immediately put air on No. 5 hose and the divers reported that they could hear air passing through the control room manifold. There was no longer any necessity for making the high-pressure air connection from the *Falcon*, so the divers brought back the high-pressure fittings and the flexible metal hose with them.

At 10.52 a. m. on February 3, the *Falcon* started salvage air into the main ballast tank blowing hose (No. 5) at about 100 pounds pressure, with the *S–4* manifold supposedly set for blowing the middle and after main ballast tanks and safety tank. Bubbles appeared forward above the S–4. Started second Westinghouse compressor at about 11.30 a. m. and blew off

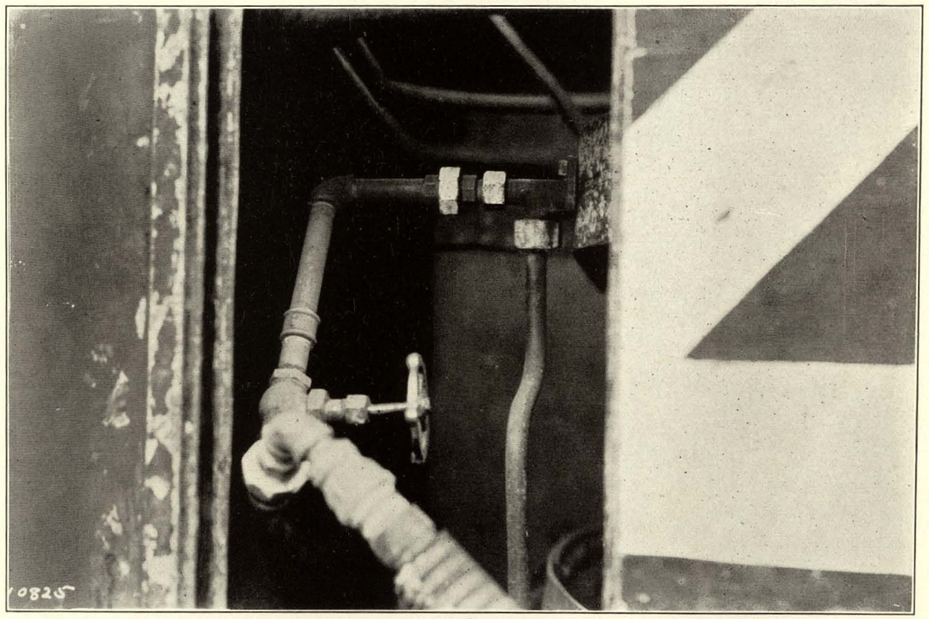


FIG. 65.—Blowing hose No. 5, for main ballast tanks, connected to external high-pressure air-charging connection. This assembly was originally made up for a charging connection pointing outboard (toward the camera), as on the *S–6*, and had subsequently to be altered as shown

and on for remainder of day at 125 pounds per square inch. This was allowing 50 pounds for static water pressure, 40 pounds for allowable excess pressure in the tanks and 35 pounds for the drop in the blowing hose and in the manifold, pipe, and fittings on the *S–4*. The pressure in the main ballast tanks balanced off at about 50 pounds per square inch. Grube went down late in the afternoon of this day to locate the source of the leaks from the *S–4* when blowing main ballast tanks but could not get forward of gun.

When Wilson was sent down the next day to close off *all* the main ballast tank blow valves and check for leaks in the piping, he found the blow valve to the forward tank open, which accounted for the bubbles the previous day. With all valves closed, could not get any salvage air in at 150 pounds nor did any air leak out of blowing hose—indicating that no other valves were open and that there was no leakage. Before coming up, Wilson opened safety tank blow

valve and *Falcon* began blowing that tank only, using both salvage compressors at 100 to 125 pounds pressure, with the blow valve at the *Falcon* salvage air manifold wide open. On these two days, air at a greater rate than usual was bubbling up at intervals from the engine-room hatch. It was known that the divers' air was accumulating in the control room and engine room and escaping now and then, but frequently air would continue to escape after the divers had come up.

On the next dive, Carr shifted the control room air manifold valves from safety tank to after main ballast tank. When he entered the control room, Carr found that the water level was down to the top of the water-tight doors, so that most of his helmet was out of water and by throwing his light up near the surface he could see around in the control room. Looking backward for Baker, who was to follow him, he saw curious bouncing bubbles on the surface, which, upon investigation, proved to be caused by a blast of air issuing from a hole in the lower cover of the valve box for No. 2 starboard main ballast vent. In other words, air being blown into the ballast tanks was leaking back through this hole into the control room. Subsequent investigation revealed that a ¼-inch iron pipe plug had been screwed into the composition cover, whereupon in the course of a few weeks, galvanic action had eaten it away so that it blew out into the control room when pressure was applied to the tanks.

A check-up on the *S-4* revealed ¾-inch pipe plugs in these valve covers, whereupon two special tapered ¾-inch plugs with long handles were made up and sent down with Carr on February 5. He found them too large for the holes but he could not tell just what size the holes were. However, while he was still down, a set consisting of duplicate brass nipples of ¼-inch, ⅜-inch, and ½-inch pipe sizes, each about 3 inches long, with a cap screwed on the end, were made up and sent down to him. With one of the ⅜-inch nipples, he succeeded in plugging the hole.

In the meantime Crilley, on February 4, reset the valves to blow the middle main ballast tanks, as it was not certain at that time that the hole found by Carr was in the ballast tank system and it was desired to proceed with the blowing simultaneously with the other work.

Before coming up from his dive on February 5, Carr opened the blow valves for the after main ballast tanks and safety tank, the valves for the middle main ballast tanks having been opened by Crilley the previous day. Each individual set of main ballast tanks had been blown into, independently, without signs of leakage of air, except into the control room, indicating with reasonable certainty that all tanks and lines were tight except the forward one. Middle and after main ballast tanks, port and starboard, and safety tank were now "on the line," ready for blowing down. The following is copied from the salvage log of February 5:

Large surges of air stopped blowing from engine room.
1004. Started blowing all main ballast tanks (except forward); 2 compressors going. 85 lbs.
1036 to 1044. Stopped (suspended) blowing M. B. tanks to clear blowing hose.
1155. Stopped blowing M. B. tanks; balanced off at 55 lbs.
1210. Started blowing main ballast tanks again; 1 compressor.
1213. Stopped compressor to allow compressor to cool off.
1250. Started blowing all M. B. tanks (except forward); 2 compressors. 85 lbs. on deck (of *Falcon*); working up gradually to 125 lbs. at 1312. Sandy water and seaweed appearing.
1410. Bubbles over C. T. of *S-4*. Stopped blowing and bubbles stopped.
1416. Stopped both compressors until check could be made of bubbles.

Crilley went down a few minutes later and reported bubbles escaping through the superstructure deck on the port side abreast the radio entering tube when air was turned into the tanks. Carr and Crilley, when sent down on February 6 to make a further examination, reported that the bubbles were coming from directly over the valve box for No. 2 (middle) main ballast vent. They were thought to be from a leaking or defective gasket in the main ballast

vent line from tank top to valve box; in either event, to reach their source it would undoubtedly be necessary to cut away the outer hull in way of the old upper tank, the superstructure above it, and perhaps burn away some framing.

In order to check up the location of leaks on *S–4* over No. 2 main ballast vent and to make sure that the main ballast vent valve itself was not leaking, the *S–6* was instructed to go into the harbor and submerge until the deck was under, then crack No. 2 main ballast vent with air in the tank. Bubbles were found to come up inside the fair water instead of up through deck. It was decided therefore that No. 2 main ballast vents on *S–4* were tight and that leak was on vent line somewhere between vent valve disk and main ballast tank top.

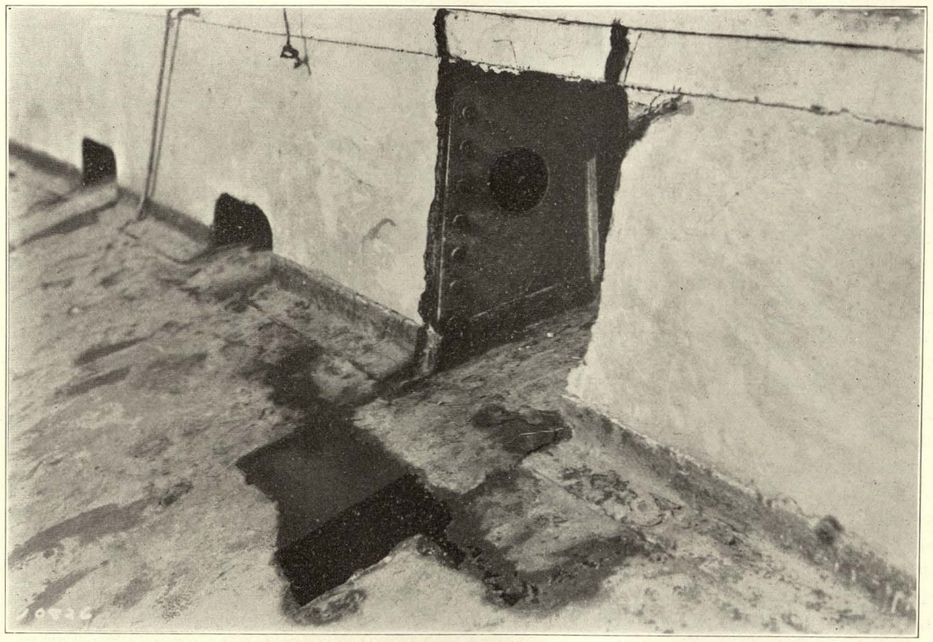


FIG. 66.—Holes cut in outer hull and superstructure with underwater arc torch to ascertain location of supposed air leak adjacent to No. 2 port main ballast tank vent valve

Kelley and McMullen, Wilson and Kallinoski, started on February 25, to burn away the outer shell in way of No. 2 port main ballast vent, but most of their time was spent in "getting set" and in adjusting the arc torch, the latter apparently suffering from too much oxygen. Carr and Stanley on the next dive burned out a large section of the outer hull (shown in fig. 66), and found no bubbles coming through, indicating that the leak was above or inboard of that point. Eiben and Von der Wall, following, burned away on the superstructure and Crilley and Grube succeeded in cutting out a large piece from the superstructure side. Putting their helmets into the hole in the side of the superstructure (fig. 66), they could see with the aid of their lamp that the air was issuing from a regular hole in the inner shell and not from the main ballast tank. In fact, they were in the next frame space abaft the vent valve. Checked up on *S–6* and found this hole to be the upper connection for the internal draft gauge. Air coming out of it would

indicate that main ballast tanks had been blown and that there was an air bubble around the Kingston plate. Air bubbles coming up from No. 1 main ballast vent also indicated that air being blown out of other ballast tanks was possibly running along keel and bubbling up into the No. 1 main ballast Kingstons.

From this it appeared that the main ballast tanks had been blowing properly on February 5 and that the air was down to the Kingstons at 2.10 p. m. on that date, when it began to bubble up through the draft gauge.

The main ballast tanks were not vented and flooded during the remainder of the operations, as it was felt that to do so might wash sand and mud back into the tanks and thus increase the dead weight of the vessel.

Part VIII.—Section 8. Normal Fuel-Oil Tanks.

The forward group of normal fuel-oil tanks, up to and including No. 6, all forward of frame 72, offered a very attractive means of obtaining buoyancy, especially as the greater part of the volume of these tanks lay directly under the flooded battery room and they would offer great assistance in lifting the bow, equaling one-half the lifting power of an 80-ton pontoon.

As the work progressed and it became more and more certain that all the expected buoyancy was going to be obtained from the principal compartments and from the three pairs of pontoons, it was realized that the buoyancy of the normal fuel tanks would not be required to bring the ship to the surface if all went well. However, the salvage work was proceeding at a satisfactory rate and the salvage force wanted to be certain of being able to master any emergency, hence it was decided to prepare the normal fuel-oil tanks for blowing. The after tanks, Nos. 7 and 8, were not touched, as the valves and fittings over the tanks were most inaccessible.

Upon the assumption that the ship's force had left open the valve on the compensation line forward in the torpedo room, it was discovered that by making a blow connection in the engine room and manipulating five valves in the port forward bilge of that compartment, fuel in tanks Nos. 2 to 6, inclusive, could be blown overboard through the deck-filling connection. Rather than blow all this fuel out into the sea, where it would pollute the water and dirty the beaches, arrangements were made to transfer it to the bunkers of the *Falcon*.

Following this procedure, Michels and McNulty, on February 6, opened the deck grating forward of the engine-room hatch, removed the plug from the deck fuel-filling connection and brought it up for use as a template in making the new discharge plugs, one of which is shown at "8" in Figure 148. Later in the same day Harris and Applegate went into the engine room and began casting loose the blow line to the forward group, since the blow manifold itself was inaccessible. All this work had to be done by feel and upon the assumption that the *S–4* and *S–6* were alike, as there was such a maze of piping under the platform that the leads could not be traced out. Harris and Baker tried it again on February 12, but did not make much progress. The arc torch then being available, Carr went down on February 13 and burned some large holes in the platform for access to the blow line. Wilson followed for the same work, but cracked his torch electrode while moving around in the cramped engine room.

On the following day, February 14, Carr, with Grube and Applegate, and Wilson, with Baker and Kallinoski, cut away some more of the flooring in way of the blow line which was to be disconnected, and the latter crew succeeded in removing two of the three bolts in the flange. This is an excellent example of the satisfactory results which can be obtained when conditions are such as to permit having the same men work on the same jobs until finished.

Eiben, Mattox, and Burd, following, removed the third bolt, disconnected the blow line and bolted on the new special flange to which was to be attached the diving-air hose for blowing the fuel oil. Fuel escaped when they uncoupled the flange, so it was reasonably certain that they had the right pipe. Twenty-one dives were spent in making this one blow connection.

In the meantime, on February 6, Wickwire, Baker, and Scott had endeavored to get into the port forward engine-room bilge to reach and set the five valves on the fuel-oil lines. They found the *S–4* floor plating and framing in the vicinity not cut away, as it had been on the *S–6* at some previous time, to permit access, and Wickwire reported a large box (apparently an electrical control panel) as blocking the space to a great extent.

Wilson and Kallinoski on February 12 removed the hinged ladder in front of this bilge corner and Wickwire, Scott, and Burd attacked the structure in front of the bilge with the arc torch, succeeding in burning through one large angle. For reference to the work now being

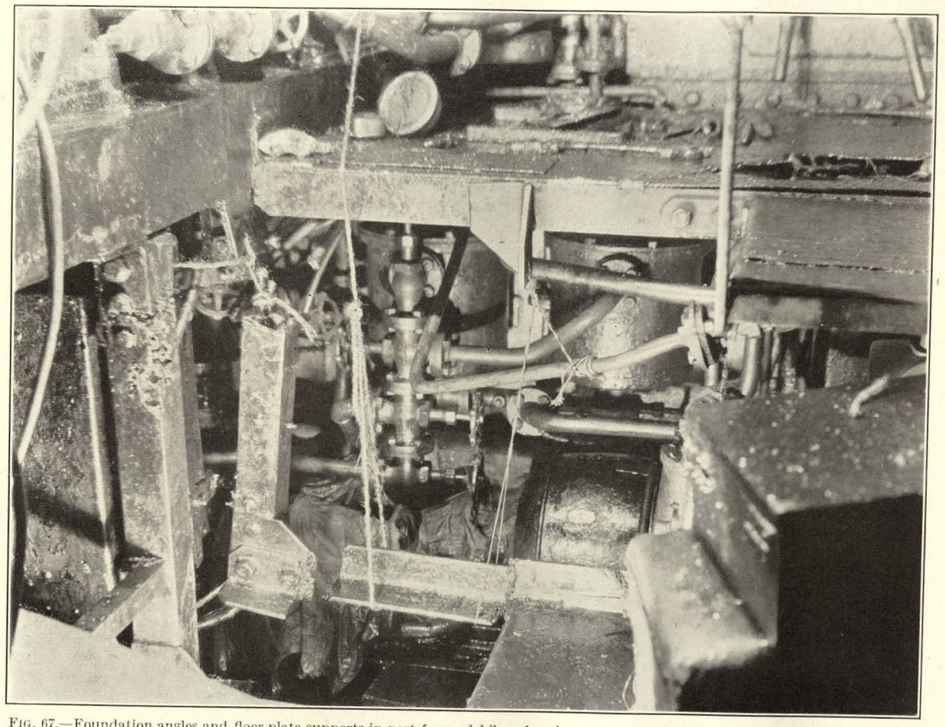


FIG. 67.—Foundation angles and floor-plate supports in port forward bilge of engine room cut away with arc torch in endeavor to reach fuel-oil valves behind box at lower left of photograph. Note ¾-inch line hanging loose in center of photograph which was broken and to which divers connected air-blowing hose for normal fuel-oil tanks

described, see Figure 67. Wickwire, Scott, and Burd repeated on February 13, burning through more structure with the arc torch. Carr, Grube, and Applegate, on the next dive, encountered four electric cables which were insulated and could not be burned, so Grube cut through them with a hack saw. They cleaned out enough so that Eadie, on February 15 and 16, with Scott and McMullen, was able to crawl into the bilge under the platform and by lying down to stretch his arm far enough outboard to reach three of the five valves and set two of them. Could not turn the third, so he did not know whether it was open or closed. These dives were all interspersed with trips to the *S–6* to check over position of valves and to have each diver tell the others what he found and what he did.

On February 16 Crilley, Mattox, and Burd made another assault on the engine-room bilge. Crilley burned away some of the hangers, but was unable to move the electrical panel. Although the smallest diver of all and able to crawl into the bilge as far as any of them, he could not do much more in the way of setting the third valve or finding the fourth and fifth. It was agreed by all hands after this dive that nothing more could be done in way of setting these fuel-oil valves—at least not by divers. Twenty dives had already been expended on this phase of the work.

Turning air into the fuel-oil tank blowing line, after the deck filling connection had been made up with a hose to the *Falcon*, produced no results. It was decided that both the filling line and the valve in the fuel-oil crossover line were closed, otherwise oil and air would have blown around through the after fuel-oil tanks to overboard. It was decided also that the valve in the compensating line in the torpedo room was closed, otherwise water and fuel oil would have blown around from forward and overboard through the filling line. After second venting of blowing hose, the air forced a bucket or more of fuel oil up the hose, indicating that the blowing connection was properly made to the crossover line between Nos. 7 and 6 fuel-oil tanks. There was accordingly nothing to do but stop blowing for the present and burn a hole later under No. 2 fuel-oil tank for the escape of water and oil. Very fortunately, the sounding machine sea chest at frame 37½ was through the No. 2 fuel-oil tank and directly under it was the tunnel at frame 39 that had been dug during the rescue operations.

Bad weather interfering with progress of work under the ship, it was February 24 before Kelley and Harris went down to clean out the starboard side of frame 39 tunnel. The report that Kelley had reached the sounding machine in one dive was highly encouraging, as it demonstrated that in the eight weeks that had elapsed since this tunnel was washed, it had not filled up appreciably. That the tunnel remained intact may be seen from an examination of the mud line on photograph (fig. 133), where its outlines are clearly discernible.

Wickwire and McMullen on the following dive, February 24, completed washing and started burning, but the torch electrode was again cracked. Carr, with Applegate, on the next dive burned through the outer hull at frame 27⅓, but a second attempt to blow fuel-oil tanks was as futile as the first. Carr and Scott, with the arc torch, went down to the sounding machine sea chest again on February 28, as it was thought that Carr might have burned in to the No. 1 main ballast tank by mistake. That he did not is clearly evident from Figure 68. Crilley was sent into the tunnel on the next dive for a check on the position of the hole. He reported it in the proper position, but still no air went in nor did fuel oil come out.

By this time the salvage force was ready to blow fuel or "bust" in the attempt. A canvass of the force with regard to other lines of attack brought to attention the fact that there was fitted on the bottom of No. 6 fuel-oil tank in the outer shell a portable manhole plate held in place by ¾-inch countersunk-head machine screws. On the face of it the solution was now simple: Take out one of the screws, put in a threaded plug, attach a blowing hose, turn on the air, and the job would be done. The only hitch in this program was the fact that the manhole lay buried about 7 feet deep in the mud—almost in to the keel of the ship—and as the screws had undoubtedly been put in there to stay, probably with a ratchet screw driver against a keel block in dry dock, they could not be persuaded to back out very easily.

The problem of digging the tunnel and developing alternate methods of making an air connection through the outer shell are explained elsewhere in Part IX, section 3, Part VI, section 2A, and section 2H, respectively.

Suffice it to say here that in one day, with 18 dives (the maximum for any day on the job) the tunnel was dug and the plate reached. In two more dives on March 2, Crilley and Mattox removed one of the screws and inserted the plug, and in the last two dives Kelley and Harris attached the blowing hose and the work was finished. (See fig. 69.)

Since the blowing connection was in the extreme bottom of the No. 6 tank and since the No. 2 tank, at the other end of the series, was open to the sea, the difference in head forced oil back up the blowing hose when the air was shut off and the hose was vented.

Part VIII.—Section 9. Outboard Ventilation Line.

In view of the extensive damage reported in the superstructure adjacent to the gun (fig. 70), it was almost certain that some sections of the outboard ventilation line were badly damaged and perhaps cut in two. Should the various hull flapper valves leading into the different compartments not hold the excess blowing pressure from beneath, tending to force them off their seats, it was a foregone conclusion that the *S–4* salvage force would experience a repetition of some of the *S–51* experiences, where much time and labor was consumed in blanking certain

FIG. 68.—Holes burned by Carr with underwater arc cutting torch (using 90° angle fitting) in outer shell plating under No. 2 fuel-oil tank to permit blowing of normal fuel oil. The sounding machine sea chest shown was used as a "landmark" for locating the proper point for the hole

sections of this outboard line. One look at these lines on the *S–6*, run as they were through the lightening holes in the superstructure framing with heavy clamps about every other frame, was enough to make one hope that the line did not have to be touched.

The writer, in his experience, has only too frequently had to take the meanest job—the one which was most feared, so to speak, and the one which everyone hoped would never have to be performed—and be forced to do it, perhaps just to demonstrate that it could be done. Likewise on the *S–4*, when upon attempting to blow the control room on February 6, an excess pressure of more than 5 pounds per square inch could not be built up and large bubbles appeared forward. Carr and Crilley went down later on February 6 and found that the air from the control room was escaping from a gash in the 6-inch outboard ventilation line in the "cut," as the damaged section of the superstructure was called. It was known that the inside securing gear on the flapper

valve leading up from the control room to this outboard line was very weak and the source of the air was easily determined. Carr and Crilley found the ventilation pipe flattened in way of the missing superstructure (see figs. 2, 126, and 136) with two flanges exposed, so that part of the structure was already torn away in preparation for the work.

n February 7 Wilson and Kallinoski began the work of disconnecting the flanges of the ventilation pipe at the after end of the cut. They managed to remove 7 bolts and 8 nuts out of 10. Michels and McNulty followed on the same day and removed all but one bolt on the bottom.

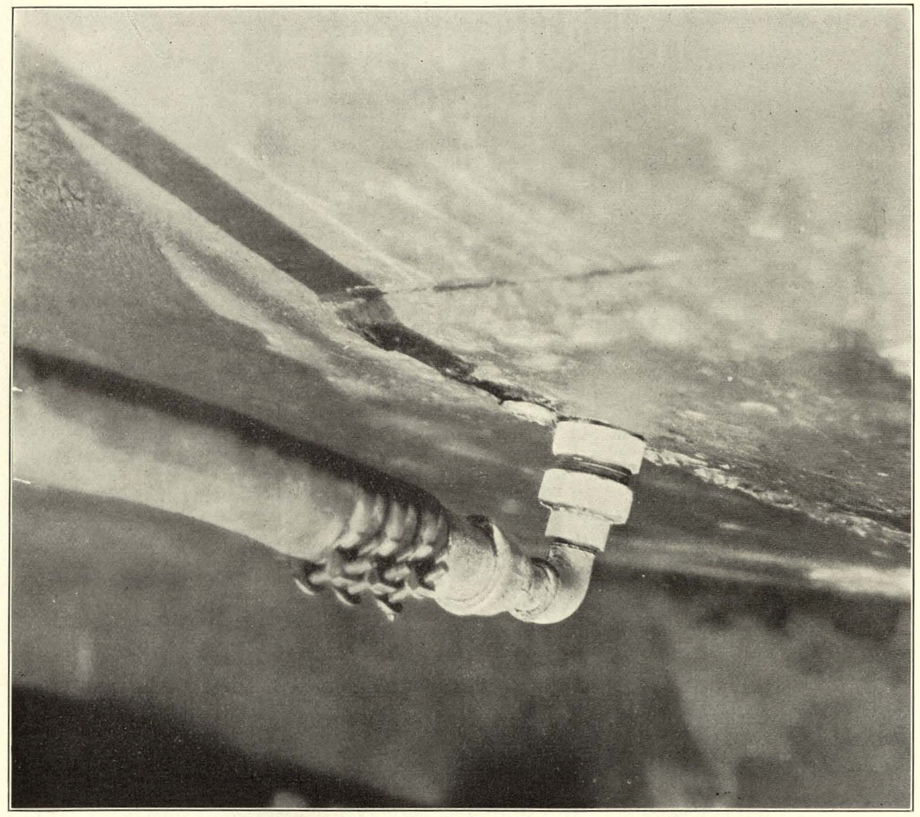


FIG. 69.—Air-blowing connection for normal fuel-oil tanks which was installed by removing one of the countersunk ¾-inch tap screws in the outside manhole to No. 6 fuel-oil tank, located about 3½ feet from the keel between frames 70 and 71

After talking with Michels on the completion of this dive, it was decided to break three flanges on the two damaged sections of pipe, so as to permit removal of each section independently. (See Plate 16.) In this manner two blank flanges on the ends of the intact pipe, as shown in that plate, would complete the job.

Michels and McNulty and Wickwire and Burd, on February 8, and Wickwire and Burd again on February 9, followed by Eadie and Scott, Wilson and Kallinoski, Harris and Baker, all put in their best energies in an endeavor to clear the damaged sections of the ventilation piping

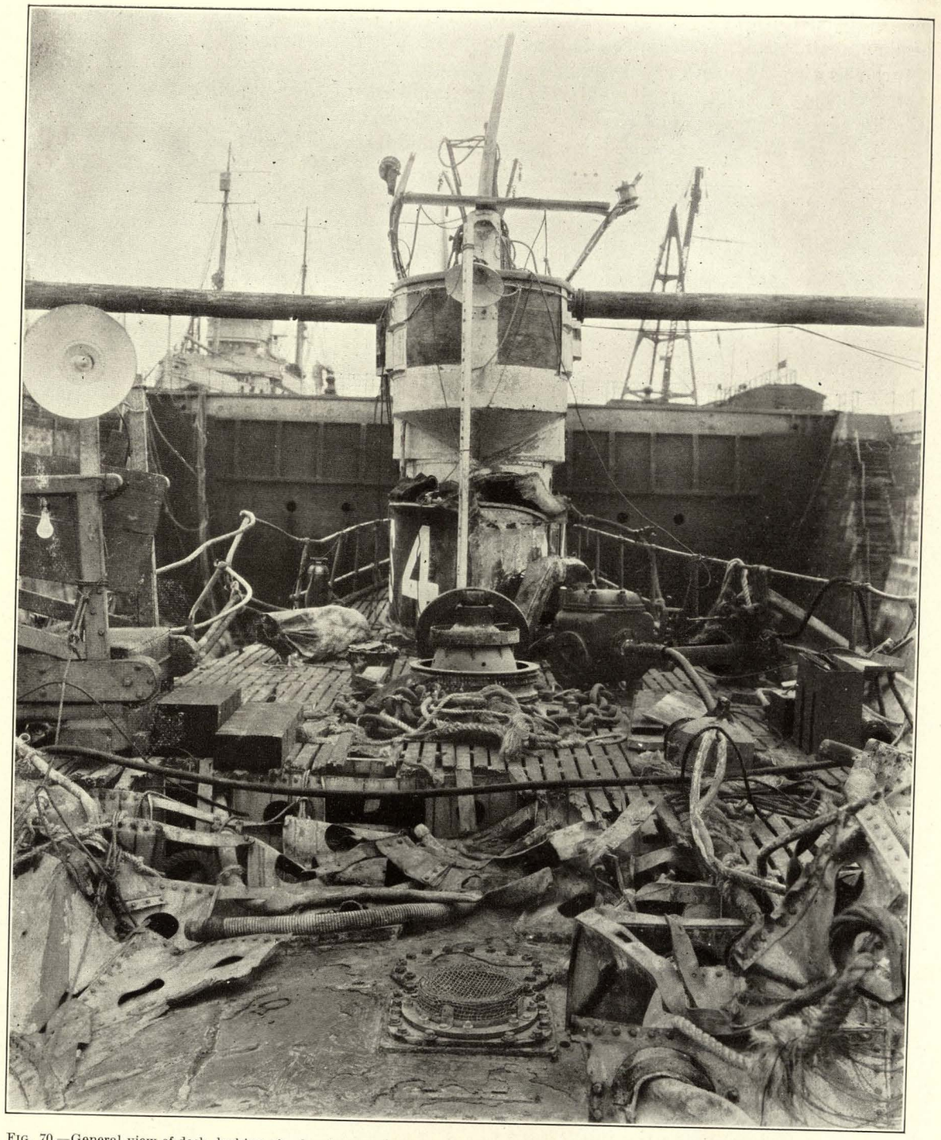


FIG. 70.—General view of deck, looking aft, showing wreckage in way of work on outboard ventilation line. The 6-inch copper pipe can be seen in right-hand lower corner

from the bent and twisted framing. One blank flange, the after one (see fig. 71), was put in by Eadie on February 9. February 10 saw the salvage force again at the job, with Eadie and Scott, Wilson and Kallinoski, and Michels and McNulty struggling with the bolts and nuts on the flanges and in the clamps around the pipe. (See fig. 72.) Snatch blocks and wire hauling lines to the *Falcon* were used to bend back the distorted superstructure framing and to work the sections of ventilation line along through the lightening holes.

Michels and McNulty, on February 11, cut off the last bolt in the pipe hangers, but after 24 dives the end was not yet in sight, for the damaged forward section simply refused to slide aft and come clear at the forward flange, so that the blank flange could be fitted. Once again the arc torch came to the rescue, for Carr, during the latter half of the dive in which he burned the torpedo room spill-pipe hole through the lower course of shell plating, came back and burned

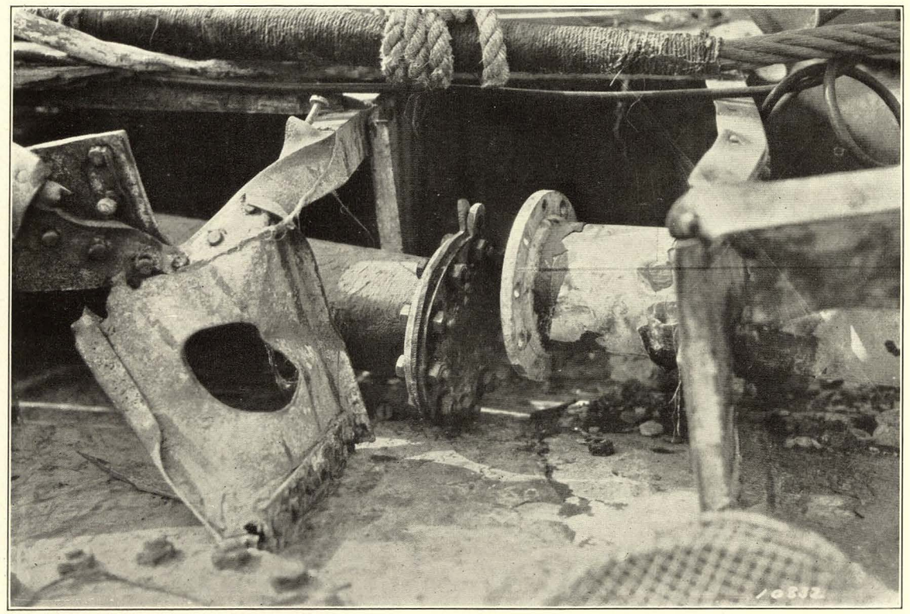


FIG. 71.—After section of 6-inch outboard ventilation line blanked to stop leakage from control room up through flapper valve leading to the line. Note nibs on top of blank flange and gasket to hold them in place while bolting

half way through the copper 6-inch ventilation line in an endeavor to take out a piece and make clearance for the blank flange. He had to start by burning a large V out of the top of the top of the pipe, since the bottom of the pipe was inaccessible and could only be burned through from the inside.

On the next dive, on February 11, Eadie and McMullen completed the burning begun by Carr, removed the burned-off section of 6-inch pipe (see fig. 39), and fitted the forward blank flange (fig. 72).

Particular mention is made of the "ears" and the extra hole through top of each blank flange and its gasket, as shown on Figures 71 and 72. A becket through this hole held the flange and the gasket together, in proper relation to each other and gave the divers something to hold the flange by when fitting it in place.

Part VIII.—Section 10. Miscellaneous Buoyancy.

Blowing of the bow buoyancy tank and the forward trimming tank was not at first contemplated and the buoyancy to be gained by emptying these two tanks was not absolutely necessary. However, the salvage work had proceeded very well and it seemed possible to provide an additional margin of buoyancy forward with comparatively little labor.

Baker and Kallinoski, on February 28, climbed over the side at the extreme bow end, with the hook pipe shown at "6" on Figure 148 on the end of a blowing hose (diving hose), they slipped the hook end into one of the flooding holes of the bow buoyancy tank and blew it.

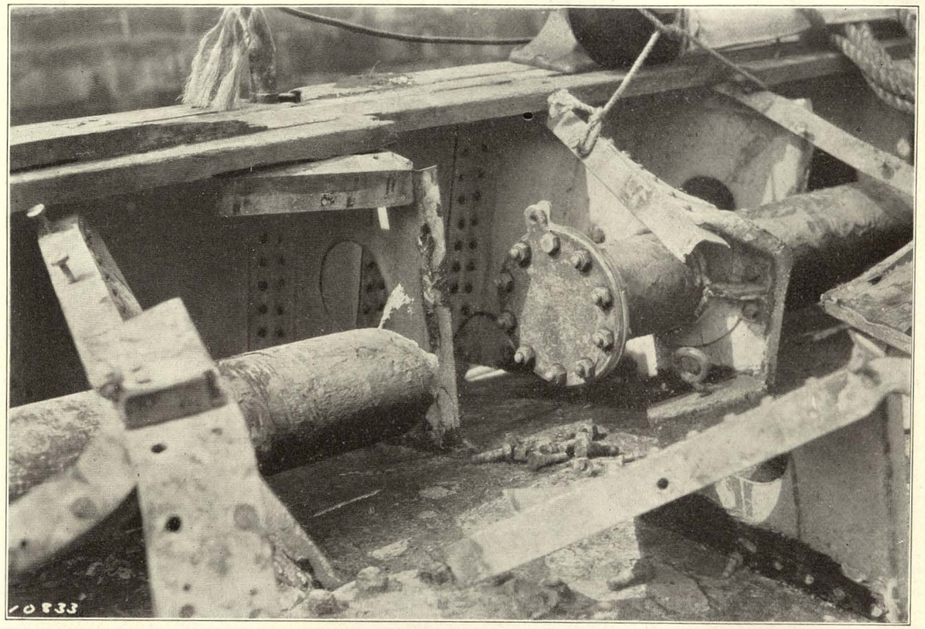


FIG. 72.—Forward section of 6-inch outboard ventilation line blanked to prevent leakage from torpedo room through damaged outboard line. Note the very substantial clips and hangers (next frame forward of flange) which had to be cast adrift on damaged sections of piping. Gap in after section of piping is due to burning out of the section. (Fig. 39)

Wickwire and McMullen on the same day, working in the tunnel at frame 11 that had been dug for shackling up the bow towing bridle, burned "a hole" in the bottom of the forward trimming tank just forward and to starboard of the mush room anchor well. Figure 73 shows at least seven holes made by Wickwire in an endeavor to make sure that one good hole was burned into the tank. Carr and Applegate went down the next day with the same hooked blowing pipe and blew the forward trimming tank through one of these holes.

After examination of the *S–6* and consultation on that vessel, it was decided that too many complicated valve settings (and too many risks to divers walking around control room with floor plates up) were involved to warrant an attempt to blow the auxiliary ballast tanks on *S–4*, especially as there was every reason to believe that these tanks were filled to not more than one-half their capacity.

A number of items which had not been mentioned or recorded in previous calculations for buoyancy on submerged and flooded submarines were in the case of the *S–4* available as effective buoyancy.

(*a*) The high-pressure air flasks were all located in the flooded battery room and since it was practically certain that these were full of air to a pressure of 45 pounds per square inch, they were figured as adding about 8 tons buoyancy.

(*b*) The electrolyte in the storage batteries were only 20 per cent heavier than water and its weight would of course be to a great extent supported by the sea water surrounding it. Since the weight of the liquid fuel, although lighter than water, was subtracted from the dead weight as being supported by the sea water, so the total weight of the electrolyte, somewhat heavier than water, and amounting to about 22 tons, was similarly subtracted.

Part VIII.—Section 11. Blowing Hoses to Compartments and Tanks.

Blowing hoses to various compartments and tanks were rigged as soon as it was desired to get air on the compartment or tank for testing purposes or as soon as the volume was ready for blowing.

Numbers were assigned to all hoses at the outset, as shown on Plate 5. The numbers do not run consecutively there on account of the decision to blow the battery room subsequent to the marking and fitting of other compartment hoses.

The ship connections were, in many cases, smaller than 1¼-inch so the necessary reduction in size had to be made in the pipe connections, as illustrated in Figures 62, 63, 65, and 69. These photographs show, marked in white, the union fitting which was screwed on and secured by the diver when the hose connection was made. One fundamental rule must be observed in this connection, namely, that *the standing or fixed part on the ship should have a male thread and that the diver should take down with him the female half of the union or coupling which has a freely rotating or swiveling part.* This enables him to engage the threads by manipulation of the coupling only, whether the hose is exactly in line and in position or not, and it obviates the awkward and clumsy operation of turning the hose to screw it into place.

The manner of making up the hoses and lashing them is described subsequently in Appendix VII.

Compartment blowing hoses on the *S–4*, with a rise and fall of tide of about 10 feet and a depth to the point of attachment not exceeding 100 feet, were all made 150 feet long and were left at that length while the salvage operations were still in progress. This allowed sufficient extra length for drift of the tide, for attachment of the buoys, and for handling on deck of the *Falcon*.

All compartment hoses were, just before raising, secured down along the deck or the rail of the *S–4* and were then lashed and secured to the cleats, aft of engine-room hatch, at frame 101, so as to have them all lead upward from the same point.

The following were the distances from the point of attachment of each hose to the cleat at frame 101:

	Feet
Torpedo-room hose No. 1, at frame 36	97
Battery-room hose No. 7, at frame 59	63
Main ballast-tank hose No. 5, at frame 74	40
Control-room hose No. 2, at frame 82	28
Fuel-oil hose No. 6, at frame 97	6
Engine-room hose No. 3, at frame 97	6
Motor-room hose No. 4, at frame 119	28

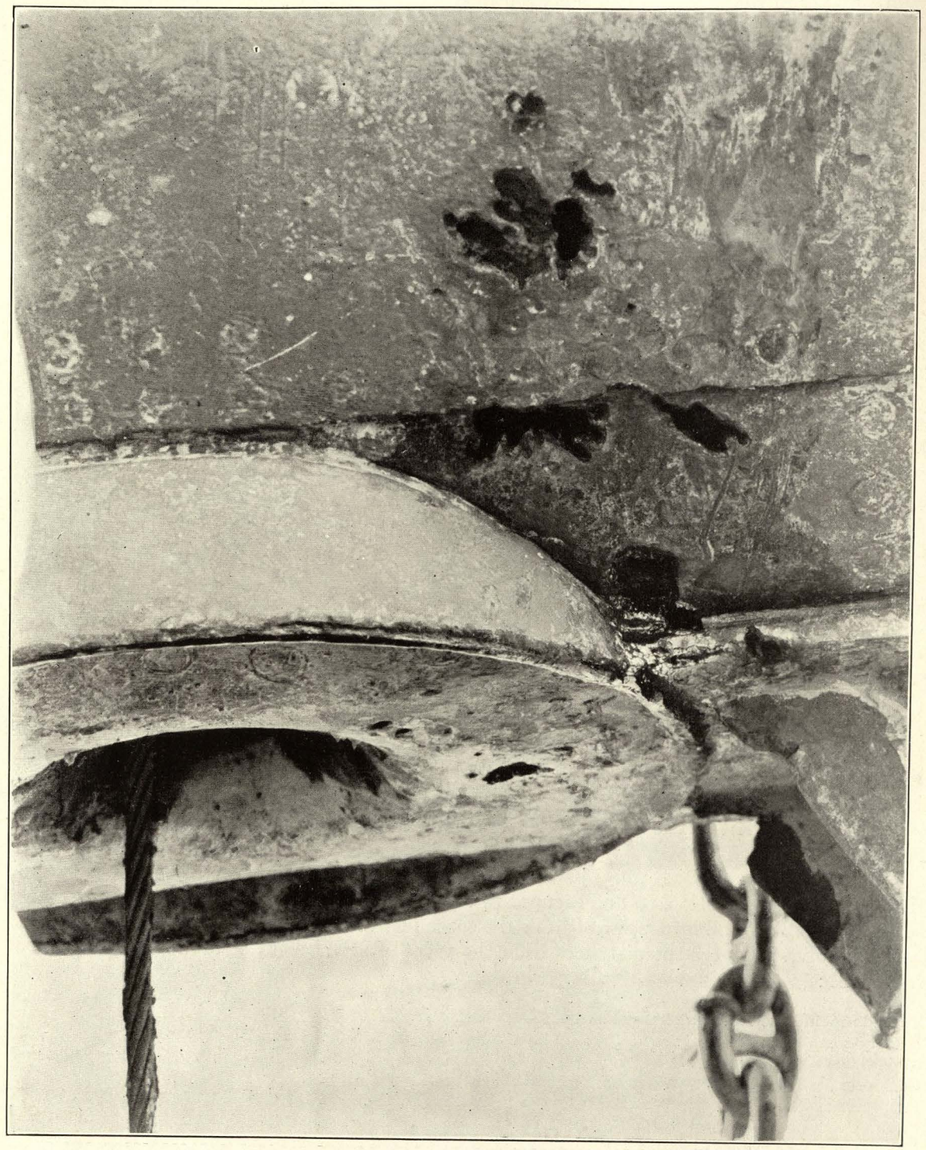


FIG. 73.—Blowing holes burned by divers Wickwire and Carr underneath forward trimming tank, Frames 10 to 11, starboard side. All work done with underwater arc cutting torch

As lashing these hoses down at the engine-room hatch would have used up all or more than the available extra length of the 150 feet of hose, the following additional hose was added to the first 150-foot sections, when the hoses were all lashed at frame 101:

50 feet to main ballast-tank hose No. 5, totaling 200 feet.
50 feet to battery-room hose No. 7, totaling 200 feet.
100 feet to torpedo-room hose No. 1, totaling 250 feet.

Additional lengths of blowing hose were made up on the *Falcon*, properly marked and attached to the blowing manifold. When the *Falcon* took station for raising, the buoyed hoses from the *S–4* were picked up and connected to the hoses already made up on the *Falcon*.

The following total lengths for compartment hoses were required for raising and towing the *S–4*, measuring from the blowing manifold on the *Falcon* to the hose connection on the submarine:

No. 1, torpedo room, 1 hose, 400 feet long.
No. 2, control room, 1 hose, 300 feet long.
No. 3, engine room, 1 hose, 300 feet long.
No. 4, motor room, 1 hose, 300 feet long.
No. 5, main ballast, 1 hose, 300 feet long.
No. 6, fuel oil, 1 hose, 300 feet long (connected up 200 feet only and it was not used).
No. 7, battery room 1 hose, 350 feet long.
No. 8, fuel-oil tanks, 1 hose, 400 feet long.

Part VIII.—Section 12. Preliminary Unwatering and Check Blowing.

The detailed procedure with regard to flooding, blowing, and venting of compartments during the *S–4* salvage operations was based upon the following general premises:

(*a*) The vessel must be held in position on the bottom until the work of the divers is finished, so that they may not be endangered by the movement of the vessel or any of the gear attached to her, and until the raising operations begin, so that it may not be necessary to repeat any of the diving operations or repair damage done by premature lifting.

(*b*) Engine room will be flooded in order to hold the vessel down and prevent the bow from rising while blowing the torpedo room, but the engine room will not be flooded until *after* the pontoon chains are drawn through the tunnel at frame 46, as otherwise the vessel might settle deeper in the mud.

(*c*) Normal fuel-oil tanks Nos. 2 to 6, inclusive, although available as buoyancy in an emergency, will not be blown unless necessity demands, since water and oil in these tanks will serve to hold the bow down before raising and to give the vessel stability after raising.

As each compartment and tank was sealed and made ready for unwatering, it was blown down to insure that all air and water piping and fittings were working properly. There was occasion, during the course of the salvage operations, to give each one a second or third unwatering or check blowing. This was deliberately done in one or two cases where there was doubt as to the compartment being fully dry. It could have been done for every compartment every few days, except for the likelihood of clothing, rags, or débris floating on the water, finding their way into the strainers and blocking the spill pipes. Also, in the case of the torpedo room, engine room, and motor room, these compartments were deliberately flooded back after being unwatered and being checked, for the purpose of holding the *S–4* on the bottom until the salvage force was ready to raise her.

The process of blowing down the compartments and watching the gauges and the air bubbles appearing at the surface was highly interesting and instructive. In view of the extensive

information which can be gleaned from so simple an operation as watching the hand of a gauge, the process of carrying out this work on the *S–4* is given here at considerable length for the benefit of those who can make use of it in the future.

It will be noted from the various photographs that, on the salvage air main on the *Falcon*, there was at each blowing connection—

(*a*) One 1¼-inch globe valve, for controlling the blowing air.
(*b*) One 1¼-inch vent valve under the globe valve, for venting the air in the blowing hose to the atmosphere.
(*c*) One air-pressure gauge, connected in *below* the blowing valve.
(*d*) One 1¼-inch union connection, for attaching the blowing hose.
(*e*) In addition, there were gauges on the salvage air main itself.

By shutting off the blow valve, the pressure in the hose and in the compartment soon equalized and the actual air pressure in the compartment could then be read on the gauge. This operation was known as "balancing off."

The "blowing pressure" referred to in the following paragraphs is the pressure registered by the individual gauge when the blow valve was open. In other words, it was the pressure in the compartment being blown plus the drop in pressure in the hose and blowing fittings.

Part VIII.—Section 12a. Torpedo Room.

Started blowing at 5.32 p. m. on February 13, using a blowing pressure on the *Falcon* of from 60 to 65 pounds per square inch. The maximum blowing pressure on this compartment was held to safe limits because it was known that the reinforcement of the torpedo hatch cover did not have any considerable factor of safety and the salvage force had no desire to lift or spring the hatch cover. When blowing began there was some air leakage. At the time this was thought to be from the torpedo hatch, but later examination revealed that it unquestionably came from the fourth bolt on the spill pipe. As the blowing continued, the leakage increased somewhat in volume, due no doubt to the increased pressure in the compartment. Finally, at about 9 p. m., a second series of bubbles appeared farther forward, apparently over the torpedo tubes, although in the darkness any accurate observations of the bubbles, even with flood lights turned on, was a very difficult operation. Blowing was discontinued at about 9.30 p. m., after it was suddenly found that the torpedo-room pressure could not be held at more than 56 pounds per square inch, when air was admitted at the previous rate. It is almost certain that the torpedo room was blown at that time.

As soon as the ship was moored the next morning (the 14th), at about 7.15 a. m., the No. 1 blowing hose was taken aboard and connected up. The pressure in the torpedo room before blowing began was found to be 48 pounds per square inch. At 8.05 a. m. air was started into the torpedo room with a maximum blowing pressure of 59 pounds per square inch. Crilley and Scott were sent down to inspect for leaks over the torpedo room. They reported air coming out of the lightening holes in the port and starboard sides of the superstructure above the upper torpedo tube shutters, indicating slight leaks in the muzzle doors of the torpedo tubes. In order to verify this, the salvage officer went to the *S–6*, had this vessel put an air pressure in her torpedo tubes, and when the muzzle doors were slightly cracked air was found to escape just as Crilley and Scott described. Air was apparently finding its way from the *S–4* torpedo room to the inside of the torpedo tubes and was starting the muzzle doors off their seats, since they seated with external pressure. The fourth bolt in the spill pipe over the torpedo room was found to be leaking slightly; the spill pipe was otherwise tight. The torpedo-room hatch was tight and air was blowing out of the spill pipe, indicating that the water level had been lowered to the spill pipe strainer. At 9.05 a. m. stopped blowing torpedo room, at which time the

pressure balanced off at 56 pounds per square inch, equivalent to the depth of water to the bottom of the torpedo room, as nearly as could be determined by the *Falcon*.

On the afternoon of February 24, when other work was underway around the bow of the *S–4*, it was decided to make a check blow on the torpedo room, so the No. 1 hose was brought aboard and connected up. The indicated pressure was 48 pounds per square inch, approximately equivalent to the depth of water to the top of the torpedo room. The fact that this pressure had decreased from 56 pounds on February 14 to 48 pounds on February 24, did not necessarily indicate that the torpedo room had flooded back again, but it did show that the excess pressure in the torpedo room had caused air to escape from the fourth bolt around the spill pipe until the pressure in the torpedo room was lowered to the pressure corresponding to the depth of water at the bolt, whereupon the escape of air practically ceased. While it is true that some water probably entered around the bolt and some air subsequently escaped off and on, the amount of leakage in either direction was insignificant.

It is observed that in almost every case on the *S–4*, when compartments which had previously been blown were left for a day or more, the pressure in them would decrease in the same fashion.

At 6.35 on February 24, 1 hour and 45 minutes after starting the check blow on the torpedo room, this compartment indicated dry at a pressure of 56 pounds per square inch. It is to be noted that 35 minutes of this time were required for building up the pressure in the torpedo room to the pressure equal to the depth of water at the spill pipe strainer, and that at no time in the following 70 minutes was it possible to maintain a pressure in the compartment of more than 60 or 61 pounds per square inch. This was due primarily to leakage through the muzzle doors, as above described. The fact that over an hour was required during the check blowing before air began to blow out of the spill pipe, does not necessarily signify that any great amount of water had found its way back into the torpedo room, since the excess blowing pressure was at no time greater than 4 or 5 pounds per square inch. The greater part of any water which was lying in the bottom of the compartment was no doubt due to incidental drainage from other parts of the torpedo room in the 10 days which had elapsed since the first blowing.

Part VIII.—Section 12b. Battery Room.

At 5 p. m. on February 13, after the blowing pipe had been inserted in the hole in the battery room and the No. 7 hose had been connected, air was turned on the battery room. The full amount of air bubbles (equivalent to the air going down the hose) was found to appear in about two minutes. On the next day, February 14, when Crilley was down, he was sent to inspect the battery-room hatch and the top of the battery room while air was turned on that compartment. The battery-room hatch was found tight and the only air escaping was that coming out of the hole in the inner hull around the blowing pipe. The pressure in the battery room balanced off at 51 pounds per square inch.

Part VIII.—Section 12c. Control Room.

Air was first turned on the control room at 11 a. m. on February 6. It was found impossible to build up a pressure in the control room to more than 5 pounds per square inch in excess of the sea pressure, and large bubbles of air came up forward. Later in the same day, Carr and Crilley went down and discovered that the air escaping when the control room was being blown was issuing from a cut in the 6-inch outboard ventilation pipe, indicated at frame 51 in the top view on Plate 16. The leakage was undoubtedly due to springing of the flapper valve fitted at the inner hull overhead in the control room at the point where air for supply ventilation of the control room was taken from the outboard line. The location of this valve at frame 82 is clearly marked on Plate 16. The flapper valve in question seated with external pressure;

since the internal securing gear on it was rather weak, it could not have been expected to hold much excess pressure when applied on the under side.

After blanking off the 6-inch outboard ventilation line so that air leaking into it through the flapper valve could not escape to the sea, air was again turned on the control room on February 12 at about 4.30 p. m. Bubbles appeared as the blowing pressure increased but it was possible finally to build up the compartment pressure to 61 pounds per square inch, an excess of 17 pounds per square inch over the sea pressure at the level of the upper conning-tower hatch. Blowing was continued until about 10 p. m. on that date and was not yet completed when it became necessary to unmoor on account of rising wind and sea.

On the morning of February 13, the No. 2 hose was picked up and connected, whereupon it was found that the pressure in the control room had dropped overnight to 48 pounds per square inch. This indicated that the greater part of the excess air pressure in the control room had leaked out in the meantime but it did not necessarily mean that the control room had flooded back up to a level corresponding to a pressure of 48 pounds per square inch, as has been explained previously for the torpedo room.

Blowing of the control room was resumed at 8.32 a. m., and the pressure in that compartment was built up from 48 pounds to 61 pounds per square inch in about 20 minutes. The fact that such a long time was required to raise the pressure indicated that there was a considerable volume of air in the control room. Had it been possible to measure the amount of air pumped in during these 20 minutes, it would have been an easy matter to calculate the total cubic feet of air then in the compartment.

A blowing pressure of 65 pounds per square inch was maintained at the blowing valve on the *Falcon* and this pressure was held deliberately low in order not to risk lifting the upper conning-tower hatch off its seat. The excess pressure of 4 pounds per square inch was utilized in forcing the blowing air through the hose and the excess pressure of 17 pounds per square inch in the control room was similarly utilized for blowing water out through the spill pipe. The blow valve on the *Falcon* salvage air main was shut off at frequent intervals; since the flow of air was then stopped, the gauge on the *Falcon* read directly the pressure in the *S–4's* control room. By this process of "balancing off" frequently, it was possible to supply air at just about the same rate that water was being expelled and to keep the air pressure in the control room practically constant. There was considerable leakage evident over the control room during this blowing operation but, since it was possible to hold the excess pressure of 17 pounds in the compartment, no apprehension was felt.

Blowing was continued until about 1 p. m. (some 4½ hours), when the pressure in the control room dropped to 56 pounds per square inch, whereas it had previously held from 60 to 61 pounds per square inch. A similar phenomenon was experienced in the torpedo room and it was an indication that the water level had reached the spill pipe strainer and that air was escaping directly to the sea through the spill pipe. Since the resistance to passage of the air through the spill pipe was extremely small as compared to the resistance for the passage of water, the excess pressure which could be held in the compartment when the spill pipe was dry would be only a fraction of a pound, whereas the excess pressure when the spill pipe was discharging water would be 16 or 17 pounds.

While this blowing was under way, Michels went down to the bridge and found that the bubbles were coming mostly from the conning-tower hatch, although some were escaping, as had been the case ever since the *S–4* sank, from around the periscopes, around the whistle, and through the loop antenna leads. It was decided to rearrange the pig lead over the conning tower hatch and to add 1,000 pounds more of lead, followed by 400 or 500 pounds of cement. The additional pig lead was placed on February 14, and on February 15 Michels went down,

over the port side of the *S–4*, and found that all air and no water was escaping from the trimming manifold sea chest, thus indicating that the control room was blown dry. Air was turned on the control room for about 45 minutes altogether on this date; it required 20 minutes to raise the pressure in the control room from 49 pounds to 60 pounds per square inch and, shortly after reaching the latter pressure, the air dropped to 56 pounds per square inch, an indication that miscellaneous water had in the meantime drained from various parts of the control room and covered up the spill pipe strainer, but that it had quickly been blown out. The conning-tower hatch was apparently tight at 56 pounds per square inch.

Part VIII.—Section 12d. Engine Room.

Blowing of the engine room was begun at 8.55 a. m. on February 17, using two salvage compressors running at full speed. The engine room was blown dry at 10.45 a. m., 1 hour and 50 minutes later.

In this connection it should be stated that a week or so after, when connecting up the individual blowing hoses to make sure that each hose had air in it and was flooded properly, the No. 4 hose to the motor room was found to carry a pressure of about 48 pounds per square inch. The motor room was at that time supposed to be flooded, to hold the stern down, but, as was customary, the vent valve on the *Falcon* was opened to note whether the pressure would drop at a rapid rate, since this was the procedure followed in order to determine that there was just enough air left in the top of the motor room to supply incidental leakage in the blowing hose during any period of stormy weather when the *Falcon* might have to remain away from the wreck. On this occasion, however, continued venting of the motor room resulted in no appreciable drop in air pressure, and the behavior of this compartment was rather puzzling until upon a later day it was recalled that when blowing the engine room, a considerable quantity of air undoubtedly leaked through the shaft stuffing boxes into the motor room, resulting in a partial blowing down of the motor room. Leakage from the engine room to the motor room was similarly observed during the raising of the *S–4* on March 17, when it was found that the motor room could not be vented down so long as pressure remained in the engine room.

Part VIII.—Section 12e. Motor Room.

The motor room was the first compartment to be sealed and blown down, this procedure taking place on February 5. At 9.48 a. m. on that date air was turned on the motor room, using one salvage compressor. The pressure at the blowing valve of the *Falcon* was raised first to 65 pounds and slowly worked up to 75 pounds per square inch, since it was realized that an excess pressure could not very well be built up in the motor room through a small blowing connection with a spill pipe for discharging water as large as 5 inches in diameter. At 11.55 a. m., after blowing for two hours and seven minutes, the air was shut off the motor room and the pressure found to be 53 pounds per square inch. Just as the blowing valve to the motor room was closed, a large patch of bubbles appeared, later with oil, apparently from the motor room. When venting back, air was found in the blowing hose, so it was apparent that the motor room salvage hatch had not been lifted (the compartment was not expected to blow dry so soon).

As a check blow, air was turned on to the motor room again at 11.59 a. m., and at 12.10 p. m., after 11 minutes of blowing, large bubbles again appeared. It was assumed that the water level was down to the motor room spill-pipe strainer and that the motor room was blown dry.

Part VIII.—Section 12f. Normal Fuel-Oil Tanks.

When air was first turned on the No. 6 hose, leading to the blowing connection to the forward normal fuel-oil tanks, on the evening of February 16, the pressure in the blowing hose built up very rapidly, indicating that only about the volume of the hose was open to the blow

valve. The blowing pressure dropped very slightly when the blow valve was closed, due possibly to expansion of the structure of the tanks under pressure (assuming that the tanks were then in communication with the blowing line) and possibly to small air pockets in the fuel-oil tanks. However, the blowing pressure remained at 75 pounds per square inch on the *Falcon* for some time, with the blowing valve only cracked to maintain this pressure. The blowing hose was vented and the pressure finally dropped to zero as soon as the structure of the tanks contracted and pushed the air back out of the line. A second blowing was attempted, raising the pressure to 85 pounds per square inch and maintaining it there, but still with no results. After the second venting of the blowing hose, the air forced a bucket or more of fuel oil up the hose, indicating that the blowing connection was made to some fuel-oil line, with the hope that it was properly made to the crossover line between Nos. 7 and 6 fuel-oil tanks.

It was concluded that certain valves in the engine room were closed, otherwise oil and air would have blown around through after fuel-oil tanks to overboard. It was concluded also that the valve in the fuel-oil compensating line in the torpedo room was closed, otherwise water and fuel oil would have blown around from forward and overboard through the filling line. There was nothing to do but stop blowing for the present and burn a hole later under No. 2 fuel-oil tank for escape of water and oil.

On February 25, after a hole had been burned through the outer shell into No. 2 fuel-oil tank, blowing of the normal fuel-oil tanks was again attempted. As before, the pressure rose quickly and held, indicating a small volume of air and no delivery of air to the *S–4*. The blowing pressure balanced off at about 53 pounds per square inch, dropping very slowly. One possibility under these conditions was that the blowing line inside the *S–4* was closed off and that the minute amount of air which the *Falcon* succeeded in getting through the No. 5 hose was leaking out somewhere into the engine room.

After the attachment of No. 8 blowing hose directly to the bottom of No. 6 fuel-oil tank, on March 2, 1928, air was blown into the hose at 10.58 that morning, and it was found that the air passed through in proper fashion. While this blowing was going on, Kelley and Harris had difficulty in handling the hose, since it was buoyant when full of air, so the *Falcon* allowed the hose to vent and flood and got fuel oil back through it. Extra hose was connected and led to the forward bunkers of the *Falcon*, necessitating the lifting of the hose at one point to about 10 feet above the water line. Nevertheless, fuel oil flowed steadily under the action of gravity from 150 to 200 gallons per hour. The flow was rather slow on account of small area of hole through blow connection (three-eighths of an inch diameter) and the small differential head.

At 8 a. m., March 3, picked up No. 8 hose again and connected it up on *Falcon* so as to transfer Diesel oil from No. 6 tank on *S–4* to forward tanks on *Falcon*. Too rough for diving, so continued fueling during morning.

At 11.36 a. m., March 4, started taking fuel oil from *S–4*, and at 9.55 a. m., March 6, the *Falcon* began fueling a fourth time from the *S–4*.

Part VIII.—Section 13. Towing Bridles and Arrangements.

The arrangements developed for towing the *S–4* after bringing her to the surface, as shown on Plate 13, were developed from those employed with success on the *S–51* operations. This gear, it will be noted, was used for the regular towing operations and the ship's own towing hawser was held as a preventer, since it was considered not sufficiently rugged for handling the tow, submarine, and pontoons in the open sea, especially as the *S–4* could be expected to bear off generally to port with the 15° left rudder and perhaps to yaw and jerk badly in a sea. The circumstances surrounding the towing of the *S–4* back to the navy yard, Boston, justified the fitting of every single piece of towing gear, as detailed on Plate 9.

The *S–4* was made completely ready for towing before being raised, so that when the vessels took stations for raising, the *Sagamore* and the *Falcon* were all secure to the *S–4* and to each other, as shown on Plate 12. In the meantime the forward ends of the two towing hawsers forward and the after end of the sternfast aft, were laid out and buoyed, where they were readily available for picking up by the tugs. These buoys are indicated on Plate 12.

Work on the *S–4* was begun February 17, when Baker rigged a descending line on the port shaft for lowering the after girth chains. Eadie and McMullen, Burd and Scott, Crilley and Mattox all had a hand in lowering the stern bridle and attempting to shackle up the girth chains, but there was difficulty in getting the *Falcon* in the proper position and to get the chains to lead

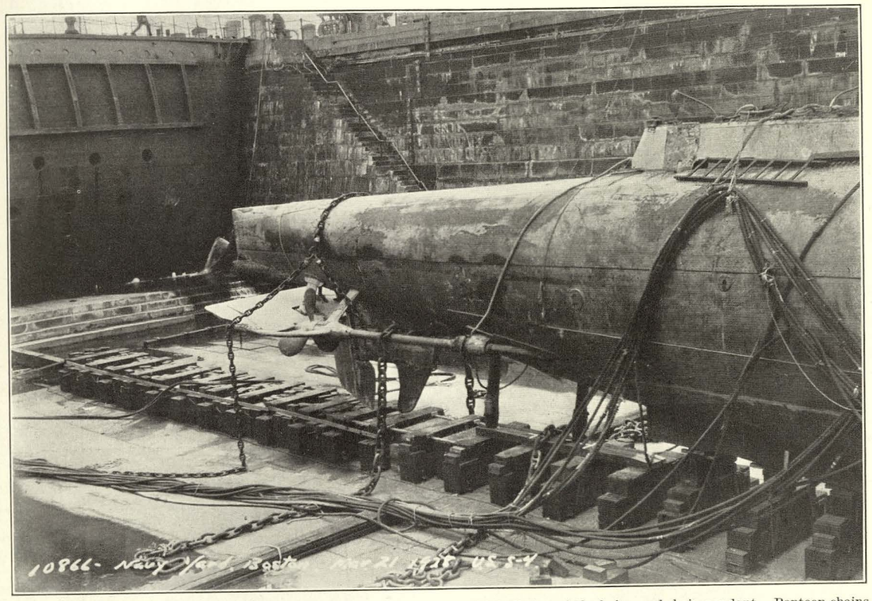


FIG. 74.—Sternfast, leading down and to the left, over stern diving plane, with bull ring, girth chains, and chain pendant. Pontoon chains for stern pair of pontoons lying under hull. Compartment and pontoon blowing hoses lying in foreground

in the right direction. (See figs. 74 and 75.) Finally, Michels and Von der Wall went down and succeeded in shackling the girth chains together under the stern. (See fig. 135.)

Baker went down again on February 22 to rig a new descending line for the forward towing gear. Wilson and Kallinoski placed the chain around the gun mount (see fig. 76), followed by Eiben and Von der Wall, who laid out the 1½-inch wire pendant leading forward, taking it along the starboard side—this for the reason that the *S–4*, with left rudder, would tend to sheer off to port. When the vessel reached Boston, the towing gear was lying off the deck, over to starboard, as an examination of the photograph (fig. 77) will reveal. At 5.23 p. m. on February 22, when almost dark, Crilley and Grube took down a 3-inch manila line to haul up *S–4's* own towing pendant. They went aft to about frame 87, just abaft the bridge, cast loose the eye in the towing end of the pendant, made fast the 3-inch hauling line, and had the *Falcon* haul the free end forward, breaking the stops in the bight of the towing pendant as it came forward

along the superstructure. The *Falcon* finally got the eye in the pendant in sight on the surface when their time was up. A very creditable dive, in which about two dives' worth of work was accomplished. Had to come up old reeving lines at frames 19 and 39, placed there in December, so as to allow the pendant to come up free.

Falcon hauled end of pendant aboard and broke all remaining stops, so that the *S–4* towing pendant was entirely clear, leading out of the bow chock of the submarine.

Took free end of pendant off on port bow of *S–4*, buoyed it and dropped it so as to have it clear.

The bow towing bridle (fig. 78) was lowered on February 24 with Crilley and Grube to guide it into place and to shackle up the girth chains under the ship. After drawing the two long links

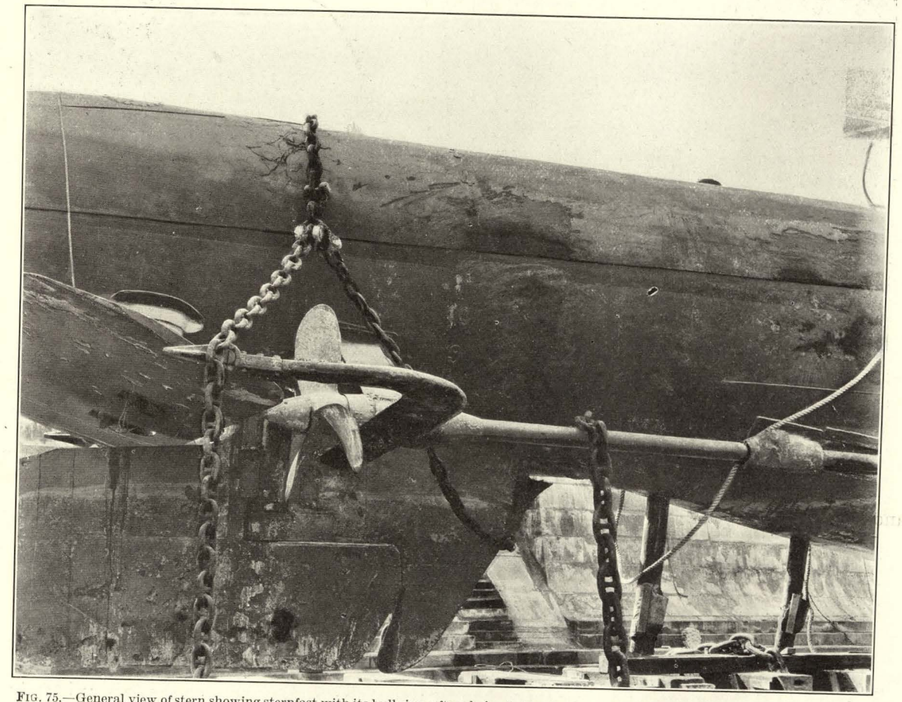
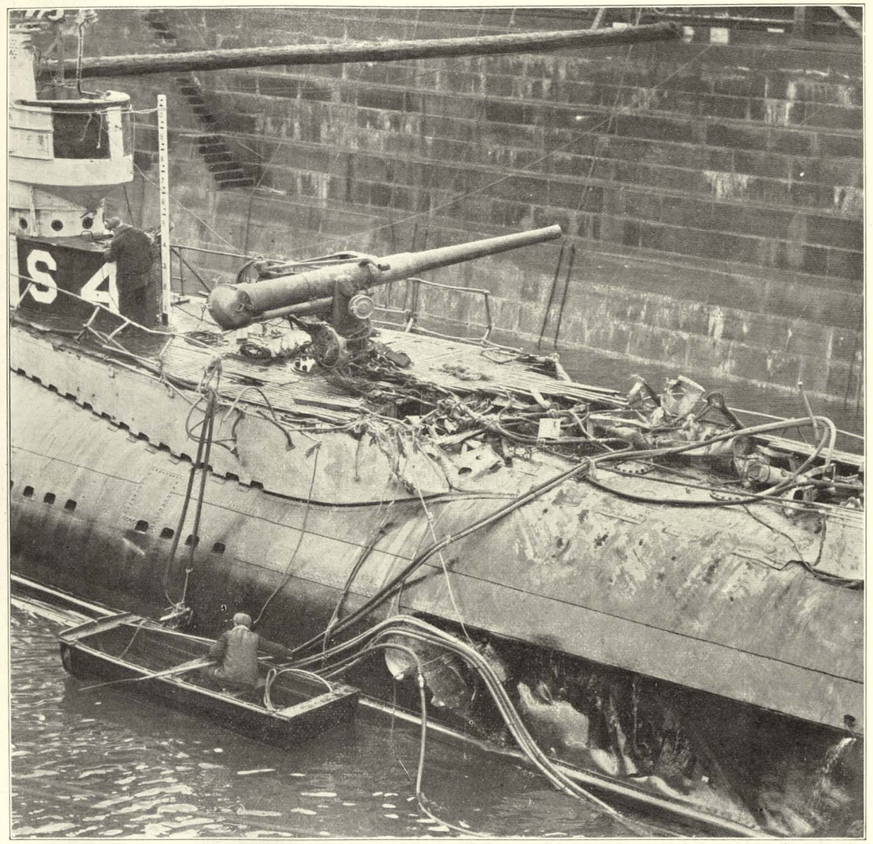


FIG. 75.—General view of stern showing sternfast with its bull ring, after chain of stern pontoons with notch cut in skeg and marks on shaft forward of forward strut casting and on hull plating made by chains of after pontoons. The mud line is very clearly defined

on the ends of the girth chains together, Crilley sat in the mud on the bottom of the tunnel under the mushroom anchor, with the 1½-inch detachable link in his lap, while Grube assembled the pieces and secured it. The finished job is shown in Figure 79. All this work had to be done by feel, and the excellent work performed by these men can not be too highly praised. Eiben and Von der Wall on the next dive, with the assistance of a hauling line from the *Falcon*, succeeded in laying out the 1½-inch pendant straight along the deck and in drawing it up to the bull ring, where they shackled it to the fittings provided.

The work was finished on February 28, when Wilson and Burd placed the 1-inch wire strap around the stock of the starboard bow plane (see Plate 9) and shackled the ends to the fore and aft pendant of 1½-inch wire, to hold the latter over to starboard, clear of the SC tube.



International Newsreel Photo

FIG. 76.—General view of "cut" in *S-4*, showing the 1½-inch towing pendant, with chain bridle around the gun mount, and the great amount of wreckage, over and through which the divers had to work

Part IX.—Section 1. Pontooning Tackle.

The following is quoted from commanding officer, *Falcon*, letter S94 of October 8, 1927, to manager, navy yard, New York, concerning readiness of pontoons for service:

2. Pontoons to be available for rescue work in connection with a submarine must have all equipment necessary for handling and hooking them up assembled at the place of stowage of pontoons. Further, the pontoons, valve gear, etc., should be kept in good working condition.

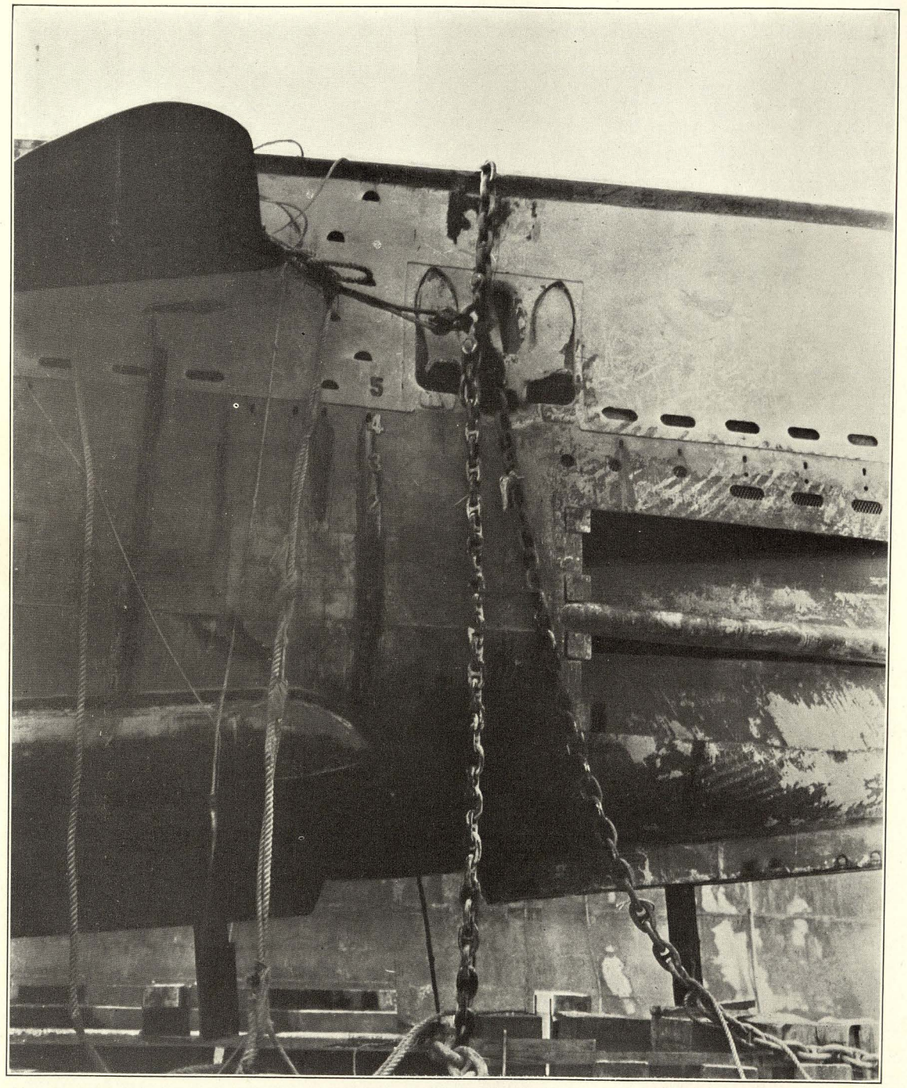


FIG. 77.—Forward towing bridle with bull ring, port and starboard girth chains, towing chain leading downward and to the right and 1½-inch wire towing pendant leading on top of bow plane and leading aft to the gun. The towing gear was deliberately run along the starboard side because the *S–4* carried left rudder and because of the presence of the SC tube

3. Gear necessary for using pontoons:

(*a*) Anchor chain—Two 15-fathom shots for each pontoon. Chain to be of size 2½ or 2⅝ inches. Should not have cast-iron studs as cast iron can not be burned under water with a gas torch. (See figs. 80, 85, 86, and 87.)

(*b*) Two alloy steel toggle bars fitted with ½-inch locking bolts for each pontoon, with 4 spares for each 8 pontoons; total, 20. Bars to be 40 by 3¾ by 3¾ inches, scarfed at each end. (See fig. 113.)

(*c*) Detachable links, Boston design (same size as chain), 2 for each shot of chain with 4 spares for each set of 8 pontoons; total, 20. (See fig. 84.)

(*d*) Steel fairing cones, made in pairs, for reeving end of chain only, 8 pairs, 2 spares; total, 10 pairs for 8 pontoons. (See figs. 84 and 86.)

(*e*) U clamps and bolts for lashing chains, 4 for each pair pontoons, 16 for set of 8 pontoons, with 4 spares; total, 20.

(*f*) Lowering lines (manila) and reeving wires. Those used on *S–51* were 12-inch manila, 180 feet long, fitted at one end with pelican hook. On *S–4* they were 8-inch manila. (See figs. 97 and 98.) One-inch, type "AA" plow steel (reeving) wire, 150 feet long, fitted at each end with long eye splice; no thimble. Four reeving wires and two manila lowering lines are needed to handle one pair of pontoons.

NOTE.—With pontoons as altered (to 3-compartment) 7-inch (or 8-inch) lowering lines can be used. Pelican hook should be capable of taking 1½-inch metal link or shackle. One coil 7-inch manila required for average pontoon job. Four reeving wires and 1 spare; total, 5.

(*g*) Blowing hose, hose fittings, etc., 6,000 feet, 1¼-inch, 50-foot lengths, fitted with male and female couplings, was used on the *S–51*. Hose must be of such construction as to safely withstand internal pressure of 80 pounds. Hose fittings, nipples, minor valves, gauges, etc., the *Falcon* carries sufficient supply. Buoys, shackles, and screws can be drawn from stock when required.

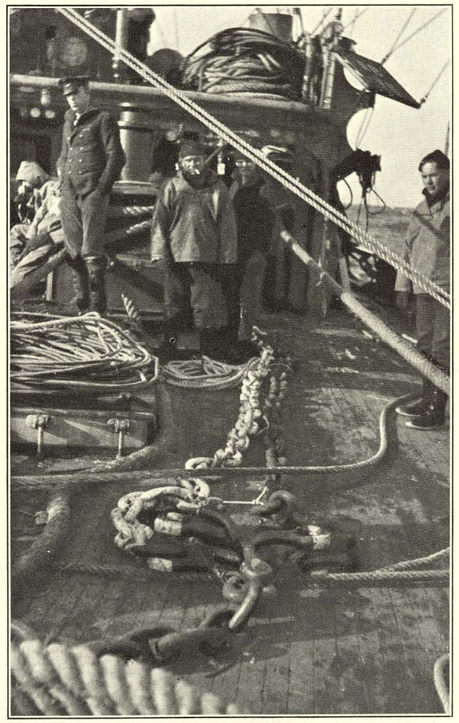


FIG. 78.—Bow towing bridle ready to be placed. Towing chain in foreground, with bull ring shackled to girth chains, white starboard and black port. Fourth shackle in bull ring connects to wire pendant leading aft to gun mount

The pontoon chains used on the *S–51* and some of those used on the *S–4* were 2½-inch chains. The later chains on the *S–4* were 2⅝-inch and the latter size should be used with these pontoons in the future, if available in order to increase the factor of safety, which is none too large when the pontoons are exerting full buoyancy. Furthermore, it is most necessary that all cast-iron studs be avoided, for should it become necessary to burn out the studs with the gas underwater cutting torch, the operation can not be performed unless the studs are of steel.

The pontoon chains supplied for the *S–4* salvage were all carefully overhauled and examined and were then cut to exact length, studs burned out, and distinguishing marks painted on.

(*a*) In way of toggle-bar positions, the open links were painted yellow. These links appear white in Figure 80.

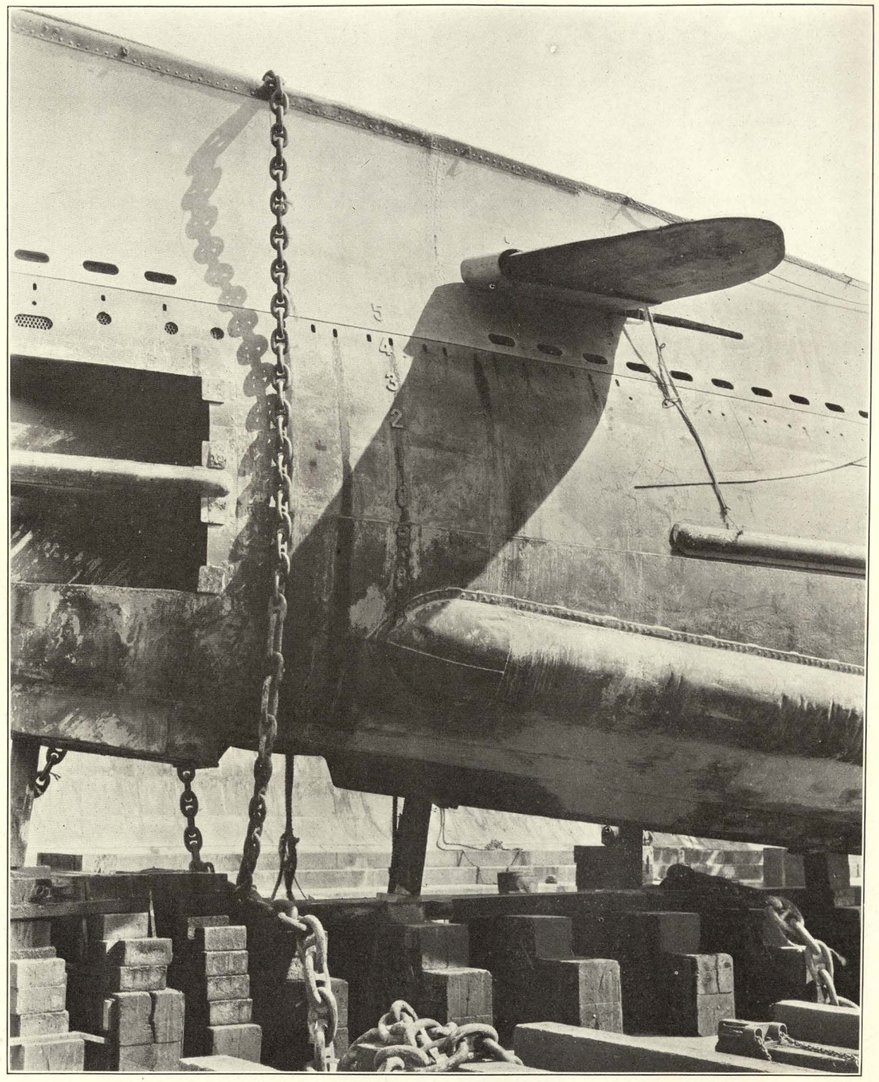


FIG. 79.—General view of bow, port side, with guard for bow plane, girth chains for forward towing bridle and forward plantoon chains. The two long links just above the submerged anchor recess were on the ends of the port and starboard girth chains and were connected together by a 1½-inch detachable link as shown by divers Crilley and Grube working in a tunnel under the submerged anchor

(*b*) Chains were numbered consecutively from forward aft and the end links of each chain were painted with green bands corresponding to the number.

(*c*) The studs of the forward chains of each pair were painted white, for assistance in identifying or clearing the chains of a pair.

On the *S–51*, as described on pages 28–29 of the salvage report for that vessel, when the use of heavy cast-steel clamps for the pontoon chains was discontinued and toggle bars inserted through open chain links were adopted, the studs were removed at the proper place by having a diver on top of the pontoon burn them out with a gas torch. It was stated there that—

> It might casually have appeared that all studs might have been burned out on the surface originally, but there was considerable danger in such a practice of the chain kinking up if the studs were missing while the chain was being handled under the submarine boat, and as such a kink would insure the parting of the chain in a load, it was considered safer to burn off the studs where wanted, rather than taking a chance on burning out a large number to insure getting an open link on the hawse pipe.

FIG. 80.—Pontoon chains laid out in gangway of *Falcon*, preparatory to sending down. Note painted links in way of toggle-bar positions

When the time came to plan the work on the *S–4*, the likelihood of the possible kinking of the chain with open links was discussed and it was decided to burn the stud out of every *alternate* link in way of the toggle bar position, thus opening 3 or 5 links in this vicinity for possible use as toggle-bar positions.

For the bow and stern pairs of pontoons the chains were never lowered or slacked sufficiently to allow the chain to pile up anywhere, so that it could not very well kink. The middle chains, port and starboard ends, were, however, lowered to the bottom at least three times, on March 9, 11, and 12, and at no time was there any evidence of kinking. It may be concluded, therefore, that studs may safely be removed in alternate links in way of toggle-bar positions if the chains are subsequently handled carefully. The advantages of this procedure are obvious; for example, when on chain No. 1, the forward chain on the bow pontoons, it was not possible to haul the chain up on the port side to within eight links of its proper position, the eight extra links were hauled in on the starboard side. Since the studs had previously been burned out for all the alternate links in this vicinity, very little, if any, time was lost.

The navy yard, Boston, is now (June, July, 1928) filling a long-felt need by preparing plans showing the appearance and the details, together with a complete list, of all parts of the pontooning tackle, so that the manufacture, storage, upkeep, checking, and shipment of this tackle, especially under emergency conditions, will be greatly facilitated.

Part IX.—Section 2. Overhaul and Testing of Pontoons.

Recalling the difficulties and the anxiety experienced with leaky pontoons on the *S–51* salvage operations, it was determined that there should be no repetition of these experiences on the *S–4* job if it was humanly possible to avoid them.

Furthermore, it was known that the pontoons were not in first-class condition, as witness the following quoted from commanding officer *Falcon*, letter S94, of October 8, 1927:

> 4. Condition of pontoons: I have made a recent inspection of the pontoons and find many of the flood and blow valves in need of overhaul. They appear to be just as left when the *S–51* was docked more than a year ago. The springs for the relief valves also are in same condition except some are painted, some not; some under compression, some not. All valve gear should be overhauled and slushed to prevent rust of working parts and freezing, particularly the springs of relief valves and screw threads of flood valves. The rubber disks of relief valves will deteriorate if left exposed to weather.

Accordingly, every pontoon, including the six that were to be used and the two spares, were sent to Boston for a thorough overhaul and tightness test. The following is quoted from commander *S–4* salvage force letter S94 (S–1029) of January 23, 1928, to commandant, Boston:

> Since all the 80-ton pontoons which are to be made ready for use on the *S–4* salvage (including the two now being converted at Boston, the five now at Provincetown which are to be overhauled at Boston, and the new one built by New York and subsequently to be towed to Boston) will be in the Boston yard at one time or another, it is considered that the navy yard, Boston, should check over the work on all eight of the pontoons and make sure that, as far as valves, marking, tightness of compartments, rigging, and fittings are concerned, the pontoons are all identical and are in first-class condition before sending them to Provincetown.

Advantage was also taken of this opportunity to install separate blow valves in the white ends and separate flood and drain pipes for the center compartments, all as shown on the then latest issues of navy yard, New York, hull division plans 77280 and 77311. A draftsman was sent from the Boston yard to Provincetown to insure that all work would be laid out as desired by the salvage force and to check up on the work involved in converting two of the old 80-ton *F–4* pontoons from 2-compartment to 3-compartment pontoons. Later, Chief Machinist's Mate W. Badders, who had had extensive experience with pontoons on the *S–51* job, was sent from the salvage force to Boston for an extended period to assist in the work. (See figs. 81 and 82.)

During the overhaul of the pontoons at Boston, the tops and valve boxes were painted as follows:

(*a*) Internal sluice-valve rod from center compartment overboard	White circle.
(*b*) End-to-end sluice valve rod	Yellow square.
(*c*) New blow valve on white end compartment	White cross.
(*d*) Red end blow	Red cross.
(*e*) Ends and hawse pipes, respectively	Red and white.
(*f*) Square ends of all valve stems	White.

Record of air test data on the *S–4* salvage pontoons is available only for pontoons YSP–5 and YSP–11 and is quoted here for information and record.

NAVY YARD, NEW YORK

Upon completion of the pontoon (YSP–11) we put 30 pounds air pressure on the three compartments and after a half hour there was a drop of about 2 pounds. We then filled the two end compartments with water, submerged it and weighed it, and determined that it had a negative buoyancy of 5,050 pounds and a total weight empty of 87,200 pounds. We then took it out and set it on deck and with the water still remaining in the end compartments we put 30 pounds air pressure in these compartments and corrected all leaks found, so that I feel that the pontoon is fairly tight and in accordance with your wishes in that respect. We then blocked the pontoon up on a solid foundation with the blocking directly under the hawse pipes and filled it with a weight equal to the buoyancy of the pontoon. This was done to determine any possible longitudinal weakness. However, we found that the deflection was only 1/16 of an inch and this probably due to an error in measurement. In any event, we feel sure that the pontoon has ample strength both against pressure and against bending.

NAVY YARD, BOSTON

The initial pressure in each case was 25 pounds per square inch, and the drop is given at the end of a period of 24 hours. The difference in temperature at the beginning and end of the test was negligible.

Pontoon	Compartment	Drop in 24 hours	Pontoon	Compartment	Drop in 24 hours
YSP–5	White end	1 pound.	YSP–11	Center	1¾ pounds.
YSP–5	Center	1¼ pounds.	YSP–11	Red end	2 pounds.
YSP–11	White end	¾ pound.			

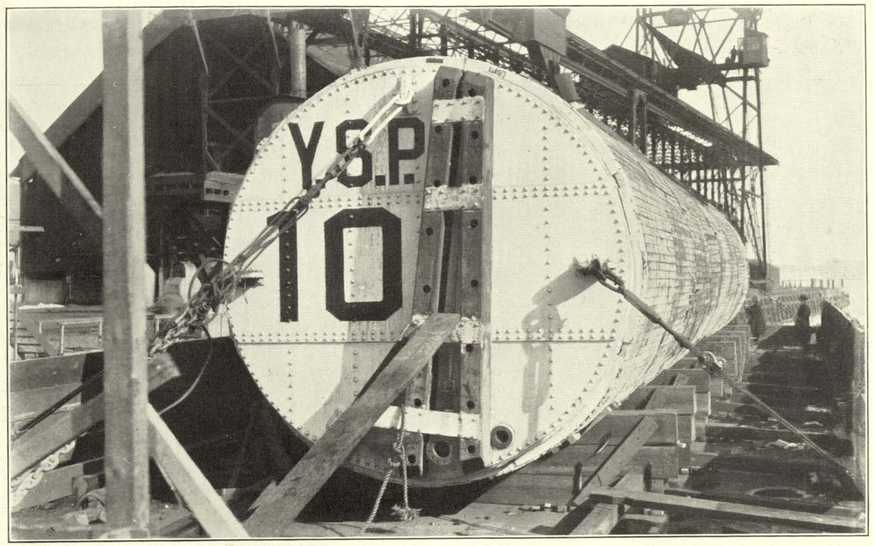


FIG. 81.—*S–4* salvage pontoon. Note at bottom the relief valve (left), flood valve for white end and discharge from flood valve on center compartment. Note method of lashing and securing pontoons on steel coal barge for transportation

The necessity for the most careful overhaul of pontoons after every salvage job and the proper maintenance of the structure and valves until they are again required can not be too strongly emphasized.

BLOW OR DROP PIPES IN END COMPARTMENTS

Before the overhaul of the pontoons was completed, the salvage force was able to discover a very simple solution for the problem of applying a definite amount of preliminary buoyancy to the end compartments of the pontoons. This problem had given the *S–51* salvage force much anxiety and it was really responsible for the premature lifting of the bow of the *S–51* on June 22, 1926, as described at length in the report of salvage operations on that vessel.

After an estimate had been made of the amount of gross positive buoyancy which it was desired to give each pontoon to hold its chains taut and to keep itself in position (about 9½ to 10 tons), the necessary volume was calculated and the position of the water line in each end compartment determined. This was actually about 31 inches to 33 inches from the top.

Extensions to the fixed blowing lines were then fitted in the form of drop pipes, each having an open end at the required distance from the top of the pontoon. Blowing down to the level of these drop pipes was a simple proceeding, as shown graphically in Plate 6, and this operation could be repeated or performed at any time with perfect reliability and assurance that excessive positive buoyancy was not being applied to the pontoon.

Part IX.—Section 3. Data on "S–4" Pontoon Blowing Hoses.

The pontoon hoses were made up in pairs for each pontoon and 200-foot lengths were sent down to the pontoons when the latter were lowered. Additional lengths were added when the *Falcon* took stations for raising, in the manner described for blowing hoses.

The pairs of hoses as prepared for use with the pontoons were seized together with marline every 30 feet. Both ends of one hose of a pair were painted white, for a distance of about 1 foot;

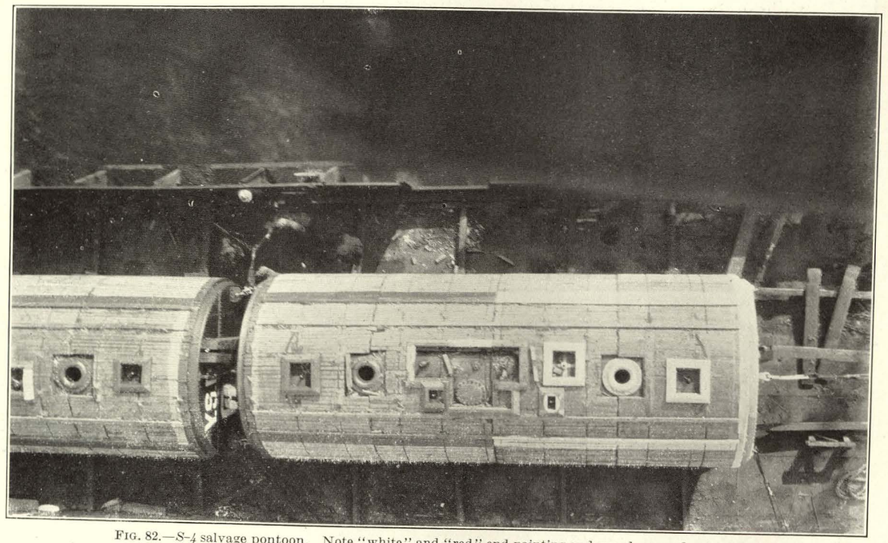


FIG. 82.—*S–4* salvage pontoon. Note "white" and "red" end painting and guards around valves on top

both ends of the other were painted red. In addition, numbers were stamped on the end couplings of the pairs as made up, corresponding to the numbers on Plate 5. As for the compartment blowing hoses, all numbers were stamped on the metal fittings *clear of wrench surfaces.*

The following total pontoon hose lengths were required for raising and towing the *S–4:*

Bow pontoons, 4 hoses, each 450 feet long.
Middle pontoons, 4 hoses, each 400 feet long.
Stern pontoons, 4 hoses, each 250 feet long.

The total length of hose, for compartments as well as for pontoons, attached to the *S–4* at the time of raising was 6,950 feet.

Part IX.—Section 4. Washing Tunnels.

The memories of washing tunnels on the *S–51* salvage job (see Report on Salvage Operations *S–51*, p. 16) brought no pleasant thoughts of anticipation for the "laundry work" that had to be performed under the *S–4*, sunk as she was until her keel was 7 or 8 feet in the mud. The washing

of tunnels under the *S–4* at frames 19 and 39 during the rescue operations and the early stages of the salvage indicated that it could be done, but there remained before the salvage crew all during January and February the specter of the tunnel which had to be washed at frame 46 for the chains of the middle pontoons.

About the end of February it was decided to wash a tunnel under the port side of *S–4*, frame 70, to reach the outside manhold in the fuel-oil tanks.

It was recognized that successful and expeditious tunneling, like so many other things, depended upon making the correct preparations and the proper start. Just what constituted the proper beginning of a tunnel was discussed at length with the divers. As a result of the thought and attention given to the matter in this most earnest discussion, it developed that the problem of washing tunnels under the wider parts of the *S–4* need not prove so difficult if the tunnel were properly begun; in other words, if the first crews on the job would wash a large hollow opposite the tunnel and would then begin the tunnel by making a large entrance, instead of endeavoring to make a burrow and to thread a way through it to the keel. It was realized after looking back upon the work performed on the frame 39 tunnel, that if more time had been spent upon making the tunnel large enough in the beginning, less time would have been required to pass the reeving lines at the end.

Particular precautions were taken to insure that the short descending lines (Plate 4) were placed at the proper frames. Furthermore, the first divers were accordingly directed to stand with their backs to the ship and wash *away* from her, making a large saucer-shaped depression into which the mud from the tunnel proper could be washed. About every third diver on the list was a man of more than the usual experience so that he could check up on the direction, shape, etc., of the tunnel and make corrections if necessary. The visibility in the tunnels is, if anything, less than zero, and with nothing but the shell of the vessel overhead, the directive landmarks are rather meager.

To Kelley, the diver assigned to start most of the later tunnels, is due the suggestion for the system of continuous washing and reliefs which worked out so well during March. The No. 1 divers in each pair were to wash and were to relieve each other in the tunnel at the nozzle, so that there was no loss of time due to shutting off water and no difficulty in the relief diver finding his way to the diver being relieved. The No. 2 divers, tending on deck, were to be down only during the interval from the ascent of the first No. 1 diver to the descent of the third No. 1 diver, so that no divers would cross or pass each other. When the first No. 1 diver came back up on the *Falcon* and stepped off the stage, the second No. 2 diver was ready to step on the stage and go down. As an example, the following is quoted from the salvage log for March 1, 1928, when excavating the tunnel at frame 70½:

0814. Kelley down to start washing tunnel at frame 70½, port. Passed fire hose down through a loop of manila line at the rail. (See Plate 4.) Turned on water at 0905.
0824. Harris down to tend life line and hose for Kelley on deck of *S–4*.
0908. Harris up to clear the *S–4* for Kelley's relief going down.
0910. Burd down and over side of *S–4*, relieving Kelley on hose while water is still going through.
0923. Kelley up; as he leaves stage, next diver steps on to go down.
0926. Scott down to tend Burd, and so forth.
1003. Wilson and Stanley washing; Wilson reached bilge keel.
1103. Grube and Sherwood washing.
1158. Eadie and Schumatz washing. Eadie stopped water at 1230 so that he could double hose back upon itself and wash sand and silt out of tunnel behind him. Started water again at 1240.
1250. Kallinoski and McMullen washing and cleaning out tunnel.

Notwithstanding the fact that the starboard side of the tunnel at frame 46 was washed in 5 hours and 11 minutes on March 4, and that the tunnel was completed in 9 hours and 20

minutes on March 6, the next diving day, the digging of tunnels under submarines is not to be considered quick nor easy. Aside from the requirements above described of making a large depression outside the tunnel and making a wide entrance, there is a natural tendency for the tunnel to be washed off to the left, due to the fact that most divers hold the hose nozzle in the left hand and the hose in their right, causing the stream of water to issue at an angle to the left. The almost inevitable result on the *S–4* was that, as shown on Plate 4, the two tunnels, even though begun at points on each side of the ship exactly opposite, were just about missing each other at the keel. It then became necessary to wash along the keel in the adjacent corners in order to get a hole through from the two sides.

Pressure up to 200 pounds per square inch can be carried on the fire hose while washing, but with the soil under the *S–4* it was found that 150 pounds per square inch was ample and that the lower pressure relieved the stresses on the fire pump very materially. In order to bend the hose sufficiently to permit the diver to turn around and wash out the tunnel behind himself,

FIG. 83.—Manila lines for reeving through tunnels preparatory to hauling reeving wires and pontoon chains; 1½-inch manila is connected by a tapered long splice served with greased marline to a 2½-inch manila, which is in turn connected to a 4-inch manila; the 4-inch manila serves as a messenger for a 6-inch manila hauling line which is spliced to the eye in the 1-inch reeving wire

he had to telephone up and have the pressure reduced from 150 pounds to about 90 pounds per square inch.

A description and discussion of the nozzle equipment for washing tunnels is given in Appendix VI, section 2, and photographs of the nozzles in operation are included under Figures 166, 167, and 168.

With regard to silting up of the tunnels under the *S-4*, the tunnel at frame 70½ filled up so much over night that whereas Michels (a big man) was able to find plenty of room in it on the afternoon of March 1, Crilley (a small man) could hardly get into it on the morning of March 2. On the other hand, the tunnels at frame 39 port and at frame 16, after an interval of a number of weeks, had apparently accumulated only soft material, for they were very quickly washed out.

At this juncture it may not be amiss to explain why it is necessary to dig tunnels at all and why ropes, wires, and chains can not be swept under or poked under through a small hole made

by some special sort of lance or water jet. Sweeping is always uncertain on a submarine on account of the nature of the bottom, the presence of projections, and the lack of definite information as to the fore and aft location of the wires or chains at the lowest point of the vessel. Passing a line or wire under through a small hole is only a part of the problem, for how is the large chain to be dragged through after it, if so much difficulty is encountered in reeving a chain through a large tunnel? The manner in which the presence of a fairly large tunnel under the vessel facilitates matters is explained in the section following.

Part IX.—Section 5. Reeving the Wires and Chains.

Passing the reeving lines and wires and keeping them clear of each other involved a great deal of work and the job had to be done over in the case of several lines. This is a ticklish operation and one that will always require the most particular attention and the utmost care.

It has been the practice in the past for the *Falcon* to lie over the submarine for this work, parallel to her and preferably bow to bow, the quarter of the *Falcon* over the tunnel through which the lines are to be passed.

One pair of 15-thread or 1½-inch reeving lines, say the after pair, for the after chain of a pair of pontoons, are sent down first with two divers who are to work from opposite sides. The end of the regular 1½-inch line (see fig. 83), with an eye splice in it, is given to one diver who takes it down into the starboard tunnel. The other diver is given the end of a piece of 1½-inch line, also with an eye splice in it, and he takes it down into the port tunnel. The divers are carefully instructed before going down that they carry with them the *after* lines and that the forward lines are to be sent down later. The divers meet under the ship and by a method prearranged between them, they connect the two eye splices with a double becket bend. In case they can not hand the lines to each other, a piece of pipe, about three-eighths inch or one-half inch or a piece of rod, is bent on the end of one line and this lance is then poked through the tunnel by one diver until the other grasps it and hauls the reeving line through.

When the divers telephone that the lines are secured, the salvage vessel hauls on the short line so as to pull the regular reeving line through the tunnel. Everything going satisfactorily, the 1½-inch reeving lines are left as they are for the time being except that they are hauled as taut as possible on the salvage vessel, carried aft with reference to the submarine, and tended by one man on each side, who has instructions that under no circumstances is he to permit another tender holding any sort of line from the submarine to walk *around* him, so as to get any other line foul of the reeving line.

The regular *forward* reeving line is then sent down to the diver on the starboard side who reports that he has it and that it is clear before the short 1½-inch line is sent down to the diver who is to go into the port tunnel with it. (In the following paragraphs it will be assumed for convenience that the hauling is all done from one side, although the sides may obviously be reversed if necessary.) The process described above is then repeated, whereupon the forward lines are hauled taut and carried forward. To make doubly sure that the reeving lines are not crossed, the direction in which they lead is very carefully noted and it is observed that nothing can be felt on one line when the other is sawed back and forth. As a final precaution, each of the divers is brought up the regular starboard reeving lines instead of up the descending line and each makes sure that his own line is clear of everything else.

By hauling on the short lines one at a time, the 1½-inch, 2½-inch, and 4-inch lines are hauled around through the tunnel under the vessel. To the 4-inch is bent a 6-inch manila and the latter is used to haul the 1-inch wire reeving line around. When reeving from the starboard side as above described, the port wire is sent down, upper eye first, so that as it comes up the port side it is in proper position. The upper eyes of the reeving wires are marked in some suitable manner to indicate the numbers of the chains to which they belong. To the lower or following end

of the port wire is shackled the port end of the respective pontoon chain and over the eye splice in the wire and the detachable link which secures it to the chain are placed two of the fairing cones, as illustrated in Figure 84.

These cones are of 7.65-pound plate, about 9 or 10 inches in diameter at the base (so that they will slide easily through the 12-inch hawse pipe on the pontoons) and are open on one side by just a sufficient amount to slip them over the 1-inch wire *above* the eye splice. The two are put on diametrically opposite, hammered well down over the splice and the link, and lashed in place with seizing wire, as shown in Figure 86.

The salvage vessel is then adjusted in position so that the reeving line being paid out from above tends just under the vessel and away from the side of the submarine on which the line is going down. In other words, if the wire and chain is going down on the starboard side of both the salvage vessel and the submarine, the salvage vessel will be slightly to starboard of a position directly over the submarine, so as to give the easiest lead for the wire and chain going *into* the

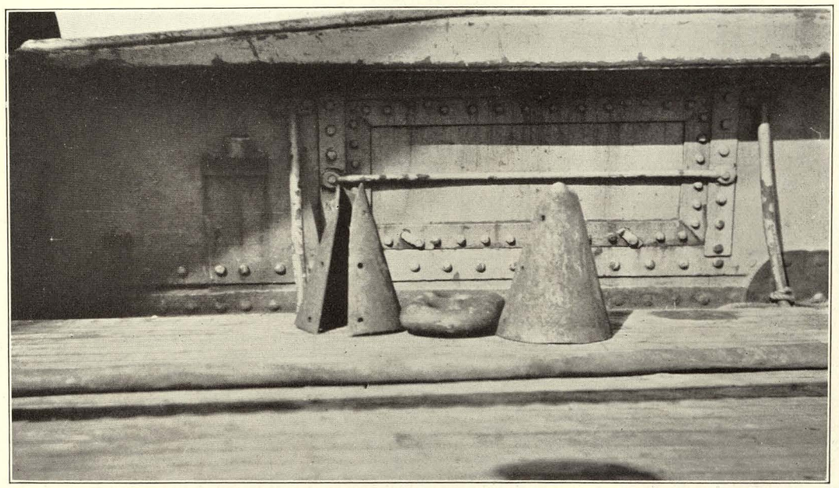


FIG. 84.—Steel fairing cones and 2½-inch detachable link for pontoon chains. Slot in side of cones is just large enough to permit slipping over 1-inch wire and large end of cones is of such size as to pass easily up through pontoon hawse pipes

tunnel. At the same time the position of the salvage vessel is also adjusted fore and aft so that the forward chain will be drawn through the forward part of the tunnel and the after chain through the after part of the tunnel. On the *S–4*, when reeving the chains for the middle pair of pontoons, the forward wires in some manner led up and aft relative to the submarine, as a result of which the *forward* chain, or part of it, lay up on the bank on the after side of the tunnel at frame 46, necessitating passing the after chain under and forward of the bight of the forward chain. To add to the complications, the reeving line on the after chain (of inferior material) carried away after the forward chain was in position and the reeving of the lines for the after chain had to be done all over again. Even with the most careful explanations from the divers and the utmost care on the diving vessel, the reeving lines were twisted up several times and it was really not until the vessel was examined in dock that the salvage party was assured that the chains for the middle pair of pontoons were not crossed.

However, the *port* reeving wires being passed, the chains are laid out in the gangway as shown in Figures 80 and 85 and shackled on one at a time. The upper end of the port reeving

wire is taken to the after capstan, the chain eased over the side (see fig. 87) and hauled around. The chain is eased out a fathom or so at a time and the reeving wire hauled around until it becomes taut. In this manner the bight of wire and chain are held up out of the mud and fairly taut under the submarine, and the chain is not allowed to pile up on the starboard side of the tunnel with the hauling part underneath.

The fairing cones and chain should pass easily under the keel if too much strain is not required to haul the outfit through the tunnel. If the chain hangs up, much time and effort will be wasted by endeavoring to haul it around with a vertical pull on account of the friction

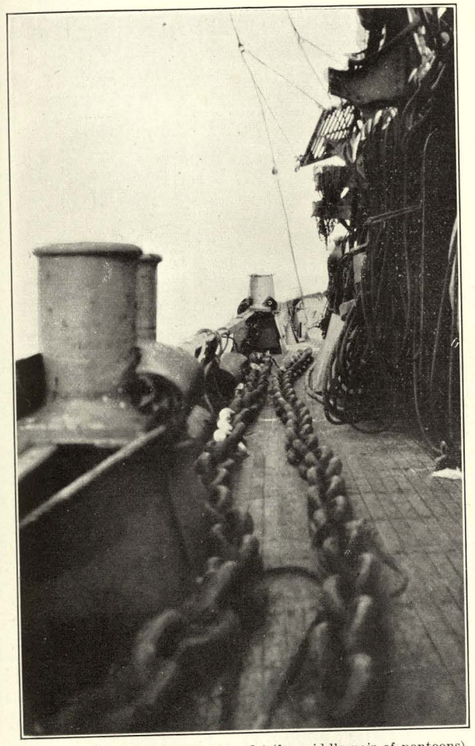


FIG. 85.—Pontoon chains Nos. 3 and 4 (for middle pair of pontoons) in starboard gangway of *Falcon* preparatory to lowering

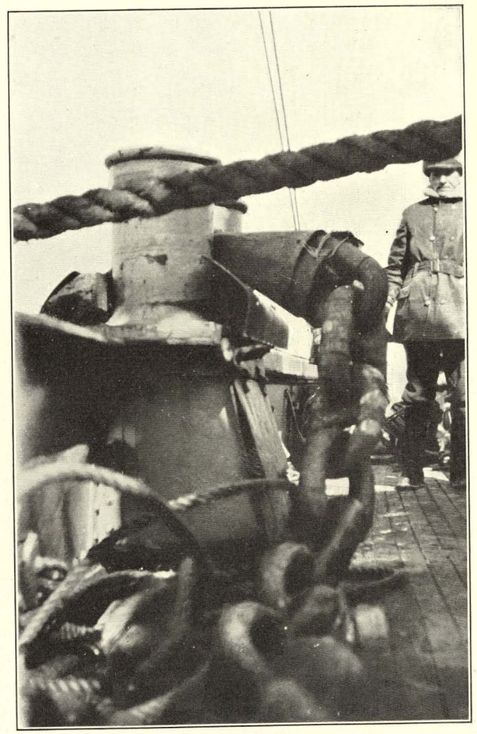


FIG. 86.—Steel fairing cones fitted in pairs over leading end link of pontoon chain. Note method of fitting cones over eye splice in 1-inch reeving wire and method of securing cones together and to end link by seizing wire

in making the double 90° turns to reach the capstan. On March 8 the after chain for the *S–4* middle pontoons hung up in this manner and no amount of slacking back, coaxing, or heaving would draw it beyond a certain point. The hauling was being done from the port side of the *S–4* and the *Falcon* and the latter vessel was moved to port to get a better lead for the port reeving line which was doing the hauling under the *S–4*, but still to no avail. Finally the *Wandank* was anchored on the port beam and a 7-inch manila line run from that vessel and shackled to the upper eye of the port reeving wire. The *Wandank* hove around on the line, taking an almost horizontal pull from the *S–4* tunnel, but there was still no action. As a last

resort, the 7-inch line was belayed on the *Wandank* and the engines started, working up slowly. At 90 revolutions per minute, turns for 12 knots, the chain slipped through under the keel and was then hauled into proper position without further difficulty.

When the chains are both equalized and hauled taut and before the 1-inch reeving wires are rove through the pontoon hawse pipes, a reliable diver should be sent down to look over all four chains and wires to insure that they are in proper position and are all clear.

On March 7, before the middle pontoon chains were hauled through the tunnel at frame 46 but after the 1-inch wires had been rove, and again on March 9, after the pontoon chains had been placed and equalized, it became necessary to unmoor on account of bad weather, involving the laying out and buoying off of the four ends of the reeving wires. The four upper eyes of the wires were carried out on the bow and on the quarter, respectively, of the *S–4* by the *Falcon* surfboat, were anchored there, and buoyed by four sets of specially marked cork buoys.

FIG. 87.—Pontoon chain going down. Note temporary bolsters and fairing pieces of wood and steel as used on *Falcon* for *S–51* and *S–4* salvage. Now to be replaced by permanent gear

On March 11, when picking up the reeving wires again, the port forward one was hauled up first, not remembering that the port after chain and wire was laid down last on March 9. As a result the port forward chain picked up the port after chain, lying piled on top of it, and this step, combined with the difficulty in reeving the wires described above, caused no end of trouble and anxiety during the next two days. Whenever it becomes necessary to lay out reeving wires and chains in this manner, it should be remembered that the last one down is the first one up.

Although the weather on the evening of March 11 was uncertain and shifting and on the evening of March 12 the barometer was falling and the wind shifting all around the compass, the *Falcon* lay in the moorings continuously for 36 hours rather than to risk fouling the reeving wires and chains by laying them out again.

Due to the hauling of the No. 3 chain (forward one of the pair for the middle pontoons) through the after part of the frame 46 tunnel, on March 8, as previously described, there arose a question as to whether the new reeving lines passed subsequently by Carr and Grube for the

after chain of the pair was clear of the forward chain or whether one had a turn around the other. The lead of the various lines and wires was checked and rechecked by the divers, and in the course of a series of operations too complicated to describe, the cross and the apparent turns discovered in the Nos. 3 and 4 chains on March 11 were very nearly jumbled up in an effort to eliminate them by reversing turns in the port reeving wires. It would almost have been less work, regarding the operations very critically, to have hauled both chains back up on the *Falcon*, cleaned out the tunnel and started all over again with the reeving lines and wires.

Part IX.—Section 6. Bow Plane Guards.

The Nos. 1 and 2 chains for the forward pair of pontoons were placed forward and aft, respectively, of the rigged-out bow planes, as shown on Plate 17, so as to hold the forward pair of pontoons in position longitudinally. There was a gap or opening of something less than a foot between the inner edges of the planes and the outer hull plating, so that there was a

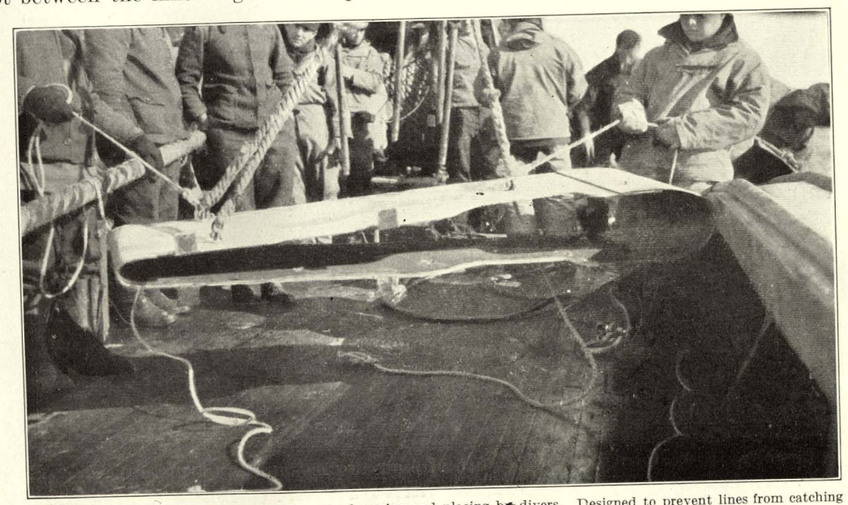


FIG. 88.—Bow plane guard, starboard, slung for lowering and placing by divers. Designed to prevent lines from catching between planes and superstructure

possibility of the pontoon chains catching there and jamming. Guards of steel plate, as illustrated in Figures 88 and 89, were made up on the *Bushnell*, and they were placed on the *S–6* during one of the rehearsal periods for the divers. The job on the *S–4* was somewhat difficult due to the angle of the planes, but in one dive each on March 4 the port plane guard was placed by Burd and Scott (fig. 90) and the starboard guard by Wilson and Kallinoski.

When the Nos. 1 and 2 wires and chains were rove on March 16 through the tunnel at frame 19, they were first brought up aft of the bow planes. When equalized and in place, Eiben was sent down on the planes to pass the forward wires around to the forward side of the planes as they were slacked.

Part IX.—Section 7. Preventer Lashing on Middle Pontoons.

Although every possible precaution was being taken to prevent the bow of the *S–4* from rising first or the ship from taking an angle by the stern at any time, there was always the possibility of such an unforeseen occurrence and as such it had to be guarded against. The No. 2 chain of the forward pair of pontoons was to be abaft the bow planes and the No. 6 chain

of the after pair of pontoons was to be through between the main shafts and the hull, both of them well fixed in position so as to hold the bow and stern pairs of pontoons, respectively. There remained, therefore, the provision of some means whereby the middle pair of pontoons could not slip forward.

The simplest means of doing this seemed to be the placing of a preventer from the No. 4 (after) chain around the gun mount, secured to the port and starboard ends of the chain under the middle pontoons. Studs were accordingly burned out of three alternate links on each side in positions which would be just under the red ends of the middle pontoons, and in these open links were to be inserted shackles for the attachment of two 1½-inch wire pendants, one port and one starboard, the after ends of which pendants were to be shackled to a short length of 1½-inch chain placed abaft the gun mount. The No. 4 chain was put down port end first, so to one of the open links on the starboard or following end of the chain the forward eye of the

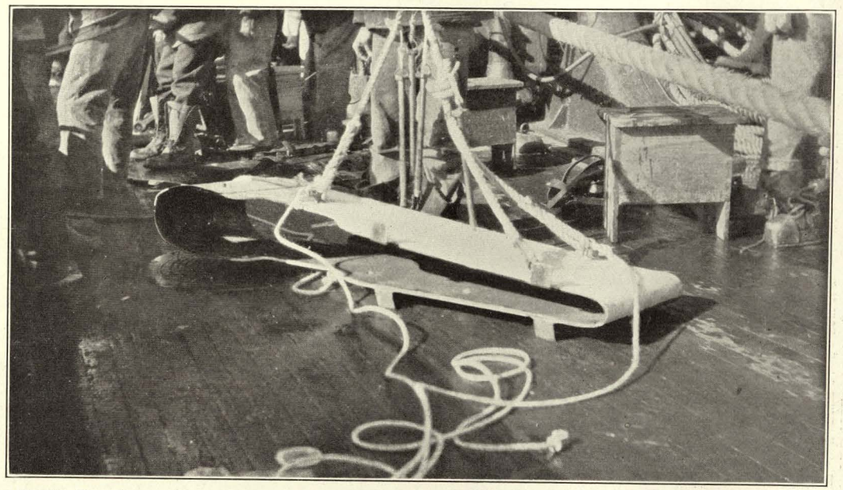


FIG. 89.—Bow plane guard. Note hanging of pins which will be cut off by divers and dropped into holes to hold guards in place. White paint is to improve visibility

starboard 1½-inch pendant was permanently secured. The after end of the pendant was held up by a manila lowering line so as to keep the pendant clear of the wreckage on the *S–4*. This part of the preventer lashing was put over the side on No. 4 chain on the evening of March 8. This method of attaching the preventer was later replaced by the use of a bull ring, as descriebd below.

The next morning, March 9, Kelley and Harris took down the port 1½-inch wire pendant to shackle it into the open links on the port end of No. 4 chain. They were not successful on account of the tight fit of the shackle in the open links and the stiffness and awkwardness of handling the heavy 1½-inch wire pendant, although they did succeed in inserting the shackle in the chain. (Figs. 92 and 93.) Crilley and Mattox followed with another shackle which it was thought would pass more easily over the thimble in the eye of the pendant, but the only result of that dive was the addition of a second shackle to the chain (figs. 92 and 93) and the loss of the 1½-inch pendant in the mud, due to chafing of the lashing on the inboard end. A talk with Crilley was sufficient to indicate that the method must be changed if success was to be achieved.

Two 1½-inch bull rings, 18 inches in diameter, were ordered from Boston, to which the preventer eyes might be shackled before threading the rings down over the chains. On the morning of March 11, one bull ring was threaded down over the starboard end of No. 4 chain, and Wilson and Kallinoski secured the starboard bull ring by passing a ½-inch wire strap through the ring and through one open link, then fastening the two ends of the strap with a 1¼-inch shackle (as shown in fig. 93). The after or inboard end of the pendant was then hauled aboard the *S–4*. Neither one of two divers following Wilson could find the port preventer, but Kelley finally dug it out of the mud and sent it up, whereupon it was shackled to the port bull ring and sent down over the port chain. Wilson made fast the port bull ring (fig. 93) on the morning

FIG. 90.—Port bow plane guard, installed to prevent reeving wires and chains from fouling between bow planes and hull

of March 12 in the same manner as for the starboard one. Eiben and Von der Wall, following, placed the section of 1½-inch chain around the gun.

On March 13, Crilley reported that he was able to get the port 1½-inch wire pendant clear of some interference with the port end of No. 4 chain, but upon going down again on March 14 he found the port pendant with a turn around No. 4 chain, caught between the chain and the ship. No amount of pulling and hauling or passing it around the chain would get it clear. There was nothing to do but order a new pendant from Boston by dispatch (it arrived the noon of the following day), take it down, and shackle it to the bull ring, all of which was done by Crilley and Kallinoski on March 16. Figure 93 supplements the description given above.

Crilley and Kallinoski brought the inboard ends of both pendants over toward the gun and shackled them to the section of chain with a string of 1½-inch screw shackles, thus completing a job that had required 24 dives and had extended for nine days.

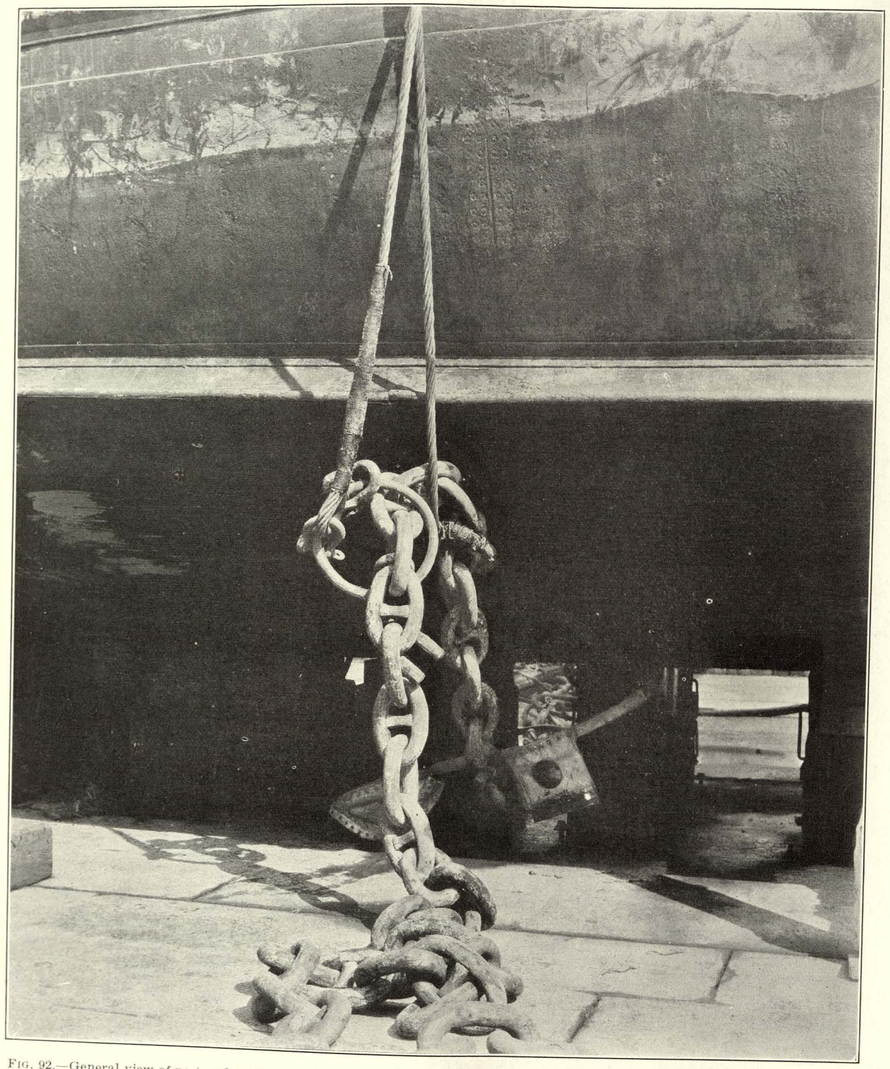


FIG. 92.—General view of port end of No. 4 chain for after ends of middle pontoons, showing the two 1½-inch preventer pendants and a piece of wreckage from *S–4* superstructure which was caught in tunnel at frame 46 between the two chains for the middle pontoons

Part IX.—Section 8. Pontoons.

Although six of the pontoons sent to Massachusetts Bay for the *S–4* salvage had been altered after the *S–51* salvage to 3-compartment pontoons in accordance with recommendations made by the salvage force on that job, none of them had been tested or tried in service to insure that the alterations had accomplished the purpose intended. Accordingly, on December 30, *YSP–7* was lowered in Provincetown Harbor and subsequently blown to the surface, with no indication of instability or any other feature of unsatisfactory performance.

On this occasion the same 12-inch manila lowering hawsers were employed that had been used on the *S–51* operations. It was evident, however, that with a negative buoyancy of only

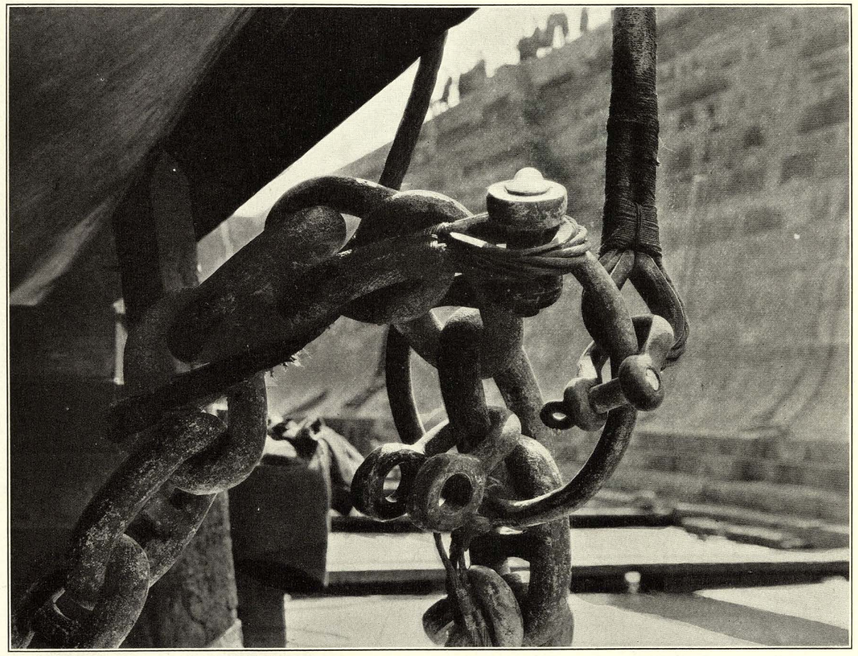


FIG. 93.—Wire preventer lashings secured to after chain of port middle pontoon to prevent pontoon from sliding forward in case bow of *S–4* accidentally came up first. Shows (*a*) two 1½-inch bending shackles by which it was originally planned to secure the eye of the 1½-inch wire pendant; (*b*) bull ring, 18 inches by 1½ inch shackled to eye of preventer pendant and lashed to chain with ½-inch double wire strap; (*c*) second 1½-inch preventer pendant shackled to bull ring when first pendant became foul

3 to 5 tons, 8-inch hawsers would be sufficient. Lowering lines of this size, 30 fathoms in length, and marked with 6-inch bands of colored paint, as indicated in the table on Plate 8, were made up and used for the *S–4*.

Figure 94 shows a small sectional model, 24 inches in length, of the 1928 3-compartment pontoon which was constructed by the navy yard, Boston, and used for the instruction and rehearsal of the divers for their work on the pontoons. The ends and the top were painted and marked in the distinctive colors and in the manner adopted for the large pontoons. The

inside drain pipes, as shown in the photograph (fig. 165), made clear an arrangement that was quite difficult to describe and explain otherwise.

The dead weight of the *S–4* pontoons was less than 40 tons and hence well within the lifting capacity of the usual type of dock crane. When filled with 80 tons of water, however, and fully submerged, their inertia and resistance to movement in a vertical direction was tremen-

International Newsreel Photo.

FIG. 94.—Model pontoon made up for instruction of divers. The painting on top is the same as on the pontoon

dous, so that holding them on lowering lines with the salvage vessel rolling and pitching was no small problem. In fact, on March 15, when holding the after pair of pontoons for toggling up, etc., the lowering lines strained and chafed on the *Falcon* and for parts of their length they were reduced in size from 8 inches circumference to nearly 5 inches. Excessive loads were thrown on them by the combined movements of the *Falcon* and the pontoons and undoubtedly it was

only the resiliency in the long lengths of manila which prevented them from carrying away and letting the pontoons drop to the bottom. The divers reported every possible sort of motion on the pontoon and they had to work under the disadvantage of having their hoses and life lines held very tightly, to prevent dropping them suddenly in the event the lowering lines should carry away.

The manila lowering hawsers stretched excessively, so that although the square marks at the water's edge showed exactly the same amount of line out on each end of each pontoon, the starboard pontoon was almost below the port pontoon, the additional stretch in the starboard

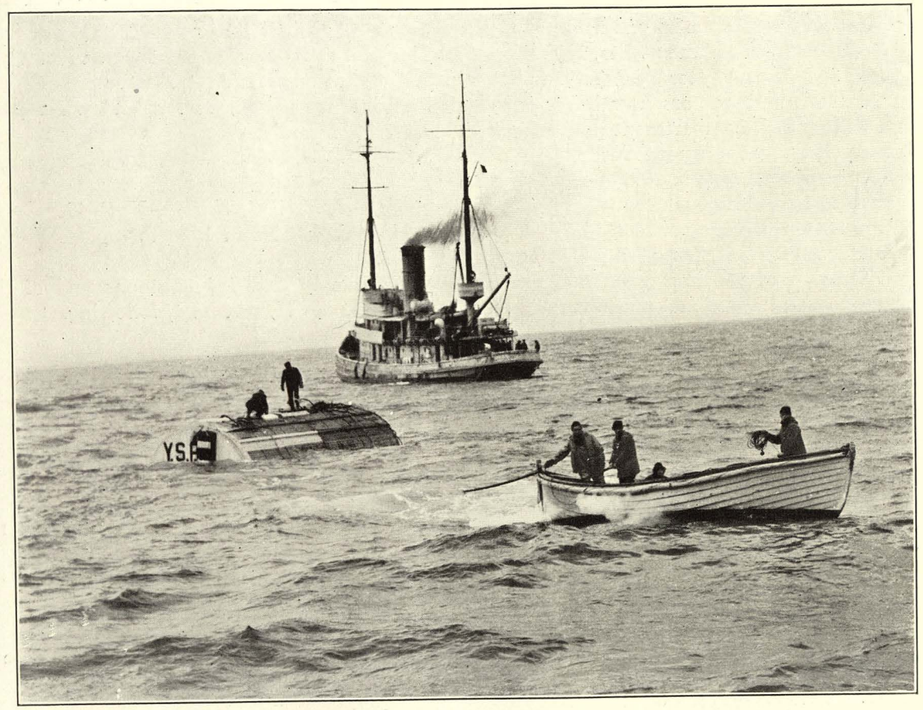


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FIG. 95.—Transferring a pontoon from alongside the *Sagamore* to the port side of the *Falcon*. The pontoon is being flooded en route in order to shorten the time during which it must lie alongside the salvage vessel in the choppy sea. March 15, 1928

lines coming about due to the fact that the starboard pontoon had been lowered first and had been hanging longer on the lines (about three hours altogether) and perhaps to the fact that the starboard side was the weather side and the vertical movement there was greater.

While the use of wire lines for leveling off, as described for the *S–51* salvage operations, would have rendered the *S–4* leveling operations somewhat more accurate, it is almost certain that the wire lines would not have had sufficient resilience to take up the loads due to inertia of pontoons and movement of salvage vessel in choppy weather.

For the reasons given above, manila lowering lines less than 8-inch size should not be used for the 80-ton pontoons unless it is known that smooth water can be counted upon.

The difficulties experienced with pontoons on the *S–4*, as regards

(*a*) Fairing cones catching in hawse pipes,
(*b*) Vent pipes clogging with dirt,
(*c*) Pipe fittings missing inside pontoons, and
(*d*) Vent hose valves becoming loose,

are all noted, and the remedies described, in section 9 following.

Improvements in the arrangement and design of salvage pontoons, based upon experience on all pontooning jobs to date, are noted under Part XVII, section 4, following.

The official identification numbers of the 10 salvage pontoons now (June, 1928) on the east coast was established by Bureau of Construction and Repair letter S94–(7) (M) of September 30, 1926, to commandants, New York and Norfolk, and by subsequent Bureau of Construction and Repair letter YSP (M) of January 28, 1928, to commandant, Boston.

All these pontoons are now being overhauled at the navy yard, Boston, and when completed will all be 3-compartment pontoons of the latest 1928 model.

Two 60-ton salvage pontoons, ex-*F–4*, *YSP–1*, *YSP–2*.

Two 80-ton salvage pontoons, ex-*F–4*, *YSP–3*, *YSP–4*.

Five 80-ton salvage pontoons, ex-*S–51*, *YSP–5*, *YSP–6*, *YSP–7*, *YSP–9*, *YSP–10*.

One 80-ton salvage pontoon, *YSP–11*, built by New York yard in 1928 to replace *YSP–8* lost at Horton's Point, Long Island, in December, 1927.

Discussion of the improvements and changes possible in the *S–4* pontoons and of the program to build additional pontoons will be found in Part XVII, section 4, following.

Part IX.—Section 9. Pontooning Procedure.

This procedure is as developed on March 7, 1928, for use on the *Falcon*, but it has been revised slightly to suit the procedure actually followed on March 13, 15, and 16. Hence it will serve as a description of the operations as well as a statement of the procedure.

I. Pontoons leaving derrick:
1. Reeve ½-inch wire messenger lines through hawse pipes and secure both ends of each line on top of pontoon.
2. Remove relief valve gag screws and put screws on *Falcon*. (See note 1 at end.)
3. Close all valves.
4. Put 1½-inch screw shackles on all towing clips.
5. Attach long links to lowering clips by 1½-inch screw shackles.
6. Attach short venting hoses to vent valves.
7. Deliver pontoons to *Falcon*, white ends forward with reference to *S–4*. (See note 2 at end.)

II. Pontoons—Prepare for lowering alongside *Falcon:*
1. Open white-end and red-end flood valves, if not already open.
2. Flood pontoon, venting back through vent hoses and blowing valves, controlling trim by operating vent valves on *Falcon*.
3. Attach pelican hooks of lowering lines to long links on lowering clips.
4. Place toggle bars, secure them to safety line, and lash near hawse pipes. Place locking bolts for bars. (See fig. 96.)
5. Thread reeving wires through hawse pipes. (See note 3.)
6. Bring white and red venting hoses to rail of *Falcon;* station men at upper valves on these hoses.
7. Set and check all valves on the top of pontoon—
   (*a*) White-end vent; white hollow square; open.
   (*b*) White-end blow; white solid square; open.

II. Pontoons—Prepare for lowering alongside *Falcon*—Continued.
7. Set and check all values on the top of pontoons—Continued.
   (*c*) Center compartment flood; white hollow circle; shut.
   (*d*) Center compartment blow; brass, bright; open.
   (*e*) Center compartment vent (telltale); brass; shut.
   (*f*) End-to-end sluice; yellow hollow square; shut.
   (*g*) Red-end blow; red solid square; open.
   (*h*) Red-end vent; red hollow square; open.
8. Attach white blowing hose to center compartment blow valve and red blowing hose to red-end blow valve. (See note 4.)
9. Lash blowing hoses to screw eyes and to each other. Stop the pair of blowing hoses (sufficient length to reach working depth) to the rail of the salvage vessel with rope yarn or light material which will break when pontoon is lowered.
10. Check center compartment blown dry by venting from telltale pipe. Build up pressure in center compartment to 15 pounds.
11. Let one end of pontoon go under water first, to vent air from compartment at opposite end; then hold lower end and trim pontoon the other way, to let air vent from both end compartments. (See note 5; also fig. 97.)
12. Hold pontoon with top about 3 or 4 feet under water to check all around.

III. Pontoons—Lowering:
1. Ease turns on bitts and pay out lowering lines evenly.
2. Close valves on ends of vent hoses and cast off hoses from *Falcon* when hoses come taut.
3. Blow air into center compartment, through white hose, maintaining compartment and sea-water pressure within 15 pounds. (See note 6.)
4. Hold pontoon just before chains are figured to come through top of hawse pipes.
5. Divers down on pontoon to count links and watch for painted links. (See note 7.)
6. Lower pontoon until toggle bars can be inserted in proper links.

IV. Pontoons lowered into position:
1. Slip toggle bars in chain links, insert locking bolt and secure.
2. Cast off reeving wires and send up. (See note 8.)
3. Close vent valves on both ends and break unions on vent hoses, leaving hoses lashed.
4. Close center compartment blow valve (brass color).
5. Shift white hose from center compartment blow to white-end blow (white solid square). Check white blow valve open.
6. Divers come up.

V. Pontoons—Leveling off (see note 9):
1. Blow white and red ends of both pontoons of a pair, simultaneously, until water level is at bottom of blow pipes.
2. Diver down (on each pontoon) to check position.
3. Open sluice valve (yellow hollow square).
4. Close red-end flood valve (after end of pontoon when stern is to be raised first).
5. Check top of pontoon for air leakage.
6. Trip pelican hooks on long links and send up lowering lines. Divers up.
7. Buoy off blowing hoses.

NOTES

NOTE 1. *Gags on relief valves removed.*—The following reasons governed:

(*a*) Relief-valve springs, fully compressed, limit travel of valve.

(*b*) Gag screws project beyond wood fenders on ends and are liable to be damaged, whereupon they could not be turned or used.

(*c*) If necessary to gag the valves, insert screws and set up.

(*d*) Relief valves are set to 7 pounds per square inch, about equal to head of water in end compartments.

NOTE 2. *Delivering pontoons to salvage vessel.*—If the towing vessel stands in close to the salvage vessel and the weather conditions are favorable, time can be saved by having one or two members of the pontooning crew go over to the towing vessel in the boat which is to tow the pontoon back and begin flooding it at once. The pontoon should have not less than 3 feet of freeboard when delivered to the salvage vessel. (See fig. 95.)

NOTE 3. *Threading reeving wires through pontoons.*—The eye in the inboard or upper end of each 1-inch reeving wire is secured to the lower end of the ½-inch messenger wire (fig. 98) which has already been run through the hawse pipe of the pontoon; in the meantime the reeving wire and pontoon chain on the submarine are held taut by a rope stopper. The upper end of the messenger wire is taken on deck and to the winch or

FIG. 96.—Sinking *YSP-9*, the first pontoon on the *S-4* job. Placing and lashing toggle bars, securing vent and blowing hose, and preparing all gear. Ideal pontooning weather

capstan and by this means the reeving wire is hauled up through the bottom of the pontoon hawse pipe, all as shown in the view to the right of Plate 8. When the hauling end of the reeving wire is taut the rope stopper is cut at the rail of the salvage vessel and the slack on the reeving wire taken in. (See fig. 99.) Since the reeving wire at this stage of the operations leads from the bottom, thence up to the rope stopper at the rail of the salvage vessel, thence down under the pontoon, up through the hawse pipe and over to the salvage vessel and through the pontooning chock, it will be seen that cutting the rope stopper throws slack into the reeving wire temporarily. Should the lead of the pontoon chain or reeving wire be such that the chain might slip out of position or the reeving wire foul some projection when the "loop" of this slack travels down to the bottom, it may be necessary to send down a diver to check the position of the chain before the pontoon is acutally lowered.

Also, should the port and starboard reeving wires be hauled taut when this operation takes place, the pontoon chain is liable to slip transversely through the tunnel when one wire is slacked, thus throwing the chain out of symmetrical position.

NOTE 4. *Venting of end compartments.*—When the red blowing hose is secured to the red-end blow valve the vent valve on the manifold of the salvage vessel is opened and the red end allowed to vent as before, but through this manifold valve. However, the reduction in air flow due to the long length of hose will cause the red end to vent more slowly than the white end, as there will be no hose on the white valve. This unsymmetrical

arrangement will not affect the handling of the pontoon when just about awash, for by that time the water level in the end compartments will have reached the ends of the drop pipes and air will no longer escape through either of the blow valves.

NOTE 5. *Venting of pontoon.*—Since the internal vent pipes are small it is possible that they may become clogged with débris floating on the surface of the water in the end compartments. This actually occurred with both after pontoons on the *S-4;* the resultant excessive trim and failure of the pontoons to sink promptly was the cause of much anxiety due to the violent motion of the pontoons when lying alongside in the choppy sea. (See fig. 98.) To guard against such a contingency have ready a diving hose or small air hose which can be quickly secured to the valve at the upper end of the vent hose. Blowing a small amount of air back into the pontoon will dislodge the obstructions.

NOTE 6. *Equilization of pressure in center compartment.*—On the *S-4* the pontoons were held every 24 feet during their descent to build the internal pressure in the center compartment. In case of an emergency it is probable that no great damage would be done if the internal pressure lagged somewhat behind sea pressure. For a salvage operation the difference could with safety very nearly equal the test pressure on the bulkheads, although if it is known that pontoons may have to remain in position for a considerable time, perhaps without frequent checking and blowing, it is the part of wisdom to follow a procedure which will keep the internal bulkheads fully tight.

On the *S-4* the blowing hose to the center compartment was disconnected as soon as the pontoon was toggled up; hence it was not practicable to relieve the pressure in this compartment before raising the vessel. The pontoon was allowed to come to the surface with a center compartment pressure of 45 to 50 pounds per square inch, knowing that the bulkheads were able to withstand this pressure, even though they might subsequently leak. The greater part of the excess pressure vented itself rapidly by unseating or springing the flood valve to the center compartment; the remainder vented more slowly here and there and had the effect of insuring that while any excess pressure remained no water would leak into the center compartment.

FIG. 97.—Lowering the first pontoon, *YSP-9*, to the *S-4*. Note 8-inch lowering line and pelican hook in foreground

NOTE 7. *Toggling up.*—Watching for painted links was not particularly difficult on the end of the chain which went down last. Picking them up on the other end, which had passed through the tunnel, was much more difficult on account of the coating of mud and slime which the divers had to rub off before they could see the paint. The most satisfactory and expeditious scheme was to have the divers count the links of the pontoon chains as they came up through the hawse pipe, repeating the consecutive numbers over the telephone. When the proper link came through the divers were told to insert the toggle bar in it.

NOTE 8. *Casting off reeving wires.*—This necessitated slacking away on the reeving wire until the end link came down in a working position over the pontoon, then driving out the forelock pin, taking out the two connecting pieces, dropping the chain down on the pontoon and unhooking the detachable link from the chain. Once unhooked, the connecting pieces were replaced on the link, the forelock pin pushed in by hand, and the detachable link, complete, hauled up on the end of the reeving wire. This is preferable to removing the heavy detachable links entirely and sending them up in the tool bag.

NOTE 9. *Leveling off.*—When both pontoons of a pair are toggled up, fore and aft, the pontoon chains under them will in all probability be somewhat slack, since a little extra length is required on the chains to get

the toggle bars entered and in position. Furthermore, when toggled up, the pontoons may not be in proper and exact position relative to each other or relative to the submarine.

On the *S–4* it was planned to level off the pontoons, fore and aft, or to bring up the low pontoon of a pair, assuming the high pontoon already in position, by blowing the low pontoon first and taking up the slack in the pontoon chain on that side (perhaps rendering the chains around slightly under the vessel). The lowering hawsers on the high pontoon would be held so as to prevent the high pontoon from being dragged down out of position.

Actually it worked out that the lowering operations on the *S–4* pontoons were done on a falling tide and that by the time blowing of the pontoons was to take place, changing from negative to positive buoyancy, the

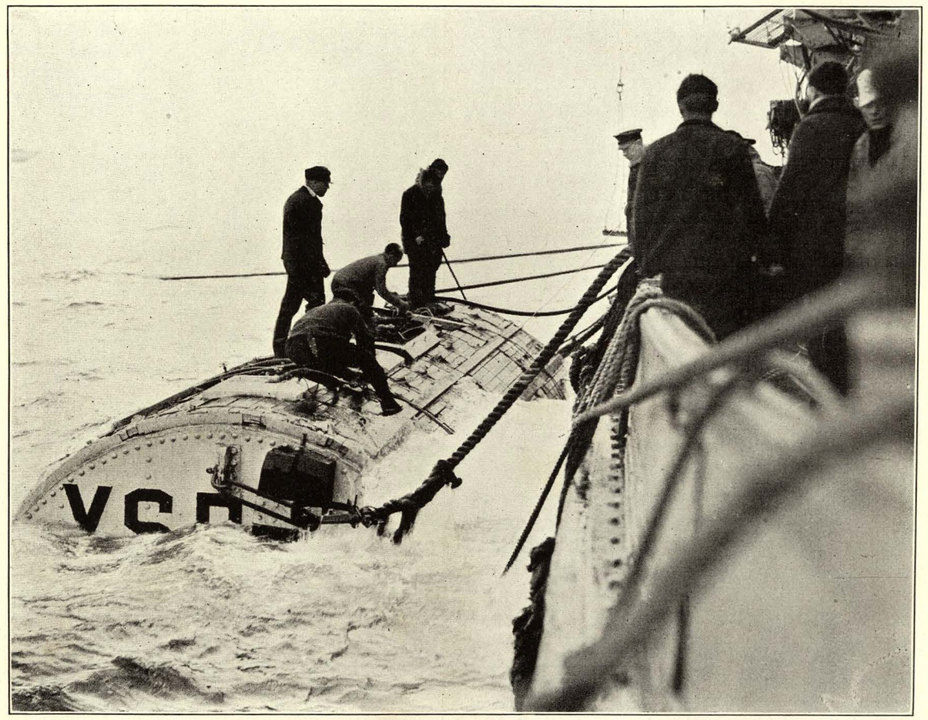

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FIG. 98.—Preparing the starboard after pontoon for lowering during choppy weather on Thursday, March 15, 1928. Note shackle, long link, pelican hook, and 8-inch manila lowering line. Warner, in the foreground, is unshackling the ½-inch messenger wire preparatory to reeving the 1-inch wires through the hawse pipes. (See Plate 8.)

tide was slowly rising. By proper manipulation of the lowering lines the upward movement of the salvage vessel could thus be made to hoist the pontoons automatically.

However, leveling off the pontoons where there is little or no tide and where the pontoons are placed low down and as close to the submarine as possible (within 1 or 2 feet), it will undoubtedly be found necessary, in order to insert the toggle bars, to lower both pontoons somewhat below their proper level. The same procedure would be necessary were the tunnels not accurately excavated so as to permit reeving the pontoon chains at right angles to the center line of the submarine. Under the above conditions it would most likely be found that when the pontoons were toggled fore and aft they would both be below the leveling positions.

The procedure for leveling off would then be as follows:

(*a*) Blow both ends of the high pontoon until the lowering hawsers come slack at the bitts. Then take up the slack on the lowering hawsers, vent back the end compartments, and allow the pontoon to become heavy, slacking away on the lowering hawsers until the proper colored square marks are at the water line.

(*b*) Blow both ends of the low pontoon until its lowering hawsers become slack.

(*c*) Continue blowing, if necessary, or else vent back until the water level in the end compartments of the low pontoon is at the height of the drop pipes. Take in the slack on the lowering hawsers of the low pontoon and belay.

(*d*) Blow both ends of the first pontoon (the one which was originally high) until its lowering hawsers become slack. Since the lowering hawsers of the second pontoon are belayed, there will be no danger of its being pulled down below its proper position. Continue blowing or vent back on the first pontoon until the water level is at the bottom of the drop pipes.

(*e*) Both pontoons will now be at their proper levels and pulling equally on the pontoon chains. Divers may then be sent down on top of both pontoons to disconnect and send up the lowering hawsers.

In cases where it is imperative to get out of the moorings on account of bad weather or other unforseen circumstances, before both pontoons of a pair have been secured and blown, it may become necessary to lower the pontoons all the way to the bottom and possibly to disconnect the lowering hawsers or buoy them off. The following procedure will then be found applicable:

(*a*) Pick up or attach the lowering hawsers, in readiness to continue work where it was left off.

(*b*) Blow both ends of one pontoon first (assume the starboard pontoon). This pontoon will then rise, pulling up the slack in its chains and perhaps rendering them around under the submarine so as to hold the port pontoon close aboard. The starboard pontoon will then, of course, be considerably higher than its proper position.

(*c*) Take in all the slack on the lowering hawsers of the starboard pontoon, belay them, and vent back until the pontoon is heavy, slacking away on the lowering hawsers until the starboard pontoon is at its proper height, as shown by the square marks at the water-line.

(*d*) Blow both ends of the port pontoon until it pulls back the proper amounts of pontoon chain and rises to its proper position.

(*e*) Blow the starboard pontoon until its lowering hawsers become slack, then blow both pontoons down to the bottom of the drop pipes and secure as described above.

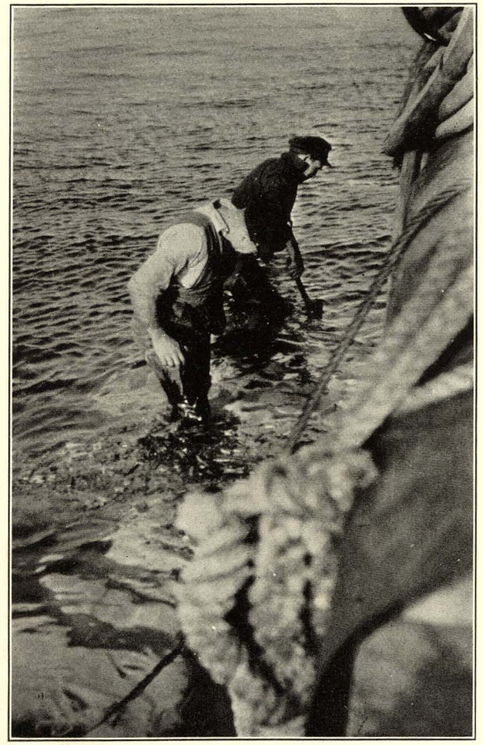

FIG. 99.—Badders and Weaver tightening leaky blowing hose connection on pontoon already submerged. Note 1-inch reeving wire leading over bolster in pontooning chock in foreground, thence down to hawse pipe in white end of pontoon

In cases where it is possible to place the chains fairly accurately in the tunnels, pontoons can be toggled up while being held in their proper positions by the lowering hawsers, all of which will simplify the leveling operation.

Part X.—Calculations and Preparations for Raising. Section 1. Draft.

It was at first planned to bring the *S–4* to the surface with a draft of about 32 or 33 feet and to place her in the No. 3 dry dock at South Boston. In fact, she could have been docked there at any draft less than 35 feet.

When definite plans were later adopted it was decided to take the *S–4* to the Boston Navy Yard and to place her in No. 2 dry dock, where the available depth of water was limited to 30

feet on high tides and where it was mandatory, for practical purposes incidental to docking and landing on the blocks, to reduce the draft to 28 feet.

This decrease in draft of 4 or 5 feet necessitated "hitching" the pontoons much lower on the *S–4* than had heretofore been considered safe or practicable, as the chains were laid out originally to bring the bottoms of the pontoons 5 feet above the level of the superstructure deck. There was much discussion as to the feasibility of drifting the pontoons down close to the *S–4* on account of the rather sharp nips in the chains leading to the hawse pipes and on account of the unfavorable leads which might obtain during the actual raising operations. However, after a study of the possible effects on the *S–4* and on the pontoons of encountering swells and of having to take the ship through a seaway en route to Boston, it was decided that if the pontoons were left at least 2 feet clear of the superstructure and the hull there would be sufficient clearance to prevent serious damage to ship or pontoons.

In case it were found necessary or desirable after arrival at the navy yard to decrease the draft of the *S–4* still further, it was known that this could be done in the period of at least nine hours which was allowed between the scheduled time of arrival and the time of the next high tide on which the vessel could be docked by shortening down on the chains until the pontoons lay directly on the hull or superstructure.

To insure that the vessel would be at zero trim fore and aft when finally docked and to obviate any tendency for her to plane downward while towing, it was planned to trim the vessel only a few inches by the bow when raising. (See Plate 17.) With the sheer of the superstructure and the slope of the hull, this left the upper surface of the vessel about horizontal for the towing operation.

Laying out the pontoon positions on this basis, it was seen that the after pontoons would be actually about 5 feet above the hull, touching each other on the inboard sides. The forward pontoons would also be touching all along, due to the narrowness of the ship at the bow. The middle pontoons would be separated, they would lie about 2 feet lower than the forward pontoons, and their bottoms would actually be lower than the level of the superstructure deck, although the pontoons would clear the corners of the superstructure by the required 2 feet. The respective positions are clearly shown on Plate 7.

An allowance of 1 foot on draft was made and carried throughout for the pontoon chains, so that actually the designed draft under the keel of the *S–4* when ready for docking was only 27 feet. It might be added here that the navy yard, Boston, desired to have the ship delivered to them with a difference in trim of not more than 1 foot and a list of not more than 3°.

A convenient displacement curve for the 80–ton pontoons, which was used in calculating water levels for the *S–4* afloat, is included in Plate 15.

Part X.—Section 2. Final Calculations for Weight, Buoyancy, and Moment.

When making final calculations for absolute values and moments of weight and buoyancy the general scheme was adopted of—

(*a*) Assuming that all liquids and liquid weights of a density approximating 1 were supported by the weight of the sea water displaced.

(*b*) Calculating or estimating the "earned" buoyancy by figuring the actual volume of the air space or air bubble available; in other words, obtaining the volume of the free air space in each tank or compartment, measured to the *inside* of the boundaries and excluding all structure, fittings, etc., but including air volumes inside of pipes, tanks, etc., which were wholly within compartments or spaces filled with air.

(*c*) Calculating the absolute dead weight of the structure in sea water by obtaining the best possible estimate of its weight in air and then assuming or estimating a figure for the average density of the structure as compared to sea water.

(*d*) Neglecting the "suction effect" or the pressure of the atomsphere upon areas under the bottom of the *S–4* where she lay in the mud and sand, since it was known that the water from the main ballast tanks, when blown, had found its way out from the Kingston openings, buried 7 or 8 feet in the mud at the very bottom of the ship. The character of the bottom indicated that it was sufficiently permeable for sea water to find its way anywhere under the bottom, and the behavior of the vessel during the latter part of the operations verified this.

(*e*) Figuring horizontal moments on a basis of frame spaces (1½ feet in length) rather than on a basis of feet, as is customary in regular calculations, in order to simplify the work.

(*f*) Carrying along at least three sets of calculations, one for average assumed conditions and one each for the extremes on either side. For example, on the *S–4* the technical assistant to the salvage officer worked out the regular calculations with *average* weight and buoyancy figures while the salvage officer worked out one for "maximum weight–minimum buoyancy," to insure that the ship could be lifted, and another for "minimum weight–maximum buoyancy," to insure that she would remain in place on the bottom until all preparations were made for raising. Similarly, condition 1, on the left diagram of Plate 11, is for battery room partly dry, safety tank partly blown, and maximum buoyancy from battery electrolyte, whereas condition 2, on the same diagram, is for battery room completely flooded, safety tank flooded, and minimum buoyancy from battery electrolyte.

(*g*) The following assumptions were taken for granted and the respective weights, buoyancies, and moments remained fixed throughout all the regular calculations:

1. Eight torpedoes in torpedo room, not damaged or leaking.
2. Lubricating-oil sump tanks three-fourths full of lubricating oil when sunk. Full of salt water when raised.
3. Battery fresh water tanks three-fourths full of fresh water when sunk. Full of salt water when raised.
4. High-pressure air flasks, torpedo impulse tanks, and volume tanks free of water.
5. No. 1 fuel-oil tank, empty.
6. Nos. 2 to 6 and Nos. 7 and 8 fuel-oil tanks, full of fuel oil.
7. One auxiliary tank empty, one half full of salt water.
8. After trimming tank, empty.

NOTE.—The latter two items do not appear in the table on Plate 10, since the latter was calculated for a minimum buoyancy condition.

(*h*) Since the available inclining experiment data did not contain a base or "zero" weight statement to which the known weights in the *S–4* could be added, it was necessary to begin with the total displacement and weight and to work backward. Allowance was made for known weight (and buoyancy) of the pig lead on the conning-tower hatch, the towing bridles, the cement used, and the salvage hatches; also for clearing lines, superstructure, mushroom anchor, etc., which had been removed.

(*i*) The correction for density on the *S–4* regular calculations was 13 per cent. In other words, the calculated dead weight of the *S–4* in air, 830 tons, was reduced by the factor 0.87 to the calculated dead weight in sea water—722 tons.

Flotation diagrams were drawn, similar to the loading and buoyancy diagrams on a surface vessel among waves, which represented by ordinates, on a basis of frame spaces, the tons dead weight and the tons effective buoyancy, internal and external, throughout the length of the vessel. These diagrams indicated in a general way the location and distribution of excess dead

weight over internal buoyancy and of external buoyancy to be applied to overcome it, but they did not produce quantitative answers without a great deal of calculation. Furthermore, since the problem was one of external forces rather than of internal forces, so to speak, the weight and buoyancy of the vessel, when once determined, could each be treated as a single force acting at the center of gravity and the center of buoyancy, respectively.

Two sets of moment curves or diagrams were subsequently found desirable; one serving to give quickly and accurately the resultant totals and moments for weight and buoyancy covering a number of assumed combinations, such as flooding one or more compartments or tanks accidentally (as happened with the control room on the *S–51*); the other giving conveniently the resulting moment of weight or buoyancy under any one of the combinations assumed about any selected axis, for calculating and placing the buoyancy required to be exerted by the pontoons.

The first set of moment curves, prepared after the calculation of the individual weights and buoyancies (which had to be done in any event) gave a definite answer as to resultant weights, buoyancies, and moments after totaling two columns of figures. The second set demonstrated its simplicity and effectiveness when figuring the position and amounts of reactions on the bottom; in other words, when ascertaining the amount of negative buoyancy under any assumed combination, the point on the keel where it could be assumed that the weight of the vessel was concentrated and the buoyancy which the pontoons would have to exert in selected positions for overcoming the negative buoyancy and balancing the moment of weight of the submarine so that she would rise and float level. As a considerable amount of time was spent during the *S–4* salvage operations in working out the most convenient methods, the diagrams will be explained here in some detail.

Plate 10 illustrates the moment curves for individual buoyancies and for total weight, laid off on a basis representing the length of the ship in frame stations. These particular curves were drawn during the salvage operations for an assumed condition on the *S–4* somewhat different from those described elsewhere, and hence they serve only as an example or illustration of the method. Each "curve" is a straight line passing through the base line, or ordinate of zero moment, at the point where the center of buoyancy or gravity of the corresponding air space or weight is located. Each lies at such an angle as to indicate, by its ordinate at any point, the resultant moment at that point. The method of quickly drawing in the curves is explained under the note on Plate 10 and the method of designating moments is shown by the sketches at the left.

When it is desired to determine the buoyancy and moment of any given group or combination of buoyant spaces or compartments, a point is selected about which moments are to be taken—generally the calculated position of the reaction (on Plate 10 this is frame 56), or else the forward perpendicular, and an ordinate is drawn through this point. The arithmetical sum of the buoyancies available is then the total buoyancy (536.1 tons on the plate) and the algebraic sum of the moments intercepted by the ordinate is the moment of buoyancy about the point selected (16,010 frame tons on the plate, tending to lift the stern about frame 56).

While the calculation of the individual moments and their algebraic summation, for any one combination of buoyancies and weights, can quickly be done on a calculating machine or otherwise, the latter operation involves one step to ascertain the distance from the center of buoyancy of each unit to the point about which moments are to be taken and another step to multiply out the moments. On the other hand, the curves on Plate 10 can be drawn in without any preliminary calculations by using a strip of paper 100 frames long, laying one end of the paper at the center of buoyancy or gravity of the item in question (point A on Plate 10) and marking off 100 times the tons buoyancy (or weight) at the other end of the paper (point B on Plate 10). A straight line through these points completes the "curves." Once this is done,

the work is completed and a summation of the moments about any axis selected (frame 56 on Plate 10) involves inspection and addition only. Furthermore, when it is desired to take moments about some other point or when a number of conditions are to be worked up, as they were on the *S–4*, assuming various tanks and compartments as flooded, partially filled or empty, the time saved and the accuracy gained by the used of the simplified operations is quite considerable.

If the axis of moments is taken as the forward perpendicular, the moment of buoyancy divided by the total buoyancy is the frame station where the center of buoyancy is located. The position of the center of gravity by frames is calculated in the usual manner. For the remainder of the work, analyzing one condition or combination of weights and buoyancies at a time, the total weight and total buoyancy can each be treated as single forces, acting at the center of gravity and center of bouyancy, respectively.

The simplified diagrams illustrated on Plate 11 can then be used, indicating graphically and readily the positive or negative buoyancy, the position of the reaction on the bottom, and the amount of that reaction for any given condition or set of conditions which is to be investigated.

For condition 1 on the *S-4*, shown on the left diagram of Plate 11, the center of buoyancy was found to be at frame 82.3, the total buoyancy being 550 tons. This is marked off on the base line as point B. For point A, go forward 100 frames, then lay off *below* the base line an ordinate equal to 100 times 550, or 55,000. Draw the straight moment of buoyancy curve for condition 1 through the points A and B. Although a strict interpretation of the rule on Plate 10 would require the point A to be laid off *above* the base line, since the moment of buoyancy about the selected point forward tends to turn the vessel in a clockwise direction, the conditions may be more graphically represented by having the weight and buoyancy moment curves lie alongside each other, whereupon the arithmetical difference between the two is readily visible to the eye.

For instance, on the left-hand diagram, Plate 11, it is desired to find out how much buoyancy must be applied in the forward set of pontoons to lift the bow (assuming that the stern pontoons at frame 137 are supporting the stern). Taking moments about frame 137, a vertical line CD is drawn through this point. Then,

	Frame tons
Moment of weight is	42, 600
Moment of buoyancy is	30, 000
Required moment of pontoon buoyancy is	12, 600

To be exerted at frame 32 about an axis at frame 137.

Distance from after pontoons at frame 137 to forward pontoons at frame 32 is 105 frames.

Then buoyancy required in the forward set of pontoons is $\frac{12{,}600}{105} = 120$ tons.

The buoyancy actually being exerted by the after pontoons may be determined similarly by taking moments about frame 32. It will, of course, check with that found by the following quick and simple process—

	Tons	
Deadweight of submarines		722
Buoyancy of submarine	550	
Buoyancy of bow pontoons	120	
		670
Buoyancy of stern pontoons		52

Auxiliary scales and diagrams may be drawn, as at the left side of the left diagram on Plate 11, to give the above result by inspection only for various conditions or combinations.

When preparing the moment curves for the right diagram on Plate 11 it was assumed that each pontoon exerted a net positive buoyancy of 8 tons, this being the calculated preliminary buoyancy when the end compartments were blown down to the ends of the drop pipes, as explained in Part IX, section 2, and as shown on Plate 6.

For the calculation and determination of moments to lift one end of the ship, when the other end has already been brought to the surface, the same figures and the same base line are used, since the weights and moments all act vertically and the answer is the same, regardless of the projected length of the ship on a horizontal base line, so long as the centers of buoyancy of the air spaces remain fixed and the point of attachment and application of the external buoyancy does not shift.

On the *S-4* it was possible to gain more buoyancy in the battery room when the stern was up at about 30° and it was inevitable to lose certain buoyancy in No. 2 main ballast tank since the Kingston valves were at the extreme after end of the tank, in addition to which the free water and bilge water ran forward in each compartment. Hence it was necessary to make separate calculations for the amounts and centers of individual buoyancies, but all the plotting was done on a standard base line.

Part X.—Section 3. Advance Preparations for Raising and for Arrival at Boston.

While salvage was in progress studies were made of the following features to permit the salvage force to take advantage or make use of them:

(*a*) Depths and character of bottom in Provincetown Harbor and vicinity for beaching the *S–4*, if found desirable or necessary, in order to make sure that all buoyancy arrangements, pontoons, chains, etc., were correct and intact before beginning the tow to Boston. The sandy beaches and the considerable rise and fall of tide afforded a good opportunity of depositing the *S–4* in shallow water at high tide, using the 100-ton derrick *United States* to assist in handling pontoons and of making everything safe and secure before leaving shallow water.

(*b*) Depths, currents, distances, etc., from Provincetown to Boston Harbor entrance (North Channel) over the routes by which the tow might proceed.

(*c*) Boston Harbor; depths, tides, currents, buoys, landmarks, etc.

Arrangements were also worked out for—

(*d*) The disposition of vessels and assignment of duties for actual raising of *S–4*.

(*e*) The disposition of *S–4* and of vessels of tow en route to Boston.

(*f*) Keeping channels in Boston Harbor as clear as practicable of shipping during progress of tow, stopping ferryboats temporarily, etc.

(*g*) Boston Harbor and Navy Yard pilots to take the tow through the harbor channels.

(*h*) Necessary yard assistance to berth tow at Boston yard, for reduction of draft of *S–4* after arrival, depth of water over sills and blocks of the dry docks, etc.

(*i*) Press, news-reel, and camera facilities during raising, towing, and arrival of *S–4* at Boston.

(*j*) Disposition of vessels and personnel upon completion of *S–4* salvage.

(*k*) Lifting and disposing of *Falcon's* permanent moorings after *S–4* was raised.

In addition to the above, the navy yard, Boston, prepared and issued certain notices and memoranda to cover the work to be done there upon arrival of the *S–4* and to explain very carefully the procedure to be followed and the duties of all concerned. A considerable amount of time was spent upon the preparation of these papers and the smoothness with which everything was carried along fully justified the work involved.

(*l*) Docking notice for the *S–4*, covering all steps and phases of the procedure to be followed, much more in detail than is customary.

(*m*) Precept for the board of officers which was to make the examination of the *S–4*, including notes prepared and submitted by the salvage force as a result of the work done upon the *S–4* and the conditions found.

(*n*) Commandant's notice SS109/L11–1 of March 5, 1928, to all hands, covering procedure and duties of all concerned in connection with arrival of *S–4* at the Boston yard, and including police and guard duties, arrangements with press and news-reel men, removal and identification of bodies, opening of navy yard to public, etc.

Part XI.—Blowing Procedure. Section 1. Compressed-Air Supply for Raising Operation.

For the final expulsion of water from compartments and tanks on the *S–4*, when blowing would have to be carried on simultaneously for a number of compartments, there were available four sources of supply of salvage air—the three mentioned previously in Part VI, section 7, and the compressed-air supply on the *S–6*.

Of these sources of air supply it was intended to utilize the air supply on the *S–6* first, then the *Falcon* salvage compressors and the *Falcon* diving compressors, keeping the high-pressure air in the *Falcon* air banks as a last reserve.

Accordingly, submarine *S–6* was directed to have all four high-pressure air banks charged to 2,800 pounds per square inch and to run both high-pressure air compressors if necessary, provided, however, that the *S–6* was to retain on board sufficient compressed air to insure that the vessel could be handled in any emergency which might present itself. High-pressure air from the *S–6* was supplied through the external connection on that vessel to a stop valve and a special expansion chamber, both installed on the deck of the submarine where the operator at the stop valve could see signals from the *Falcon*. A 2½-inch connection at the delivery end of the expansion chamber was connected to the 2½-inch fire hose which led through the water, as shown in Figure 100, to the air manifold on the *Falcon*. The arrangement of the gear on the *S–6* and the manifold connection on the *Falcon* are clearly shown on photographs. (Figures 101 and 102, respectively.) During the blowing operation on the *S–6* frost formed on the outside of the small copper high-pressure air pipe visible in the photograph (fig. 101), but there was no appreciable clogging due to ice on the inside.

Actually, on March 17, 1928, blowing was begun on the *S–4* before the *S–6* got into position and air connections were made from that vessel to the *Falcon*. The standard blowing pressure of 100 pounds per square inch at the *S–6* delivery manifold on deck was established at that figure because it was thought that the *Falcon* equipment would not be able to maintain a pressure in the salvage air manifolds in excess of 80 pounds per square inch. When it was found, however, that, for the greater part of the blowing operation, the Westinghouse and diving compressors on the *Falcon* could maintain a pressure in the salvage-air-blowing manifold of about 100 pounds per square inch, it was necessary to signal to the *S–6* and raise the delivery pressure on that vessel to 125 pounds per square inch, in order to establish a flow through the fire hose and to make use of the air in the submarine. The volume of compressed air delivered by the *S–6* to the *Falcon* was equal to about one-third the capacity of the *S–6* air banks.

When the *S–4* had reached the surface and the pontoons and compartments were blown dry the air hose was disconnected from the *S–6* and the Westinghouse salvage compressors were shut down, leaving the two diving compressors to carry 150 pounds pressure on the *Falcon* blowing manifold. These compressors ran on their governors practically continuously from the morning of Saturday, March 17, until the morning of Monday, March 19, and their performance under these conditions left nothing to be desired.

Part XI.—Section 2. S–6 Air Supply; Procedure.

The following instructions were prepared and issued to the *S–6:*

Connect up all air lines and fire hose on *S–6*. *Falcon* will observe when connections are all made.

Blowing station on *Falcon* is at manifold on platform forward of pilot house. Keep continuous watch for signals from *Falcon* blowing station.

Starting signal will be one arm overhead, palm out. *S–6* to answer. For night, one flashlight flashing.

When *Falcon* wants air shut off, signal will be two arms overhead, palms out. *S–6* to answer. For night, stopping signal will be two flashlights flashing, close together.

S–6 to feed air automatically after starting signal is given. If pressure falls below 100 pounds, feed air as rapidly as possible. If pressure rises above 100 pounds, shut off air. (For a period during the blowing operations on the *S–4* the *S–6* was directed by visual signal (semaphore) to raise the blowing pressure to 125 pounds per square inch.) If anything carries away in line, shut off air.

Within five minutes of time *S–6* banks will be blown down to safe limit, *S–6* will blow one short blast on whistle. When *S–6* air is to be shut off, blow two short blasts.

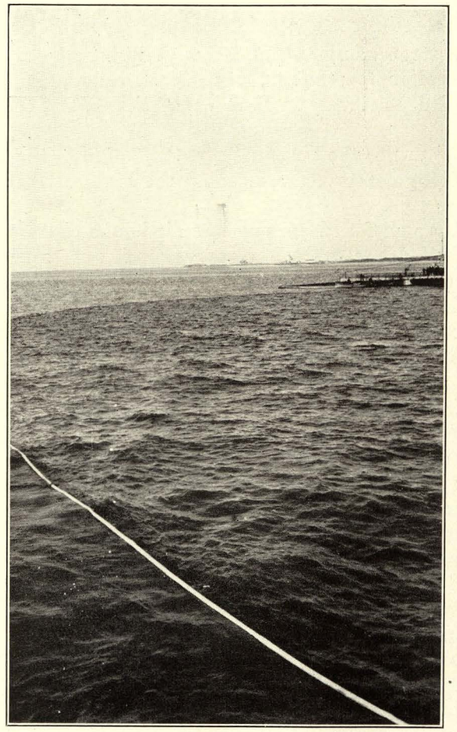

FIG. 100.—Submarine *S–6* supplying air through 2½-inch fire hose during raising of *S–4*

Part XI.—Section 3. Blowing Procedure.

The procedure with regard to blowing and venting of compartments and pontoons at the conclusion of the *S–4* salvage operations was based upon the following premises:

(*a*) External buoyancy in pontoons and internal buoyancy in *S–4* will be more than sufficient to overcome the dead weight of the *S–4*. Furthermore, the moment of buoyancy which can be applied by pontoons and by compartments will be in excess of the moment of weight about any point at which there may be a reaction on the bottom.

(*b*) The procedure will be such as to insure that the stern rises first in order to give the chains of the forward and middle pontoons a much better grip on the hull than would be the case if the bow came up first.

(*c*) Blowing of the normal fuel-oil tanks will not be undertaken except in an emergency, since the removal of this liquid and its substitution by air will only accentuate the upsetting moment caused by the reaction of the pontoon chains on the bottom of the vessel. The behavior of the *S–4* when the middle pair of pontoons were straightened out, as explained later in this report, is a good example of what can be expected of a submarine resting on pontoon chains. Incidentally, this is another reason for attaching pad eyes, if such are to be fitted, on top of the vessel where the pull of the pontoon chains will improve her stability.

(*d*) All compartments will be vented down to 25 pounds per square inch before lifting of the ship is attempted in order to reduce the pressure tending to unseat and blow off the hatches, especially in the torpedo room where the spill pipe is small and the available opening for

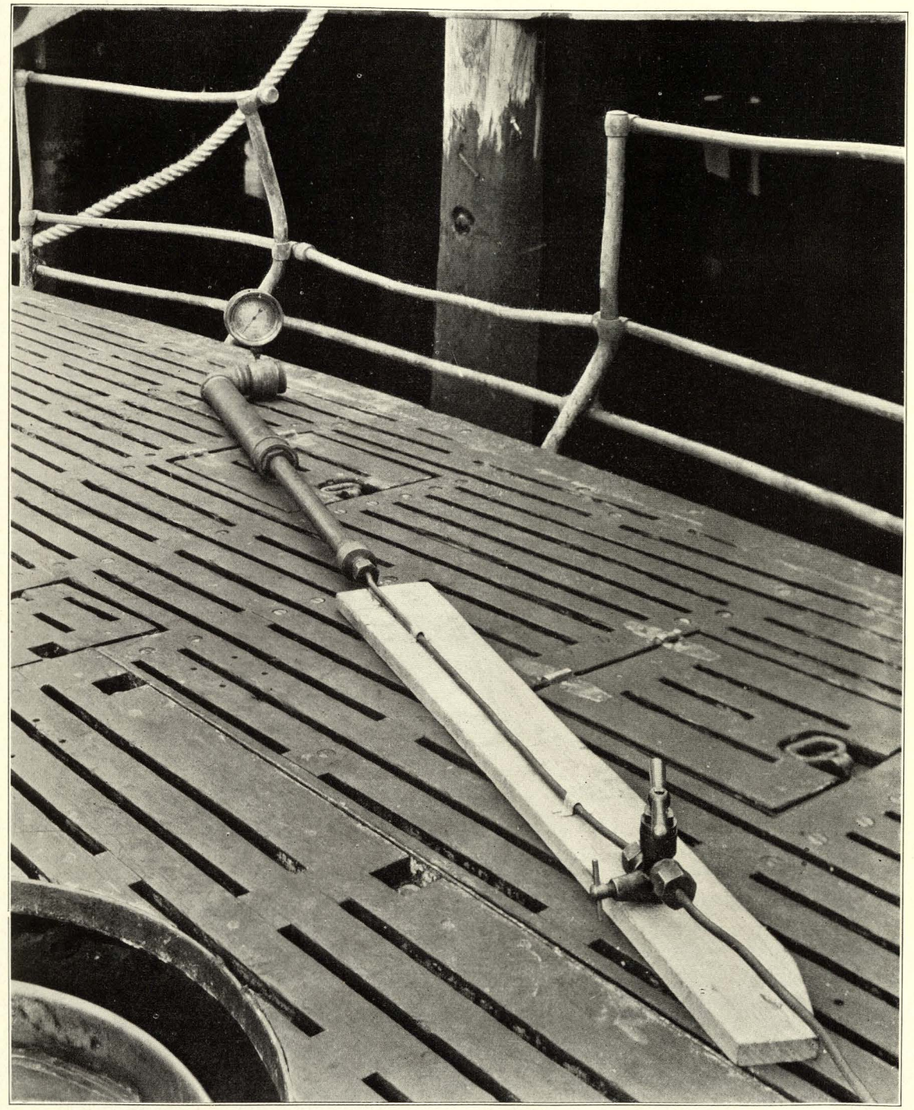

FIG. 101.—Special air fittings installed on *S–6* for supplying salvage air to *Falcon* during raising of *S–4*. Small copper tube with stop valve was connected to external high-pressure air-charging connection; special expansion nozzles were provided in an endeavor to reduce refrigeration and clogging of line with ice. Regular 2½-inch fire hose was connected to fitting near gauge and led to *Falcon*

escape of air is very limited. The compartments would be vented to a pressure less than 25 pounds per square inch were it not for the fact that the 1¼-inch air hose would begin to collapse under the differential pressure applied externally, whereupon venting would be restricted or possibly stopped entirely.

In the preparation of the instructions which were actually used on the day of raising the *S–4* it was planned that—

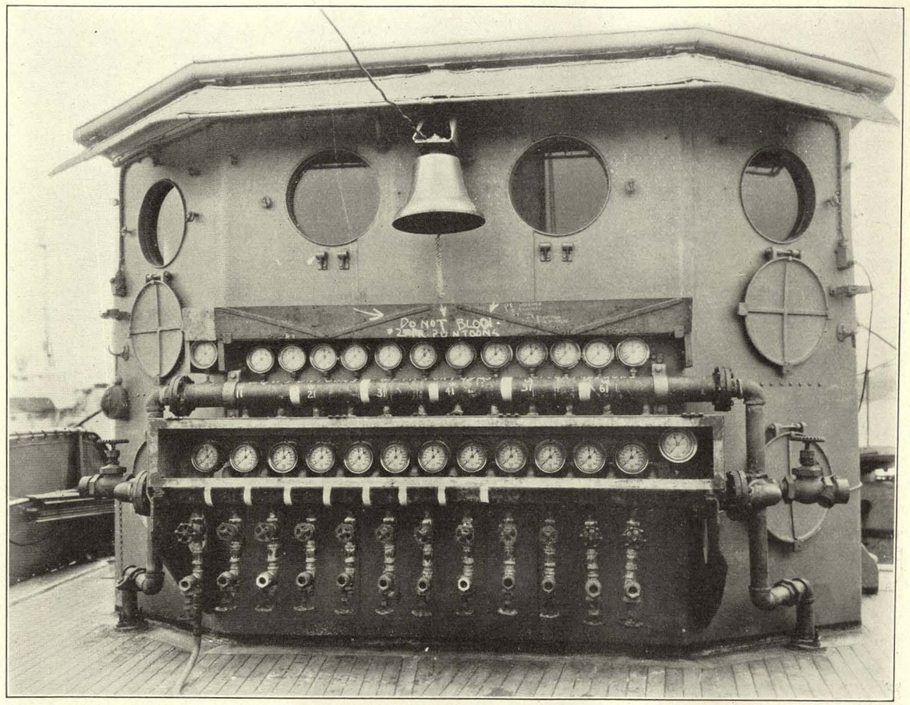

FIG. 102.—Salvage air-blowing manifolds on forward deck house of *Falcon*. Upper manifold was used for pontoons and lower manifold for compartments. Two and one-half inch fire-hose connection for salvage air from *S–6* was made at large valve on extreme left. Note combined vent, blow, and pressure gauge at each connection

(*a*) About twice as long would be required to blow the torpedo room as one of the after compartments. In other words, it would take as long to blow the torpedo room as to blow the motor room and engine room in succession.

(*b*) Differential pressures would be used when blowing the pontoon compartments to insure that equal amounts of air went into all compartments, since the end compartments of all the pontoons were not exactly at the same level, and since the gauges on the *Falcon* were not all exactly in step. The manner of accomplishing this was to mark in chalk on the blowing manifold opposite each valve the actual reading of its corresponding gauge. As each one of the two operators at the manifold had to watch as many as four gauges at once, it was possible in this manner to set the differential blowing pressure at 10 pounds per square inch and keep the

valves so regulated that the pressure on each gauge would be 10 pounds above the chalked figure. The same for 20 pounds differential, and so forth.

(*c*) When the stern rose the white ends of the forward pontoons (the low ends, toward the bow of the submarine) would be blown for several minutes to give greater certainty that the pontoons were pulling hard on their forward chains and to avoid any likelihood of the pontoons rising red end first and perhaps slipping out of place on the vessel.

The table hereunder quotes verbatim the blowing procedure laid out and followed for the *S–4* raising operation.

"*S–4*" SALVAGE—BLOWING PROCEDURE

MARCH 17, 1928.

Check and record all pressures and status of all compartments.

Operation 1. Control room: Build up pressure to 55–56 pounds. Blow at 60 to 61 pounds.
2. Motor room: Begin blowing simultaneously.
Torpedo room: Blow at 60 to 61 pounds.
(Motor room should blow first.)
3. Motor room: When blown, vent to 30 pounds.
Engine room: Begin blowing.
Torpedo room: Continue blowing.
4. Engine room: Nearly blown dry.
M. B. tanks: Blow.
5. Engine room: When blown, vent to 30 pounds.
Control room: When blown, vent to 25 pounds.
Torpedo room: When blown, vent to 25 pounds.
6. After pontoons: Blow white ends and red ends; same differential pressure.
(Stern starts lifting.)
7. Forward and middle pontoons: Blow white ends—3 to 5 minutes at 60 pounds.
Middle pontoons: Blow white ends and red ends—20 to 30 minutes at 60 pounds. If bow lifts, blow forward pontoons immediately.
8. Forward and middle pontoons: Blow white ends and red ends.
Battery room: Blow at full speed.
9. Bow and stern at surface: Close all sluice valves. Open red end flood valves. Check draft of pontoons.

Part XI.—Section 4. Venting of Compartments.

Actually the venting of compartments on the *S–4* was carried down to only about 32 to 35 pounds per square inch, as it was known that the vessel would rise only part way to the surface at the first stage (lifting of the stern), and that considerable venting of the compartments would take place automatically, due to the decreased depth when the vessel lay at an angle with her stern up and her bow on the bottom.

It is probable that automatic venting of the torpedo room and control room was accomplished by slight lifting or unseating of the torpedo-loading hatch and the upper conning-tower hatch, respectively, although if these hatches did lift they returned to normal position and tightness. During the previous operations of blowing down the torpedo room there was evidence that air was finding its way into the port and starboard torpedo tubes and unseating the muzzle doors; hence it may have been that additional automatic venting of the torpedo room was accomplished in this manner.

The center compartments of all pontoons were left filled with air at a pressure of about 45 pounds per square inch when the raising was begun, and no steps were taken to relieve this pressure, as there were then no blowing hoses attached to these compartments, and as it was known that the transverse bulkheads bounding them would safely withstand a pressure of 50 pounds per square inch. When the pontoons came to the surface it was noted that the center

compartment floods and drains blew air for a considerable time, indicating that leakage must have been taking place through the center compartment flood and drain valves.

The air under pressure in the end compartments of the pontoons of course expanded as the pontoons rose to the surface and served to free those compartments of water. As nearly as could be observed, there was sufficient air blown into each pontoon before it rose with the submarine to clear the pontoon entirely of water.

The attempt to vent down the control room by itself was unsuccessful, due to unseating of the bulkead ventilation flapper valve on bulkhead 93, as previously described in Part VIII, section 4. The motor room would not vent down by itself on account of leakage of air from the engine room through the main shaft stuffing boxes.

When it was decided to raise the vessel before the engine room was blown completely dry and the engine room was vented, the pressure in the control room and motor room dropped rapidly when the vents to those compartments were opened.

Short lengths of blowing hose were led from the vents on the *Falcon* blowing manifold to a point over the side, near or just under the surface of the water, for the noise caused when venting from two or three compartments simultaneously was deafening.

Part XI.—Section 5. Recording of Data.

The salvage officer and his technical assistant performed all the blowing operations at the *Falcon* manifold (see fig. 103), while the assistant salvage officer for material stood by for emergency service. Recording of data was performed by Lieut. C. Shugg (CC), of the navy yard, Portsmouth, who later assisted in standing watch at the blowing manifold during the trip back to Boston. The summary of the blowing data, as recorded in the salvage log, is quoted here as being of interest and possible use in future operations of the kind, although the raising operation itself is described in Part XII following. The pressures recorded in the fourth column are those registered on the gauges at the *Falcon* salvage-air manifold. (Fig. 102.)

Time group	Elapsed time	Compartment or room	Pressure	Blowing or venting	Total elapsed time blowing	Total elapsed time venting	Remarks
	m. s.		*Pounds*		*m. s.*	*m. s.*	
1023		Control	48	Blowing			Check blowing of control room.
1026	3 00	do		Stop	3 00		
1028		do		Blowing			
1032		do	51				
1042		do	50				All compressors going.
1100		do	54	Blowing			
1105	37 00	do	56	Stop	40 00		Control room blown 53 pounds.
		Torpedo	65	Blow			Torpedo room initially at 52 pounds.
		Motor	75	do			Motor room initially at 50 pounds.
1112		Control	92	do			Recheck blowing.
1123	11 00	do		Stop	51 00		Bubbling showed control room blown.
1125		Torpedo	70	Blowing			
		Motor	90	do			
1126		Control		Stopped			Bubbling from control room stopped.
1127		do		Vent			
		Torpedo	72	Blowing			
		Motor	100	do			
1132		Torpedo	60				Balanced off.
		Motor	57				Do.
1145							Cut out Falcon's Westinghouse compressors; S-6 air turned on.
1157		Control	47	Venting			
	52 00	Motor	48	Stop	52 00		Blown; started bubbling.
1159		do	48	Vent			
1200		Engine	80	Blow			Initial pressure, 50 pounds.
1201		Motor		Stopped			Stopped bubbling.
		Torpedo	75	Blowing			
		Engine	78	do			
1228		do	88	do			
1230		Torpedo	72	do			
1251	106 00	do	62	Stop	106 00		
		do		Vent			Tried venting to find out how fast it could be done.
1302		do					Bubbles no longer coming from spill-pipe leak.
1303	12 00	do	42	Stop		12 00	
1305		Control	48				Balanced off.
		Motor	35				Do.

Time group	Elapsed time	Compartment or room	Pressure	Blowing or venting	Total elapsed time blowing	Total elapsed time venting	Remarks
	m. s.		*Pounds*		*m. s.*	*m. s.*	
1307		Torpedo	60	Blow			Compartment pressure, 42 pounds.
1310		do					Bubbling at spill pipe again.
1314		Motor	33				Balanced off.
1319		Main ballast	89	Blow			Initial pressure, 48 pounds.
1323		Engine	51				Balanced off.
1327		Main ballast					Bubbles.
1328	9 00	do	49	Stop	9 00		Balanced off.
1330	23 00	Torpedo	60	do	129 00		Balanced off; bubbles forward from torpedo tubes.
		do		Vent			
		Engine	97	Blowing			
1335	96 00	Motor	32	Stop		96 00	
1337		do		Venting			
1342	5 00	do	33	Stop		101 00	Gauge reading not entirely accurate.
1345		Torpedo	41				Balanced off.
1346		Engine	118	Blowing			Compartment pressure, 52 pounds.
1349	142 00	Control	48	Stop		142 00	Air apparently leaking from engine room to control room.
1352		Engine	120				Pressure in engine room, 53 pounds.
1400		Torpedo	33	Vent			Balanced off.
		Control	52				Built up to 52 pounds from engine room, showing leak.
		Motor	45				Also getting air from engine room.
1405	35 00	Torpedo	32	Stop		35 00	Torpedo room sufficiently vented.
1407	127 00	Engine	56½	do	127 00		Engine room considered sufficiently blown.
		do		Vent			
		Control		do			Venting down with engine room.
		Motor		do			Do.
1422	15 00	Control	38	Stop		157 00	Compartment pressure.
1427		Motor	34				Balanced off.
		Engine	39				Do.
1430		Torpedo	32½				Closed. Compartment blown and vented.
		Control	35				Do.
		Engine	38				Balanced off.
		Motor	32				Do.
1435	28 00	do	29	Stop		124 00	Closed. Compartment blown and vented.
	28 00	Engine	36	do		28 00	Do.
		Control	33				Balanced off.
		Torpedo	32				Do.

Time group	Elapsed time	Pontoon hose No.—	Pressure	Blowing or venting	Total elapsed time blowing	Total elapsed time venting	Remarks
	m. s.		*Pounds*		*m. s.*	*m. s.*	
1436		51	63	Blowing			Commenced blowing stern pontoons.
		52	67	do			
		61	60	do			Port pontoon higher than starboard.
		62	63	do			
1441	5 00	51	43	Stop	5 00		Balanced off.
	5 00	52	51	do	5 00		Do.
	5 00	61	40	do	5 00		Do.
	5 00	62	41	do	5 00		Do.
1445		51	(1)	Blowing			
		52	(1)	do			
		61	(1)	do			
		62	(1)	do			
1450	5 00	51	44	Stop	10 00		Do.
	5 00	52	54	do	10 00		Do.
	5 00	61	40	do	10 00		Do.
	5 00	62	42	do	10 00		Do.
1451		51	(2)	Blowing			
		52	(2)	do			
		61	(2)	do			
		62	(2)	do			
1458	7 00	51		Stop	17 00		Stern pontoons at surface.
	7 00	52		do	17 00		
	7 00	61		do	17 00		
	7 00	62		do	17 00		

[1] Base, 60 pounds.

[2] Base, 70 pounds.

STARTING TO RAISE BOW

Time group	Elapsed time	Pontoon hose No.—	Press	Blowing or venting	Total elapsed time blowing	Total elapsed time venting	Remarks
			Pounds		*m. s.*	*m. s.*	
		11	(2)	Blowing			Blowing white (low) ends only.
		21	(2)	do			
		31	(2)	do			
	m. s.	41	(2)	do			
1500							Secured on stern pontoons.
1501½		12		Blowing			Blowing red (high) ends also. Base pressure 70 pounds.
		22		do			
		32		do			
		42		do			
1502				Blow			
1507	9 00	(3) 11	45	Stop	9 00		Originally 43 pounds.
	5 30	12	47	do	5 30		Originally 46 pounds.
	9 00	21	63	do	9 00		Originally 42 pounds.
	5 30	22	69	do	5 30		Port bow pontoon apparently dropped to bottom.
1510	12 00	31	38	do	12 00		Originally 43 pounds.
	8 30	32	31	do	8 30		Originally 41 pounds.
	12 00	41	28	do	12 00		Do.
	8 30	42	33	do	8 30		Originally 44 pounds.
		21		Blow			Endeavoring to raise port forward pontoon.
		22		do			
1513	3 00	21	48	Stop	12 00		Bow pontoons all right.
	3 00	22	46	do	8 30		
1515		11		Blowing			Resume blowing on both forward pontoons.
		12		do			
		21		do			
		22		do			
1516		(4)		Blow			Blowing out water from low end, forward.
1522	6 00	(4)		Stop	133 00		
	20 00			do	20 00		
1523	8 00	(3) 11		do	17 00		S-4 and all pontoons at surface.
	8 00	12		do	13 30		
	8 00	21		do	20 00		
	8 00	22		do	16 30		

[2] Base, 70 pounds. [3] Battery number. [4] Engine.

RÉSUMÉ

Torpedo room: Blowing, 2 hours 9 minutes. Venting, 35 minutes.
Battery room: Blowing, 20 minutes.
Control room: Blowing, 40 minutes. Compartment previously blown down. Venting, 15 minutes, counting from time venting of engine room was begun.
Engine room: Blowing, 2 hours 13 minutes. Venting, 28 minutes.
Motor room: Blowing, 52 minutes. Already partially blown. Venting, 23 minutes, counting from time venting of engine room was begun.
Main ballast tanks:
Blowing, 9 minutes.
Tanks previously blown.
Bow pontoons:
White (low) ends. Port pontoon, 20 minutes; starboard pontoon, 17 minutes.
Red (high) ends. Port pontoon, 16½ minutes; starboard pontoon, 13½ minutes.
Middle pontoons:
White (low) ends. Both pontoons, 12 minutes.
Red (high) ends. Both pontoons, 8½ minutes.
Stern pontoons:
White (low) ends. Both pontoons, 17 minutes.
Red (high) ends. Both pontoons, 17 minutes.

Part XII.—Raising Operation. Instructions for Stations and Duties on Day of Raising of "S–4"

[Quoted from order prepared by commanding officer, *Falcon*, and approved by commander, *S–4*, salvage force. (See Plate 12)]

1. Weather condition must be such as will permit *Falcon* to moor as per plan, at daylight, on the weather side, if any, of the *S–4*.

2. *Iuka* and *Mallard* will anchor near and secure hawsers (manila) to southwest and northwest buoys, respectively, before *Falcon* moors; keeping hawser slack, in order to permit *Falcon* to get moored. When *Falcon* slips her hawsers, *Iuka* tow southwest buoy northward, *Mallard* tow buoy as directed. It will be noted *Mallard* is assigned station depending on tide. (See sketch.)

3. *Falcon* will then moor parallel to keel of *S–4*. Connect up hoses and haul clear, for blowing.

4. *Sagamore* will anchor, drop back, and pick up bow towing bridle and *S–4* towing pendant (*Falcon* surfboat will assist *Sagamore*). Shackle wire to wire buoyed by yellow log and manila hawser to *S–4* towing pendant buoyed by corks. Do not take strain until ordered.

5. *Wandank* will run line and secure to large yellow mooring log, ease in, receive stern towing pendant from *Falcon's* white surfboat. Get wire on board, ready to pass to *Falcon* when *Falcon* warps alongside. When towing pendant is aboard, *do not* take strain until ordered. Drop anchor under foot if necessary. When *Falcon* receives towing pendant, get clear, then put towline to *Sagamore* for towing in tandem. Upon reaching North Channel be prepared to drop back and lash alongside *Sagamore* (starboard side).

6. *S–6* anchor in position as indicated by marker buoy (small yellow can placed by *Falcon*). Connect up air hose (2½-inch fire hose) when delivered by *Falcon's* boat.

7. *Bushnell* send two motor launches to *Falcon*. One to have a chief boatswain's mate in charge of working party of 15 men in larger boat of the two; this boat will first go to *Sagamore* and get fenders for placing between pontoons.

8. *Boats:* Lieutenant Kaplan, in charge of motor launch having the fenders and working party. Badders, Kelley, Wickwire, and Crilley in this boat will board pontoons; lash and secure hose against chafe; place fenders; close valves, etc., if ordered. Badders will provide all necessary tools for this boat. All hose will be lifted up clear of water and stopped to top of pontoons.

Bushnell's second launch, Coxswain Burton in charge, Skumautz in bow, stand by to slip north and northeast moorings.

Falcon's surfboat, Boatswain's Mate Rogers in charge, stand by to slip northwest and southwest moorings. Then run 10-inch manila, starboard quarter *Sagamore* down starboard side *S–4* to *Falcon's* bow.

White surfboat, Chief Boatswain Hawes in charge, stand by to slip south and southeast moorings. Run *Falcon's* port quarter line to *Wandank*, then go to pontoons.

Hose crew connect up ready for blowing, then arrange hoses forward and over bow, when *S–4* is on surface and as *Falcon* drops off.

Chief Gunner Tibbals, all hose to *S–4*.

Chief Gunner Loughman, forward pontoons.

Gunner Church, after pontoons.

BOW PONTOONS

Two men to each pair of hose:

Weaver, Warner, Holden, Witters, Bierer, Smith, McNulty, Mott, Lynch, Clemens, Doherty, Syphax, Bailey, Gairing, Lehr, Parker, Loter, McCone.

HOSE TO COMPARTMENTS OF "S–4"

Two men to each pair of hose:

Badders, Pasternacki, Winters, Schuchman, Engel, Evans, Joy, Johnson, Applegate, Baker, Harris, Stanley, Sherwood, Von der Wall, Wilson, Eiben.

AFTER PONTOONS

Three men to each pair of hose:

Hammett, Bedford, Brown, Anderson, Duckett, Michels, Johnson, Grube, Scott, Burd, Mattox, Kallinoski, Dowberry.

Divers, standing by in dress: Eadie, Carr.

All lines, towing hawsers, and sternfast, Chief Boatswain Burnett, *Falcon's* deck force, and working party from *Bushnell*.

9. When tow is clear of moorings, *Mallard* and *Iuka* recover moorings and deliver them at navy yard, Boston.

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Part XII.—Raising of the "S–4."

Friday night, March 16, saw the last vestige of salvage work on the *S–4* completed. All hands admitted that it was none too soon, for "an atmospheric disturbance of marked intensity" had been hovering around the vicinity of New England for a day or so, without deciding just where and when it was going to manifest itself—and pontooning in the midst of such weather was not to be thought of. Actually it was after 1 a. m., and more nearly 2 a. m., on Saturday before all gear was cleared away, the working parties returned to their ships, and the salvage party turned in, almost all of whom had been working until nearly as late on the preceding night.

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FIG. 103.—Blowing compartments on the *S–4* on the afternoon of Saturday, March 17, 1928, watching pressures as the control room was being vented down after being fully cleared of water

The morning of Saturday, March 17, dawned bright and clear, with warm weather and hardly a breath of wind. Most of the force were rather hesitant about stirring, for it was felt that this was just the lull before the storm. Eight o'clock came and with it a special message from Mr. E. B. Rideout, our forecaster, that good weather could be anticipated for perhaps two days, that the expected disturbance had disappeared for the time being, and that he thought the time propitious for undertaking the final step—the raising of the *S–4*.

The decision to raise was made and confirmed at a conference of all the principal officers concerned at about 8.20 a. m. on the *Bushnell*. The orders were given to take stations for raising in accordance with prearranged plan, and the department was notified of the action being taken.

The *Falcon* was moored over the *S–4* at 9.18 a. m., and by 10.23 a. m. all ships were in position. At 10.30 a. m. all blowing hoses were aboard the *Falcon* and being connected up to the extra lengths which had previously been made up and laid out in front of the blowing manifold. Very fortunately, the blowing was to be accomplished on a falling tide, so that the decrease in bottom pressure due to the tide would assist and there would be the minimum pressure and the least depth of water just before raising.

At 11.04 a. m. air was turned on the motor room and the torpedo room and the real blowing began. Air turned on the control room for a check blow showed the control room blown dry at 11.23 a. m. (See fig. 103.) At 11.57 the motor room was blown dry, whereupon air was turned into the engine room. Air was turned into the main ballast tanks at 1.19 p. m., and

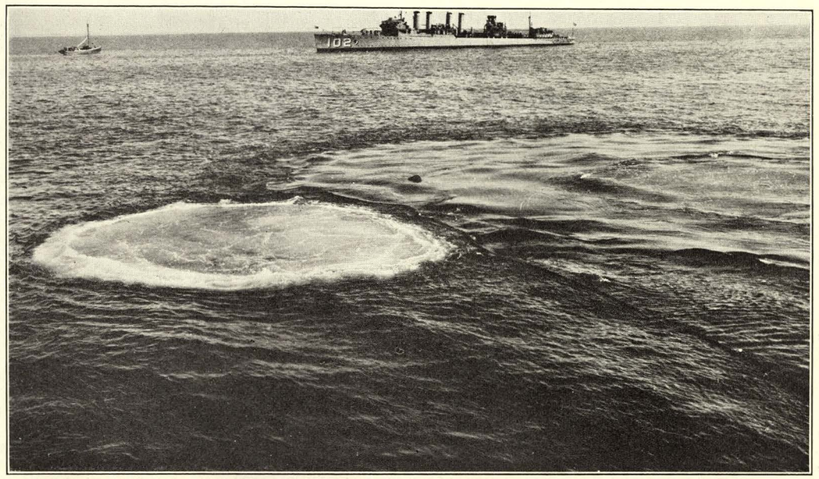

FIG. 104.—Stern pontoons on the *S–4* coming to the surface

the check blowing of these tanks was completed at 1.27 p. m. Details of the blowing, as actually performed, are included under section 5 of Part XI preceding.

As the blowing operations continued so well, there arose a perfectly natural desire to beat the time at which the vessel had sunk. Saturday afternoon, December 17, at 3.37 p. m., the *S–4* had disappeared and it was again a Saturday afternoon, March 17, three months later, that raising operations were in progress. Knowing that there was ample reserve buoyancy available, and that valuable daylight time would be required to blow the engine room down and vent it, the decision was made to blow the engine room for only about two hours and to leave part of the water in it. Similarly, to insure venting of the torpedo room at the same time that the motor and engine rooms were vented, it was decided to blow the torpedo room only about two-thirds dry. Just how much water was left in those two compartments is not known, but it was observed that air escaped from the forward ends of the torpedo tubes. Had the engine and motor rooms been blown completely dry, as they were later on the evening of Sunday, March 18, the *S–4* would have come up with the stern fully buoyant and an excessive trim by the head and she would have been an extremely awkward craft to handle. While it is perhaps too much to say that these operations were done on a pure "hunch," it is true that a sort of inherent engineering instinct, without any outstanding tangible reasons, led the salvage force to carry through the operation in exactly the right manner.

By 2.07 p. m. all compartments had been blown to the desired level and by 2.35 p. m they were all vented. Air was then turned on the stern pair of pontoons at 2.36 p. m. and, after 17 minutes of blowing, with two stops to balance off and check pressures to insure that the pontoons were both in proper position, air appeared. (Fig. 104.) A few seconds later, at 2.58 p. m., they rose to the surface. The port pontoon appeared first, as was expected; as soon as it lost buoyancy, its tension was slacked and with a great jangling and clanking of chains, the starboard pontoon rose alongside it and equalized. (Figs. 105 and 106.)

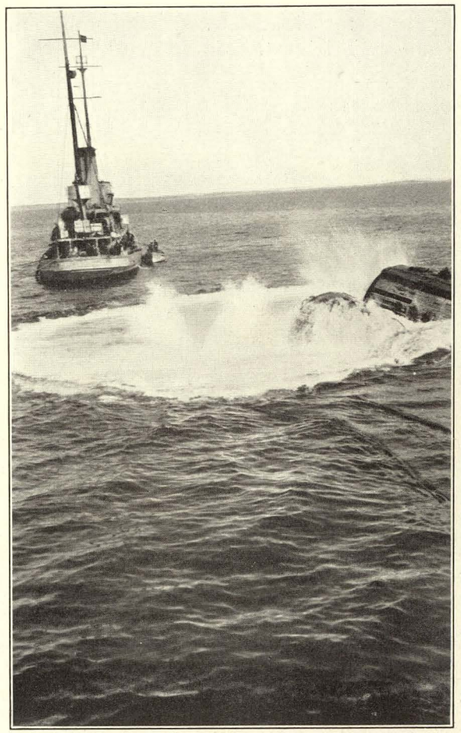

FIG. 105.—Stern pontoons at the surface and equalizing themselves. Tug *Wandank* in the background, holding the stern fast on the *S–4*

Immediately air was turned on the forward and middle pairs of pontoons, with stops at intervals to check pressures and to shift the blowing valves in accordance with the blowing procedure. The port forward pontoon at 3.07 p. m. was carrying much higher pressures than the others and showed signs of being on the bottom, although this seems rather doubtful, as it was in exact position later. At any rate, air was put into that pontoon by itself for three minutes until its pressures balanced off about equal to the pressures in its mate on the starboard side. At 3.15 p. m. blowing was resumed on all forward pontoons and one minute later air was turned on the battery room and engine room, all the loose water in the latter having by then run down to its forward end. At 3.22 p. m. the hoses of the forward pontoons began to come to the surface; it is interesting to note that these hoses gave a much earlier indication of the rising of the ship than the appearance of air bubbles or the dropping of the air pressure on the pontoons and compartments. One minute later, at 3.23 p. m., in the midst of a seething mass of foam (fig. 107), the periscope fairwater of the *S–4* appeared at the surface.

At first, the bridge rail was barely awash (fig. 108), but as the pontoons and the compartments blew themselves dry with the excess air pressure inside, additional water was expelled and the *S–4* rose until about half of the bridge was out. (Fig. 109.)

Part XIII.—Section 1. Preparations and Stations for Towing.

No sooner had the *S–4* reached the surface and the salvage force had a moment to make itself believe that the vessel was raised at last, than the working parties in the motor boats shoved off to arrange and lash the hoses on the pontoons (fig. 110), close the sluice valves and the flood valves (since the pontoons were to be "check blown" through their relief valves), and make the outfit ready for towing, while around and alongside them sailed airplanes manned by photographers and news-reel men. For stations of all ships during towing, see Plate 13.

The *S–6* cast off and at 4.15 p. m. the *Falcon* dropped back alongside the *Wandank* to pick up the sternfast of the *S–4* (fig. 111), while in the meantime the hoses on the superstructure were paid out and laid over the crotch or Y-fitting which had been placed in the *Falcon's* bow.

It was thought best not to begin the trip to Boston with the middle pontoons cockbilled, as shown in Figures 109 and 112, so at the risk of increasing the angle of keel of the *S–4*, which was at that time not more than 5° or 6°, the middle pontoons, which were carrying the greater part of the weight and were holding the *S–4* in position transversely, were adjusted to bring them level. The flood valves of the middle pair were all opened, then the red end of the port

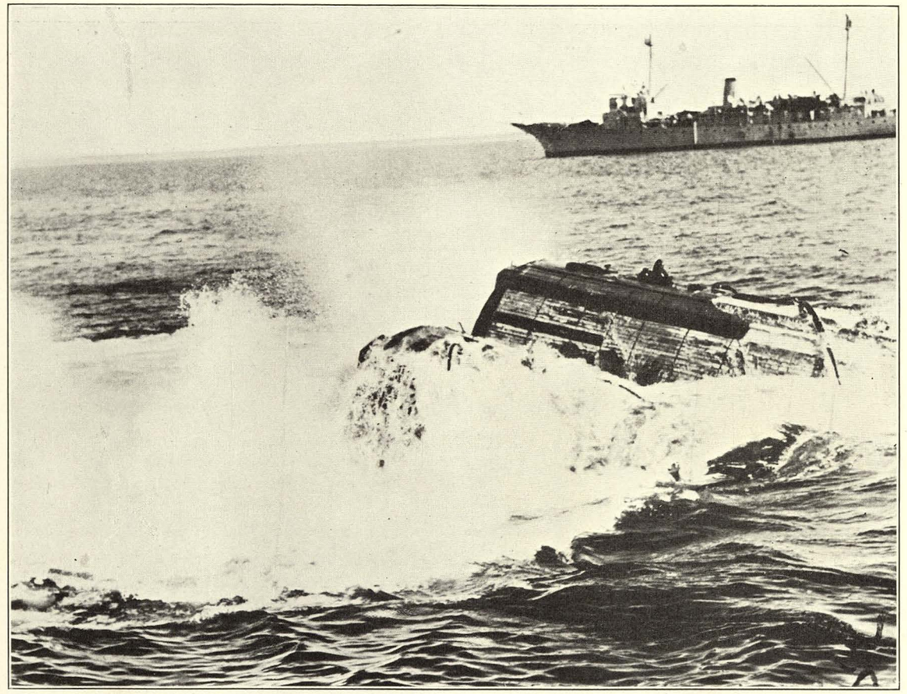

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FIG. 106.—Stern pontoons of the *S–4* breaking surface at 1458, on March 17, 1928

pontoon and the white end of the starboard pontoon were allowed to flood, while the opposite ends were blown. While the salvage officer was in the surfboat examining the position of these pontoons, they straightened themselves with sudden jerks, whereupon the flood valves were closed and secured and the pontoons blown dry. In the process, however, the *S–4* had slipped more to starboard, since there was nothing to hold her temporarily while the middle chains were slack and were reeving around, so that now she had a list of about 8°, with the radio entering insulator and the upper stern light just out of water. These two objects made very convenient draft marks when the vessel was being towed back to Boston.

Part XIII.—Section 2. Trip to Boston.

Everything in the tow appeared to be shipshape, the sun had not yet set and the weather continued excellent, save that high, windy-looking, streaked clouds could be seen here and there. Certainly there appeared to be no reason why the *S–4* needed to be held at Provincetown while the gear was adjusted or secured and there was no apparent reason for starting off in a wide circle, as had been thought of, to insure that the *S–4* and her pontoons would tow properly. The decision was made to proceed immediately to Boston, and at 4.50 p. m. the *Sagamore* started ahead slowly, setting her course to the westward, the salvage officer going out in the *Falcon* surfboat again to travel abreast the tow and observe its behavior. The speed was

International Newsreel Photo.

FIG. 107.—*S–4* breaking surface at 1523 on March 17, 1928

increased slowly to 3 and 4 knots and then up to 5 knots, which in the smooth sea and absence of swell made very good going. At 5 p. m. the *Wandank* took station ahead of the *Sagamore*, with all the vessels in position as shown in Plate 13. This speed, however, would have brought unnecessary loads on the towing and pontoon gear and would have brought the tow to the Boston Harbor entrance while the flood tide was still running. Speed was accordingly reduced to 3.7 knots and later, at 8 p. m., to 3 knots, heading in a general westerly direction for Brant Rock. The *S–4* towed along at a considerable distance off to the left, due to her left rudder, as was anticipated, but otherwise she was quite tractable. The *Bushnell* was navigating and leading, well ahead of the *Wandank*. At 5.18 p. m. Wood End bell buoy was passed and by 6.30

p. m. the tow was out in Massachusetts Bay, moving along through a gentle northeast swell on the starboard quarter, which caused the pontoons to surge slightly and the *S–4* to roll about 1°. At 9.50 p. m. the course was changed to the right, to head up the coast, the tow riding about the same with the ground swell just forward of the starboard beam.

At about 10 p. m. a most disquieting weather forecast was received from Mr. Rideout, to the effect that a northeast blow of considerable intensity was to be expected early in the morning. While the wind remained moderate and the swell had not increased perceptibly, the situation felt ominous, to say the least, and immediate discussions ensued as to the practicability of running through the South Channel to Boston Harbor, to get a lee should the expected blow arrive that soon, or of speeding up to beat the weather in, since the phrase "early morning" was rather indefinite. At 10.35 p. m. speed was again increased to 3.7 knots and messages were sent to Boston requesting the services of expert pilots to assist in getting the tow into harbor. Toward midnight the *S–4* had apparently settled from 4 to 6 inches in the water,

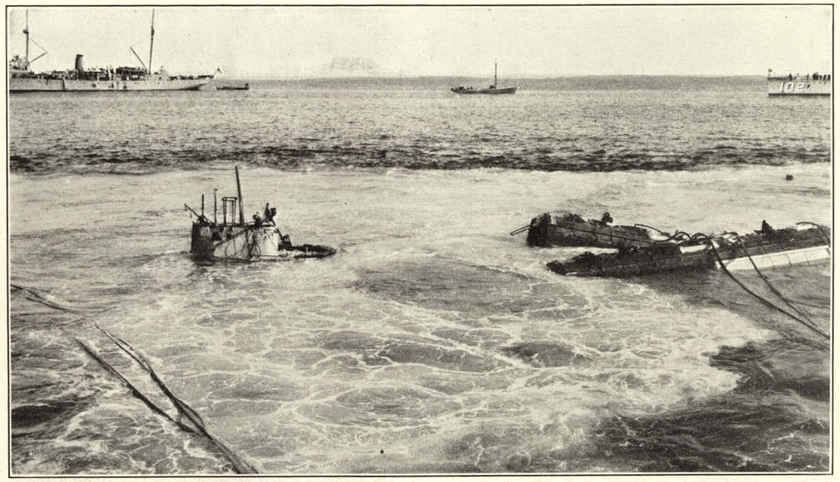


FIG. 108.—General view of *S–4* immediately upon coming to the surface, showing middle pair of pontoons at the right. *Bushnell* in left background and *Mahan* in right background. In center background is the *James M. Burke*, which kept the *Falcon* supplied with fresh fish during the latter part of the winter

but it must be remembered that, in the seven hours previous, not one cubic foot of air had been blown into the ship or into the pontoons, although of course the hoses were all connected and blowing could have been begun at any time. At 11.45 p. m. air was put into all compartments of the *S–4*, but the main ballast tanks were not blown down again, as it was desired to keep the ship somewhat heavy in the hope of steadying her, as by now the swell was steadily picking up and the motion of the ship and pontoons was becoming more pronounced.

By 12.30 a. m. on Sunday, the 18th, the starboard list of the *S–4* had increased to 10° or 12°. Two a. m. was "early morning" that day, for with it came the promised northeast storm. Sea and wind and swell steadily increased, as did the rolling and heaving of the *S–4* and the motion of the pontoons. At 3.30 a. m., the destroyer *Mahan* and the tug *Iuka* were stationed abreast the tow to windward, in the hope of making a lee for the *S–4*, but they were too small to break up the swells and they could not remain close enough to help very much. The pontoons were now beginning to pound each other, especially the bow and stern pairs, and the middle

pontoons whipped back and forth, from port to starboard, like toy balloons with short strings trying to break away in a strong breeze. (Fig. 113.)

No one had ever seen a waterlogged submarine, hanging on pontoons, dragged through such water as was found off Minot's Ledge and no one could say whether the gear would stand up under it or not. However, Boston Light Vessel was finally passed and the tow approached The Graves, with all eyes on the pontoons and the *S–4* plowing along through the rays of the flood lights. No one knew what was going to happen next, with the sea and swell still increasing, the motion of the pontoons becoming more violent and with the middle pontoons known to be

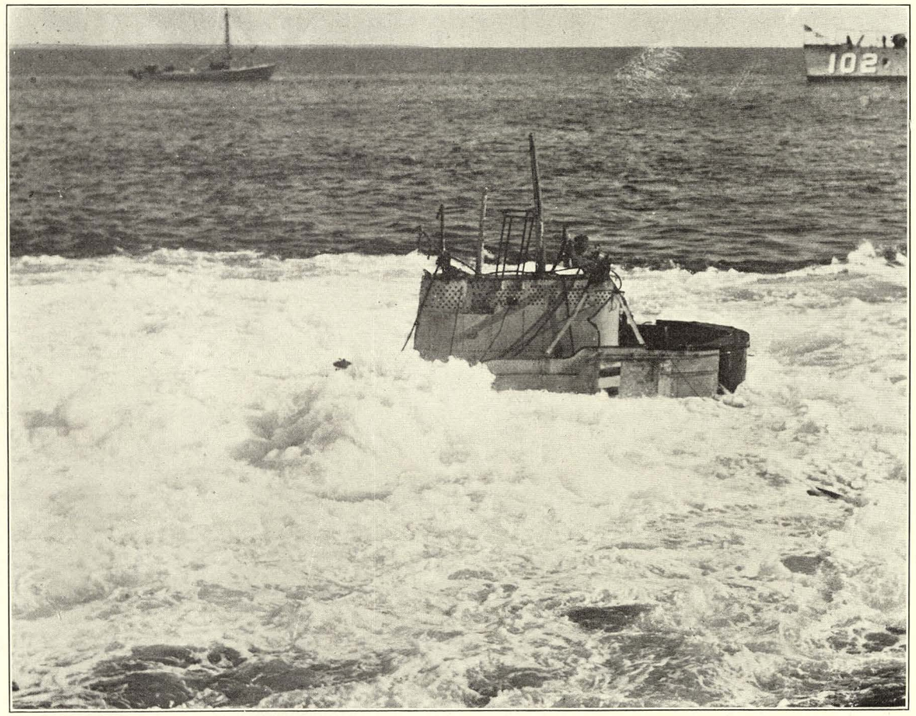
International Newsreel Photo.

FIG. 109.—Position of forward and middle pairs of pontoons just after the *S–4* came to the surface. The middle pontoons were straightened out by blowing on the low ends and flooding on the high ends but when the chains slackened sufficiently to allow the pontoons to equalize themselves, the ship took a greater list to starboard

striking the hull and superstructure of the *S–4* as they swayed back and forth. Yet there was not a physical thing that any one in the force could do about it, save to plug along and hope that the pontoon chains would hold together through it all. At 5.09 a. m. Graves buoy was passed, just as daylight began to appear, then the tow was swung away from the sea and at 5.55 a. m., it entered the North Channel to Boston Harbor.

Any relief which heading away from the sea brought to the minds of those on the *Falcon* was soon displaced by an even greater apprehension for the *S–4*, for in the shallow water of the harbor, the long swells changed to short high seas, which, when taken astern, played with both

pontoons of a pair simultaneously. The after pair of pontoons would drop in a trough until the after chains were entirely slack. Just as the stern of the *S–4* began to settle, the crest of the wave would follow and lift up both pontoons together only to have the pontoons stop with a jerk and the pontoon chains clatter and bang as they came up taut under the stern. Wave followed wave, with increasing severity, as the shallower water was reached, until it seemed that the pontoon chains could no longer withstand the shock and impact and that the next minute would see the *S–4* go to the bottom. The middle pontoons, which were carrying by far the greater



International Newsreel Photo.

FIG. 110.—Lashing and securing pontoons and blowing hoses preparatory to taking the *S–4* in tow

part of the load, would one moment be nearly slack on their chains and the next moment be entirely submerged—truly a most anxious experience for all hands and one that those who lived through it have no desire to repeat.

Had the expedition come along one or two hours later, with the wind and sea picking up all the time as they were, there might have been written an entirely different ending to the *S–4* salvage work.

Those who are interested in this phase of the work will feel indebted to Chief Gunner Tibbals for his photograph (fig. 114), taken early in the morning of Sunday, March 18, the only photograph, so far as known, which was taken while the *S–4* was making her voyage from Cape Cod to President Roads.

Once in the roads, although the swell had not then completely subsided, all thought of danger was past. The *Wandank* dropped back alongside the *Sagamore* and the tow came slowly up the harbor, to the accompaniment of a rising northeast wind, rain, sleet, and snow. Two tugs came alongside the *S–4* pontoons, to handle her (fig. 115) and the *Wandank* finally dropped back clear. At 7.50 a. m. colors were hoisted and half-masted on the *S–4*, and at 8.50 a. m. the vessel was safely alongside Pier 4 at the navy yard, Boston, with the *Falcon* just astern, across the end of the pier, and the blowing hoses still connected up. (Fig. 116.)

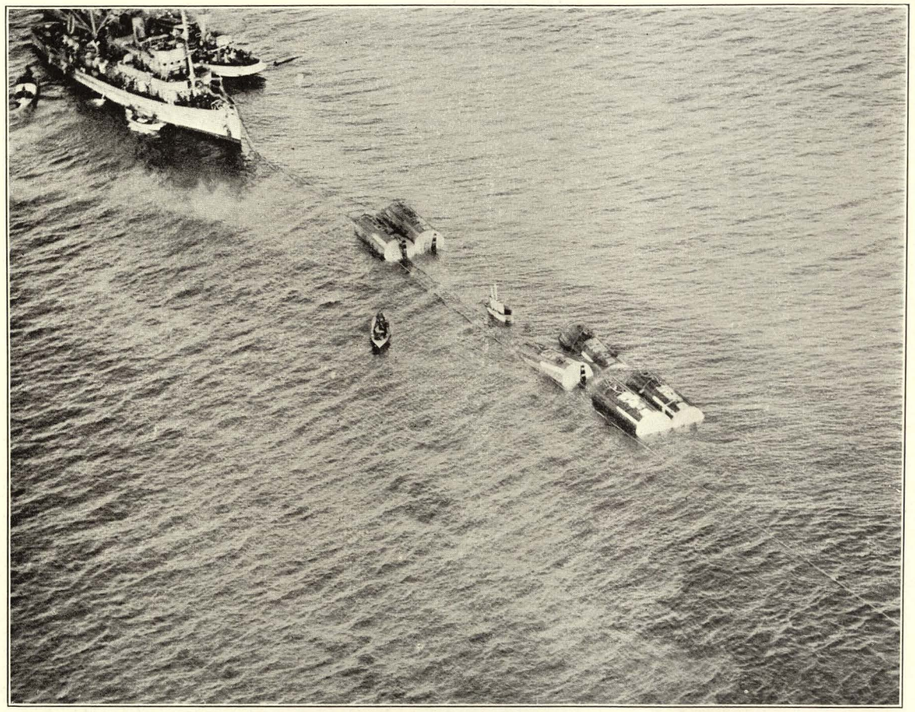


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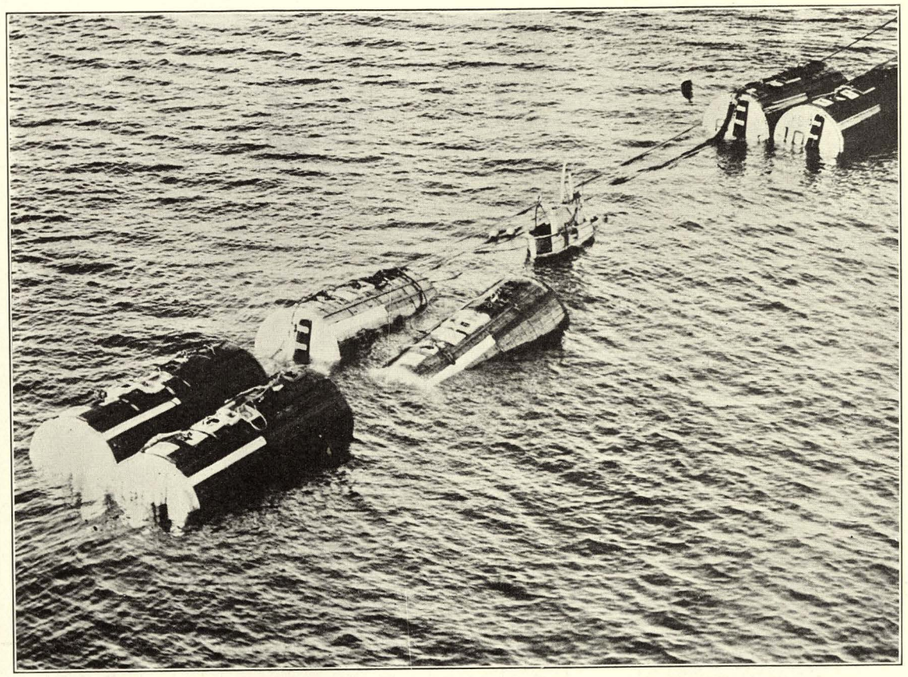
FIG. 111.—*S–4* about ready to be taken in tow, with *Falcon* dropping back alongside *Wandank* to straighten out blowing hoses and to take aboard the sternfast from the *S–4*. Note towing hawser stretched out alongside starboard pontoons

During the morning, the 100-ton floating crane was moved around as shown in Figure 117 to plumb the middle pair of pontoons and after noon began the process of righting the *S–4* and bringing her up a little forward. The two 50-ton crane hooks were first attached by 1½-inch wire straps to the starboard ends of chains Nos. 3 and 4, on top of the starboard middle pontoon (fig. 118), and by taking a load of not more than 45 tons on the crane, it was possible to lift the chains and roll the *S–4* upright with ease. The starboard middle pontoon was then flooded and the toggle bars lowered. After three such hitches, and two hitches on the port middle pontoon to lower the port ends of the chains through the pontoons, the *S–4* rested easily with a list of about 2° to starboard, which was quite satisfactory to the yard. Incidentally, it

was possible to gain an average of two whole links on each of the four chain ends during this righting operation and thus to lift the ship about 1 foot higher in the water. The forward and after pairs of pontoons were not touched.

On Sunday afternoon while this work was in progress, Grube was sent down to replace the torpedo-room blowing connection, as described subsequently in Part XV, section 3. Crilley was sent down to cast adrift the preventer lashing which went aft around the gun mount from the after chains of the middle pontoons. Crilley also made fast to the deck cleats on the *S–4* two pairs of wire pendants for centering tackles, one forward and one aft. In some manner



International Newsreel Photo.

FIG. 112.—*S–4* ready for towing, showing the manner in which the blowing hoses were lashed and led from the pontoons toward the *Falcon*. The pontoon hoses from forward have two spherical buoys attached alongside the bridge; the 10-inch manila towline from the *Sagamore* to the *Falcon* runs outboard and to starboard of the pontoons

the after pair became crossed on the next morning and the heavy hauling which was done upon them bent down the permanent rail abaft the engine room hatch in the manner shown in the various photographs. The centering lines are clearly shown in Figure 122.

During Sunday evening, it was decided to give the vessel one more thorough blowing. Not long after turning on the air, the *S–4* began to rise until finally the motor room hatch was at least 2 feet out of water and the after deck was dry as far forward as the engine-room hatch. The draft forward was about the same as before; the after pontoon chains were of course entirely slack. Water was still coming out of the engine room and motor room spill pipes. The main ballast tanks were vented and water allowed to flood into them to bring the ship back to about zero trim.

Part XIII.—Section 3. Draft Gauges.

To facilitate the reading of drafts when preparing the *S–4* for docking and while docking, two poles or standards were made up, as indicated in Figure 119. These standards were carried out in a skiff after the vessel had been partially righted at Boston on the afternoon of March 18, and were placed on the superstructure deck at frames 71 and 111, where the deck was clear.

The draft diagram shown on Plate 14 was prepared for use in quickly determining the drafts at any point on the keel from the reading of the marks ("B" and "C") on the two poles. Since

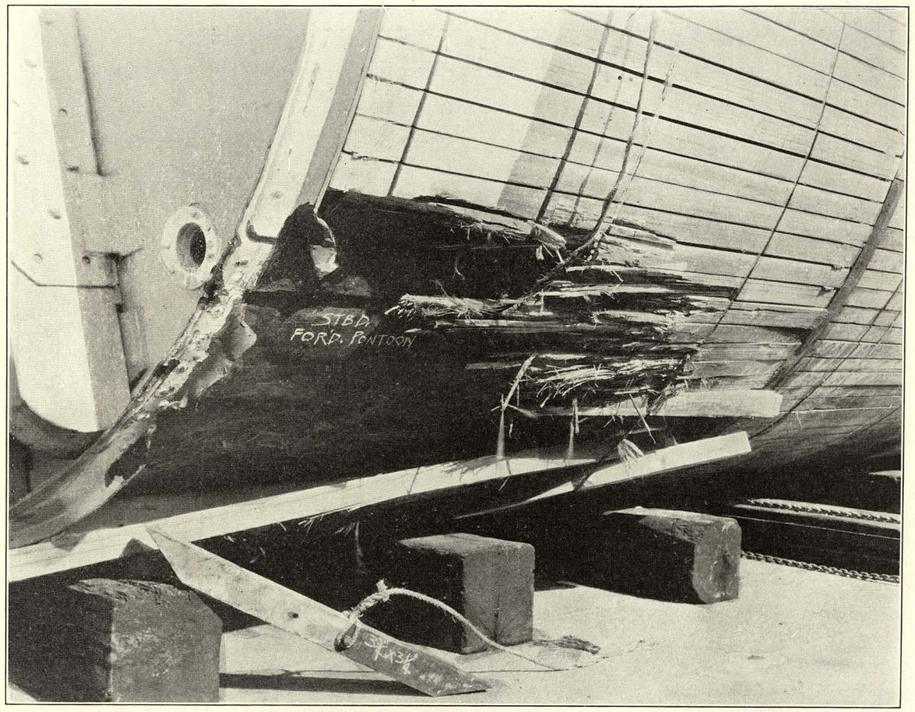


FIG. 113.—Damage to metal work and wood sheathing of forward end of starboard forward pontoon due to pounding against the *S–4* during heavy weather of March 18, 1928. At bottom of photograph is one of the nickel steel toggle bars for the pontoon chains

it was known that this diagram was to be used, the marks on the poles were placed at even feet from their bases. Actually, under the conditions of almost zero trim which were obtained, and considering the fact that the marks on the poles were used and referred to by so many people, it would have been more convenient if they had read directly to 1 foot below the bottom of the keel, allowing 1 foot for the pontoon chains, as previously described.

Figure 120 shows the position of these draft markers with reference to the vessel and the pontoons.

Part XIII.—Section 4. Docking.

Having brought the *S–4* nearly upright and to about zero trim, with a draft somewhat less than that specified by the Boston Navy Yard, docking was comparatively simple and it was accomplished in much the same manner as for any other vessel of her class.

The hauling lines for the use of the dock crew were made fast to the long lowering links on the pontoons, as shown in Figure 121, and the usual head line was employed. After the customary centering and preliminary pumping-down operations, leaving the keel of the *S–4* a foot or more clear of the blocks, two long spur shores were placed to bear against each side of the periscope fairwater, illustrated in Figures 122 and 123.

The dock was pumped down slowly and a yard diver sent down to check the position of the pontoon chains and the blocks, whereupon the ship was moved slightly forward or aft to bring all the chains clear. The after chain of the middle pontoon finally caught over the corner of a block, but the vessel was landed with a slight pressure on the blocks and the starboard spur shore wedged up until the vessel had only a small fraction of a degree list to starboard. Bilge blocks were pulled and as the pumping process continued, yard divers, as shown in Figure 123, went down and set special shores under the bilge keels and the main keel.

Figures 79, 133, and 135 illustrate the manner in which these shores were weighted and the positions in which they were placed.

Once firmly held on the blocks by the spur shores and bilge blocks, the pontoons were unshackled as soon as their chains went slack and they were hauled ahead, clear of the *S–4*.

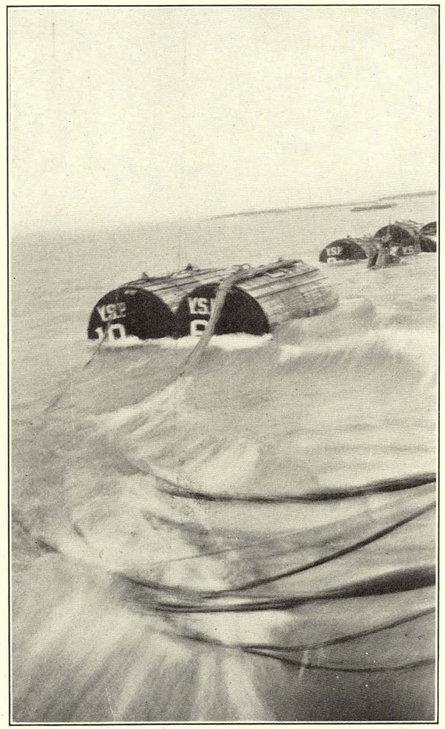


FIG. 114.—*S–4* entering Boston Harbor on morning of March 18, 1928. Note position of blowing hoses and station of *Falcon* on starboard quarter of *S–4*

Part XIV.—General Phases.

Position of "S–4."—The position of the vessel on the bottom was rather advantageous as to the accomplishment of salvage operations, lying, as she did, nearly upright and nearly level. The list at first reported as 3° or 4° to starboard was later checked and found to be about 2° to port. Whether the vessel changed position when the engine, motor, and torpedo rooms were flooded or whether the first estimates were not accurate, could not be determined. The *S–4* rested somewhat down by the head, between 2½° and 3°, lying apparently on a gently sloping bottom. (See Plate 4.) In any event, the heel and trim of the *S–4* were both so slight as to cause little comment on the part of the divers and very little inconvenience to their work. The heading of the vessel, as well as could be determined, was between 235° and 240°.

As was the case with the *S–51*, the hull was absolutely clean when the vessel was raised and the fittings in a remarkable state of preservation, the bright work on the gun, for instance, being just as shiny as it was the day the vessel sank. The sea water appeared to have a caustic effect, for even the bronze fittings on the ends of the air blowing hoses appeared perceptibly cleaner and brighter after a few days in the water. The only corrosion of ferrous metals anywhere in evidence was on bits of welding here and there and on small pipe hangers.

International Newsreel Photo.

FIG. 115.—*S–4* as viewed from bow of *Falcon* upon arrival at navy yard, Boston, March 18, 1928, during storm of snow and sleet. The manner of leading and lashing compartment and pontoon blowing hoses is clearly shown

The following is quoted from paragraph 15 of the general operations report on *S–4* salvage submitted by Captain King:

Health, etc., of personnel.—The health and physical condition of the personnel was unbelievably good. This is thought to have been due to care exercised, to full supply of adequate heavy clothing, to ample and well-cooked food, and to continuing hard work in the open air.

The *S–4* salvage operations were greatly simplified and expedited by having available the material used in the salvage of the *S–51* and a large part of the personnel engaged in the latter job, all of whom could be looked upon as experienced members of the crew.

The entire *S–4* salvage operations were characterized by a remarkable freedom from accidents, casualties, and untoward happenings which all too frequently accompany unusual and hazardous work of this character. The utmost spirit of cooperation was manifested by every one engaged in the work and there were no dissensions or mental disturbances to look back upon with regret.

Although the work appeared to be retarded at times and events did not occur with a rapidity commensurate with the plans or the expectations of the force, it was possible every day to report some progress, however small, and the days when milestones were passed came with sufficient frequency to maintain the general enthusiasm at a high level.

FIG. 116.—Bow of *Falcon*, showing manner of carrying blowing hoses over forecastle and through a crotch at the stem, thence along on surface of the water to the submarine in tow

The salvage work was undertaken and carried through with great fidelity to the plans and work schedules and the operations worked out remarkably true to schedule.

Part XV.—Section 1. Post-Docking Examination. Blowing Hoses.

All were found in good condition except as follows:

No. 1 hose to torpedo room was cut almost in two by red end of starboard middle pontoon, YSP–7, at some time during trip to Boston.

No. 3 blowing hose to engine room (¾-inch connection) had a loose nipple just above valve on engine-room salvage hatch.

No. 4 blowing hose to motor (¾-inch connection) had a loose nipple just above valve on motor-room salvage hatch.

No. 5 blowing hose to main ballast tanks (¾-inch connection), slightly loose connection where screwed to external high-pressure charging connection.

No. 6 blowing hose to fuel-oil tanks (½-inch connection), nipple loose where screwed into salvage hatch. (See figs. 62 and 125.)

No. 7 blowing hose to battery room (½-inch connection) was pulled adrift. The after nipple was pulled out of the union connecting the hose to the small brass pipe leading into the battery room through the cut. (See fig. 126.) This was apparently done by the red end of the starboard middle pontoon during the trip to Boston.

Lashings on all blowing hoses were in fair condition, but in almost every case there was only one turn of lashing line around the part of the vessel to which the hose was secured, whereas

FIG. 117.—Righting the *S-4* on March 18, 1923, at the navy yard, Boston, prior to entering dry dock, by shortening down on starboard chains and slacking away on port chains of middle pontoons

there were several turns around the hose itself. (See fig. 62, upper right-hand corner.) Lashings should have been made up with several turns around both and at least one turn around the lashing, taking this latter turn parallel to the hose, as shown at the left of Figure 63.

Part XV.—Section 2. Salvage Hatches and Spill Pipes.

Torpedo-room spill pipe.—Quite a leak in starboard forward flange-securing bolt where a double hole was drilled. Spill pipe was otherwise all right except that when the flood valve was opened, either at Provincetown or at the Boston yard, a loose end of a rope lashing found

its way back into the valve. None too much landing on the gasket, as shown by the photograph. (Fig. 52.) Strainer was clean and clear.

Control room.—Trim pump discharge satisfactory. Strainer clean.

Engine room.—Satisfactory, except for deformation of lead gaskets under the securing nuts of this hatch and of motor-room hatch as shown in Figure 127.

Motor room.—Spill-pipe strainer partly clogged with rags or foreign matter. Some foreign matter also on engine-room strainer. Value of double strainers fully confirmed.

Part XV.—Section 3. Unwatering of Compartments.

Torpedo room.—When the *S-4* was brought alongside Pier 4 at the Boston Navy Yard on March 18 and all compartments and pontoons were given a careful blow, one by one, it was dis-

FIG. 118.—Holding a strain on the starboard ends of Nos. 3 and 4 pontoon chains while flooding down the starboard middle pontoon

covered that the torpedo-room hose was cut on the starboard side near the breech of the gun. Since air was at that time escaping from over the torpedo-room hatch, some derangement of the blowing arrangements there was suspected. Grube was sent down to the torpedo hatch, using a small diver's stage slung from a locomotive crane on the dock. He discovered the torpedo-room blowing fittings broken off at the hatch casting; a galvanized-iron street elbow that had been screwed into the steel casting had been broken short off by one of the pontoons. He succeeded in unscrewing the remaining piece of nipple and then inserted a new set of fittings, with a new blowing hose attached. Figure 50 shows these fittings.

Upon examination of the torpedo room it was discovered that the spill-pipe strainer rested directly on the torpedo-room flat, lying between two of the bodies. There was not more than 3 inches of water left on the deck.

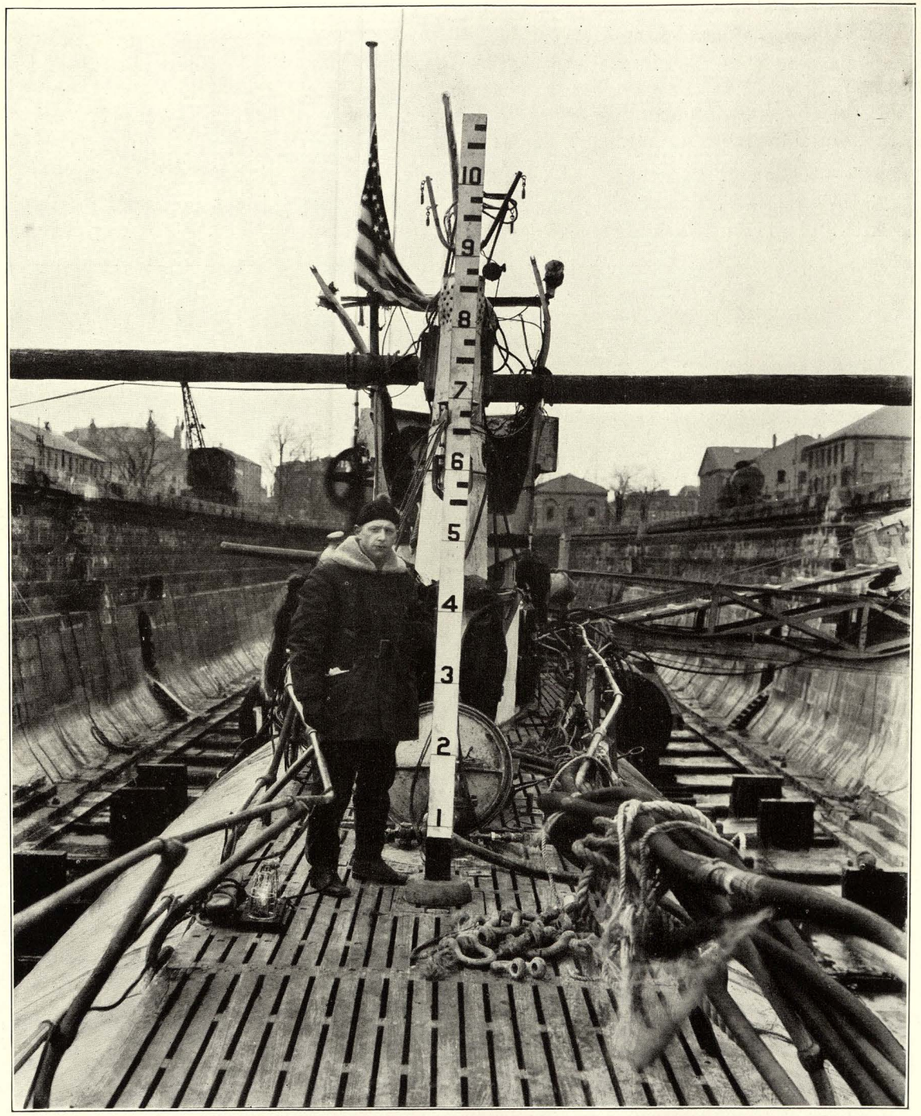


FIG. 119.—Supervising Draftsman Niedermair of the navy yard, New York, with temporary draft gauge devised for use during docking of *S-4*. The lead weight at the bottom rests on the superstructure deck and holds the gauge in position

Battery room.—Although the end of the blowpipe that Crilley rammed into the cut did not actually enter the battery room proper, the air was discharged under the *Paulding* wreckage, whence it traveled along into the compartment. (See fig. 128.) There was nothing to indicate the degree to which this compartment had been unwatered. The No. 7 blowing hose connecting to this small pipe was pulled out at the union, doubtless at some time during the trip to Boston.

Control room.—The spill-pipe strainer had been worked down into the magazine between the cartridge tanks until not more than 6 inches of water was left in the magazine. There was

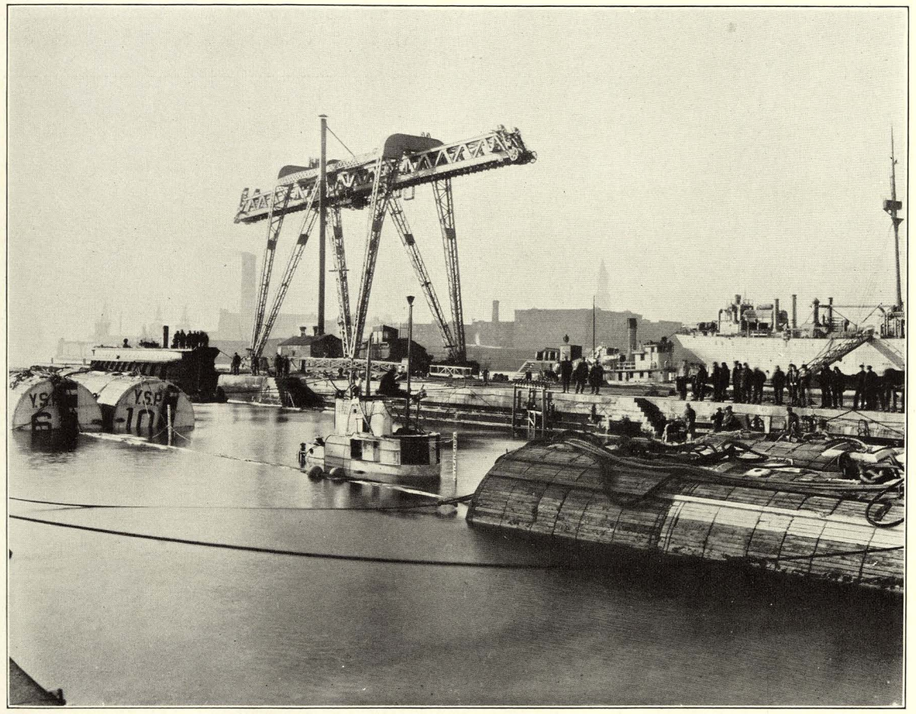


FIG. 120.—*S-4* with about 2¼° list to starboard, entering dry dock. Note temporary draft gauges and buoyed blowing hoses

about 8 inches of water in the forward bilge which could not run into the magazine, as shown in Figure 56.

Engine room.—Only a few inches of water and oil were left—not more than is usually found there.

Motor room.—The water level was well down below the level of the shafts, and all the buoyancy expected from this compartment was no doubt realized.

Tiller room.—The tiller room had apparently drained when the stern came up, for only a few inches of water were found there.

Main ballast tanks.—A careful spotting of bubbles when "blowing through" these tanks after arrival at Boston indicated that all the air escaping was from the kingstons. There is every reason to believe that Nos. 2 and 3 main ballast tanks and the safety tank were blown dry, as intended.

Part XV.—Section 4. Closing and Securing of Hatches, Doors, and Valves.

Torpedo-room hatch (see fig. 50).—Eadie and Carr had great difficulty in setting up the securing bolts on the strongback. These bolts had been made with loose eyes just under the strongback, because the securing bolts had to lie at a small angle to the plane through the center of the strongback. The bolts had been cut to length by trial on the *S–6*. The divers could

FIG. 121.—*S–4* entering Dry Dock No. 2 at navy yard, Boston, at 0706 on March 19, 1928. Blowing hoses to compartments and pontoons still connected to *Falcon* at left

not keep the securing bolts from twisting when setting up the nuts, so the eye connections each had a half turn in it. Just how much additional force was applied by the strongback to hold the hatch closed is not known, but at any rate the hatch remained seated and in position.

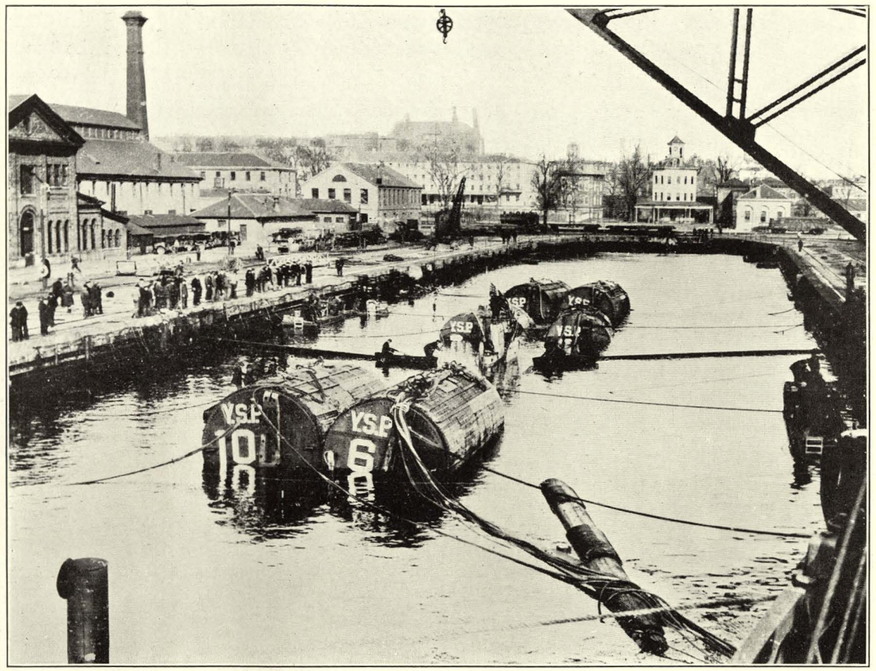
Conning-tower upper hatch.—The starboard after end of the bin for holding the pig lead had come adrift and the pigs had partly fallen out of the bin, as shown in Figure 55, but the only leak in the hatch was small and was on the port side, where the lead was in position.

Engine and motor room salvage hatches were perfectly placed and completely secure. (Figs. 62 and 63.)

Doors.—Water-tight door in the forward bulkhead of the control room was secure except for the port upper dog, as shown in Figure 54, which became caught behind the lever for the forward ventilation flapper valve and could not be engaged without undoing many hours' work.

All temporary wedges inserted by Wilson on water-tight door between engine room and control room were in place and all dogs were secure.

The four corner dogs on the door between motor room and engine room were not engaged. The dogs on all these doors must be set in the proper order or they will become foul of each other.



International Newsreel Photo

FIG. 122.—*S–4* in dry dock and being centered by the wire lines which lead downward through the water. Spur shores being placed; the inboard ends of these shores rested against a square block on each side of the periscope fairwater and held the vessel upright

Doing this from the side of the bulkhead opposite the door where the wedges can not be felt, and under the poor conditions of visibility in the after end of the engine room, is almost too much to expect of a diver, for it is not an easy operation under the best of circumstances.

The double wedge under the butterfly clamping nut on the lever of the forward ventilation flapper valve at bulkhead 72 did not set the clamp up tight, but the valve was held closed, and with excess pressure in the control room it was unquestionably tight.

The flapper valve on the engine-room side of bulkhead 92 was found open and loose on its stem. This must have been caused at some time during the latter part of the salvage operations or during the raising operation by excess pressure on the engine-room side, blowing toward the control room. This valve was clamped closed by Wilson on February 1.

Part XV.—Section 5. Burning and Cutting Performed by Divers.

The photographs illustrate the burning and cutting performed by Kelley (fig. 34), Carr (figs. 36, 67, 68, and 72), Eadie (figs. 39 and 72), Eiben (fig. 66), Crilley (fig. 66), Wickwire (figs. 67 and 73), and others. They gave a much better idea of the work than can any description.

The work of the arc torch, as shown by the plate (fig. 129) and the pipe (fig. 39), is somewhat ragged but perfectly effective and quite satisfactory for all practical purposes.

The multitude of holes burned through the outer hulls by divers working in the tunnels is, of course, the result of total lack of visibility and the difficulty of ascertaining by feel the status

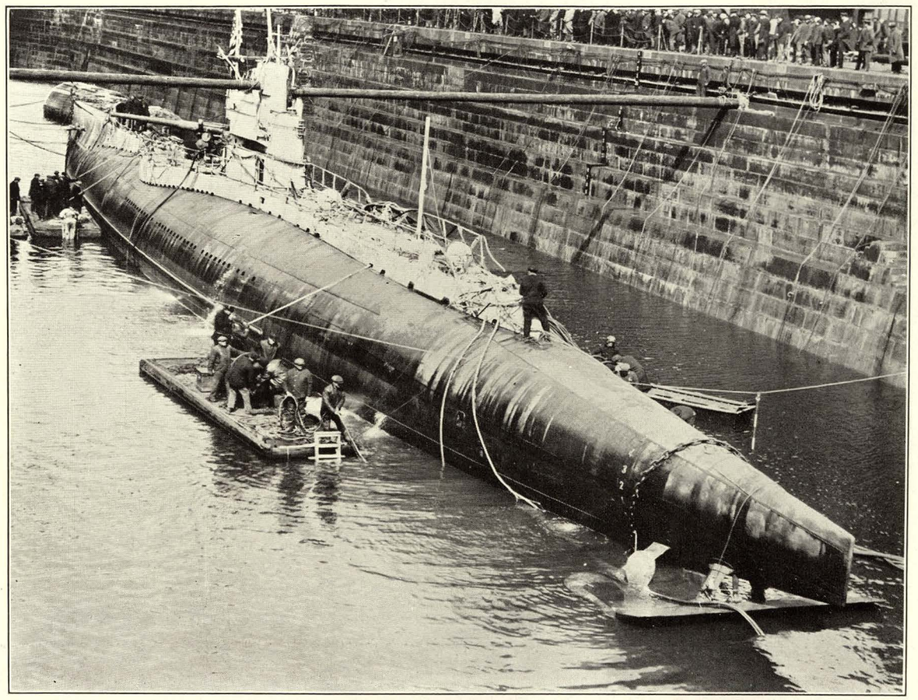


FIG. 123.—Divers placing the last of the special shores under the vessel. Residual water is being blown from the engine and motor rooms and is flowing over the port side of the vessel opposite the salvage hatches. Note the position of spur shores. The *S–4* rested in the mud up to about the level of the water in this photograph

of the work performed. It is almost inconceivable that Carr did not know that he burned several holes at frame 37½ (fig. 68) or that for 20 minutes he could not find any of the holes burned by Wickwire in way of the mushroom anchor recess, as shown in Figure 73.

Part XV.—Section 6. Underwater Examinations by Divers.

A check-up on the *S–4* during the postdocking period indicated that the features, conditions, damage, etc., as reported by the divers was remarkably correct, considering the poor visibility and the extremely disadvantageous conditions throughout.

It should be remembered, however, that in only exceptional cases were the conditions recorded as a result of one examination by a single diver. It was the practice, and it should be

International Newsreel Photo.

FIG. 124.—The *S–4* in dry dock and the duty of the *S–4* salvage force completed. Left to right: Commander H. E. Saunders (CC), salvage officer; Capt. E. J. King, commander, *S–4* salvage force; and Lieut. H. Hartley, commanding U. S. S. *Falcon*

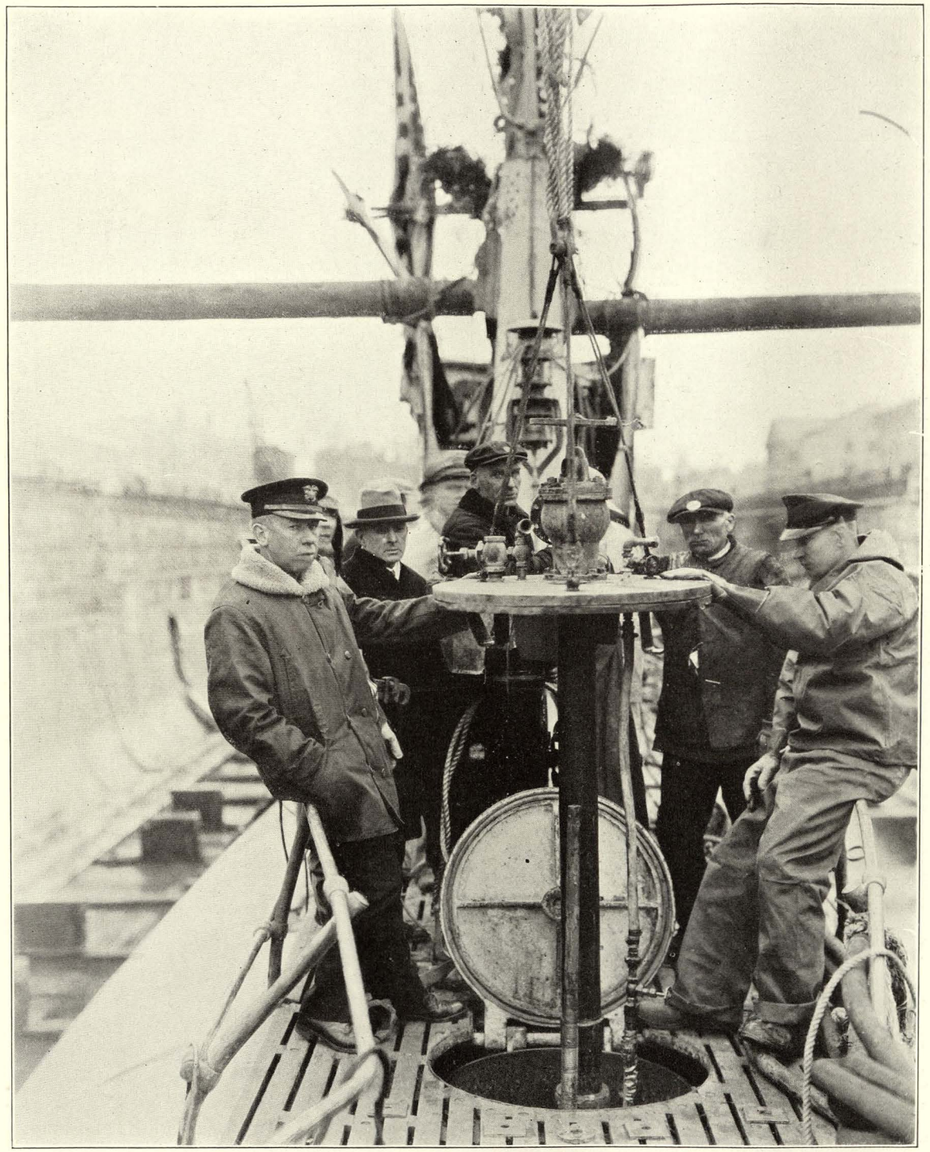


FIG. 125.—Engine-room salvage hatch and spill pipe being removed from *S–4*. Note the ½-inch blow connection on the right of the hatch which extends through it and to the normal fuel-oil tank below connection in the engine room. The kingpin of this hatch remains in position, held by the main and auxiliary strongbacks

the practice always in a job of this character, to take around the booklet of general plans and a pencil, to mark up what is told by the divers (or to let them mark it themselves); then to repeat the process every time another diver comes up with corresponding information. This information should be obtained "hot off the griddle" by going into the decompression chamber with the divers and talking to them there; then confirming it by conversation with them later on during the day.

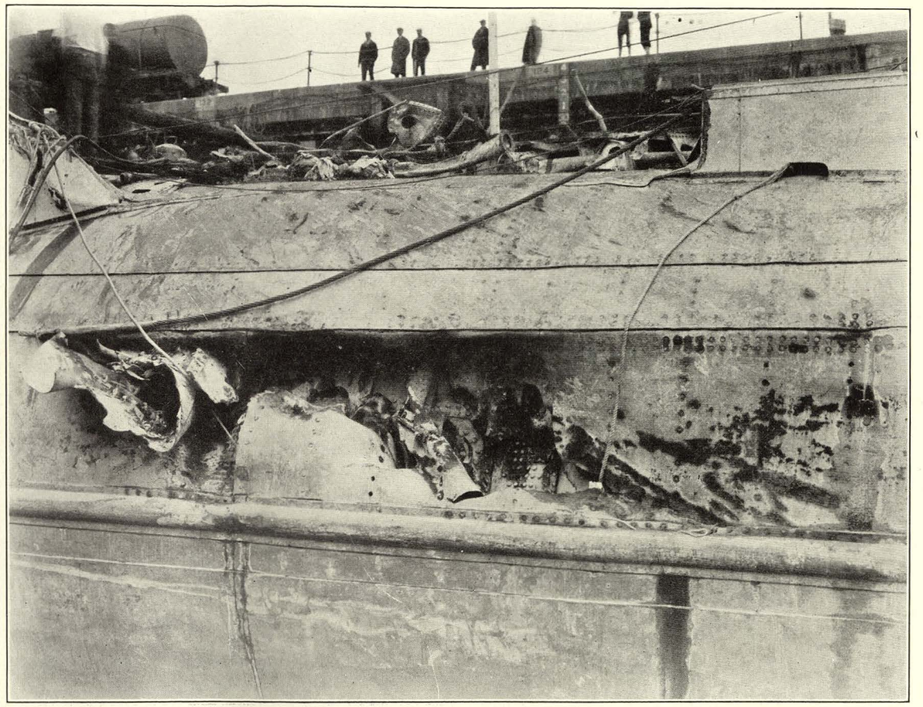


FIG. 126.—*S–4*, starboard side forward, in way of damage. Blowing pipe into hole in battery room extends from upper left-hand corner of photograph downward to right and enters beneath piece of wreckage from *Paulding*. Two disconnected sections of 6-inch outboard ventilation line shown on top of hull. Bow of *Paulding* struck first at forward end of damaged portion, denting in the inner hull of *S–4* and crumpling up a portion of the *Paulding's* bow which tore off and fell alongside *S–4*, as shown in Figure 48. What remained of the *Paulding's* forefoot finally pierced the inner hull and tore off as shown

Outstanding examples of the excellent and accurate information obtained are the control-room instrument readings by Eadie, the condition of the ventilation valve at bulkhead 72 by Eiben, and the description of the collision damage by Ellsberg and Crilley.

Part XV.—Section 7. Fuel-Oil Tanks and Piping Arrangements for Blowing.

Naturally, there was great curiosity among members of the force to ascertain why it was that the normal fuel-oil tanks forward could not be blown. This portion of the postdocking examination was conducted by Lieutenant Wakefield and the ship's force of the *S–6*, who had been of great assistance in performing the work on the *S–4*.

It was found, first, that the blowing connection from No. 6 hose through the engine-room salvage hatch picked up the correct blow line under the platform forward (see fig. 67), and that

the salvage blowing connection was properly made. Second, that there were no extra valves in the fuel-oil transfer line going forward to No. 6 tank, but that the valve in the compensating line in the torpedo room had been left closed by the *S–4* ship's force. Third, that the valves in the port forward bilge of the engine room were properly set.

When the holes burned at frame 37½ under No. 2 tank were temporarily closed the valve in the torpedo room opened and air turned into No. 6 hose, fuel oil was discharged from the

FIG. 127.—Lead washers used under securing nuts of engine and motor room salvage hatches. These washers should be covered with a thin steel washer on subsequent work

deck filling connection to a tank car, just as the salvage force hoped to do it had the valve in the torpedo room been open when the *S–4* sank.

Why the fuel oil in the forward tanks could not be blown out by turning air into No. 6 hose after the hole had been burned in the bottom of No. 2 tank was a mystery and the *S–6* crew were unable to solve it.

Part XV.—Section 8. General.

There was considerable damage to rails, deck planking, deck beams, and superstructure just abaft torpedo hatch and just forward of gun due to banging of pontoons during trip to Boston. All structure showed signs of severe chafing and rubbing. (See figs. 2, 70, and 130.)

The 1½-inch wire towing pendant was severely chafed at frame 38 by forward end of starboard middle pontoon. A considerable number of wires were broken, as shown in Figure 131. The vertical stem of the SC tube was bent over by the pontoons. (Fig. 132.)

FIG. 128.—General view looking forward and outboard on starboard side of battery room, showing portion of bow of the *Paulding* projecting into the compartment, also the size and extent of hole in inner hull and manner in which lockers were carried away due to rush of water. Blowing pipe into battery room was inserted under wreckage and extended to a point about opposite inner hull; bubbles of air slid along under wreckage and found their way into battery room without leaking into main ballast tank

The mud line was very clearly evident, as an examination of Figures 133 and 134 will reveal including even the outline of the tunnel dug at frame 39 during the rescue operations. Figure 135 will be found self-explanatory, as will Figure 136.

The torpedo room of the *S–4* was opened shortly after the completion of the docking operation on March 19, by burning out a hole some 10 inches in diameter in the center of the cover and releasing the strongback. The paint on the underside of this cover caught fire during this operation and the compartment was so full of smoke when the hatch was opened that it could not be entered for some minutes. This is an indication of what might occur should it become necessary to burn a hole in the vessel during rescue operations.

The regular examination of the interior of the vessel was conducted by a board of officers appointed for the purpose, assisted by some of the *S–4* divers (fig. 137), who performed all the necessary manual labor inside, such as opening doors, pumping out, clearing away wreckage, etc.

In this connection it is of interest to note that by previous arrangement with the Boston Navy Yard authorities it was possible for the salvage officer to enter the vessel first (and each compartment likewise) and check up on the work performed by the divers as the detailed examination of the vessel proceeded. This technical examination was preceded by the preparation of a fairly complete memorandum covering points to be observed and it was followed by the taking of official photographs, some of which are shown in Figures 138, 139, and 140, and the remainder of which are included elsewhere in this report.

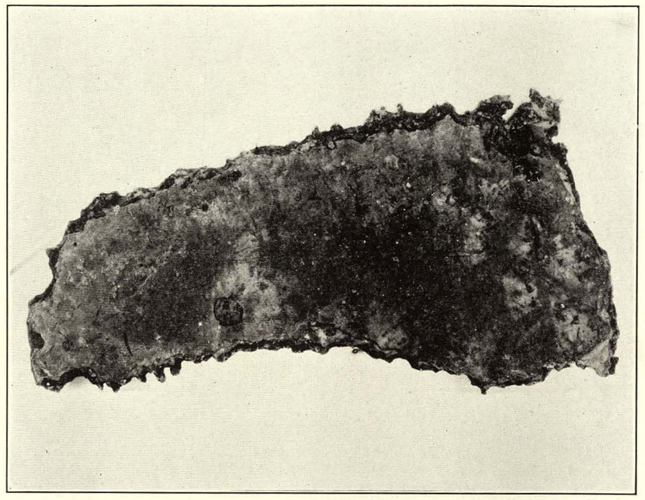


FIG. 129.—Section of ¼-inch outer hull plating cut out by Carr with arc torch in way of No. 2 port main ballast vent valve. The hole from which this plate was cut is shown in the outer hull (fig. 66)

Photographs (figs. 138, 139, and 140) will be found self-explanatory, so far as the scope of this report is concerned.

The compartment air-salvage line, which the *S–4* torpedo-room crew reported flooded, was found to contain several quarts of water, which ran out when the valve in the torpedo room was opened. The line as a whole was tested and found to be tight and intact.

Part XVI.—Data, Logs, and Records. Section 1. References.

For purposes of study, comparison, and reference there are available the reports of previous salvage operations on United States submarines where deep-sea diving and the use of pontoons was an important part of the work. Chief among these may be mentioned:

Submarine *F–4:*

Bureau of Construction and Repair Confidential Bulletin No. 66, pages 1255–1258.

United States Naval Institute Proceedings, November–December, 1915.

Submarine *S–5:*

(1) Commander C. W. Fisher (CC), letter of August 19, 1921, to commandant, fourth naval district.

(2) Commander C. W. Fisher (CC), letter of September 7, 1921, to commandant, fourth naval district.

The above *S–5* papers are on file in the Bureau of Construction and Repair.

Submarine *U–111:*

Wreckmaster, *Falcon*, Report 22–U–W. E. W. of August 22, 1922. Filed September 30, 1922, in Bureau of Construction and Repair, File 22414–A, Serial 60509.

Submarine *S–51:*

Salvaging U. S. S. *S–51*, by Capt. Ernest J. King, United States Navy, United States Naval Institute Proceedings, February, 1927, page 137 and following.

Report on salvage operations, by Lieut. Commander Edward Ellsberg (CC), United States Navy, salvage officer. Printed in book form as Bureau of Construction and Repair Technical Bulletin No. 2–27, 1927.

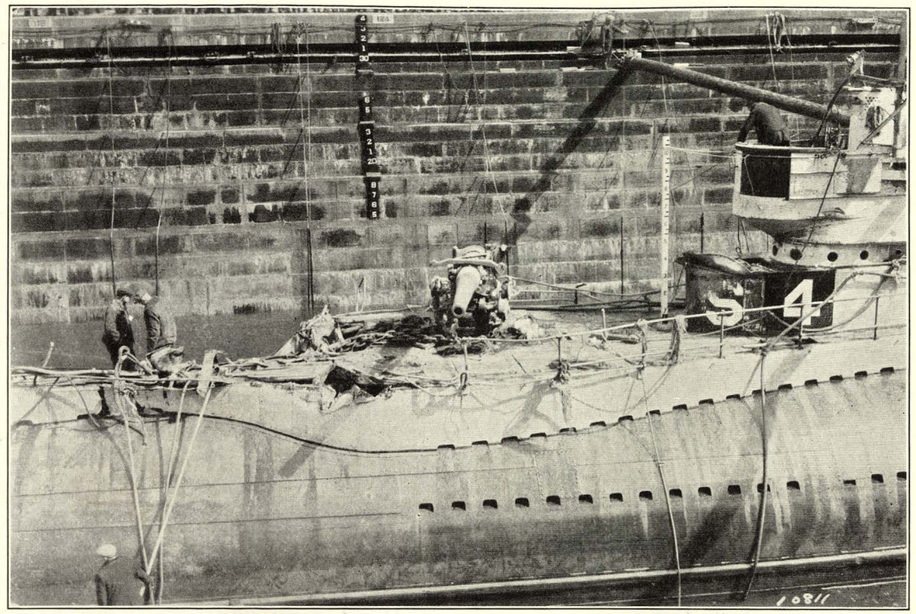


FIG. 130.—Port side of *S–4*, in way of "cut." Damage at corner of superstructure forward of gun was done by port middle pontoon on trip to Boston

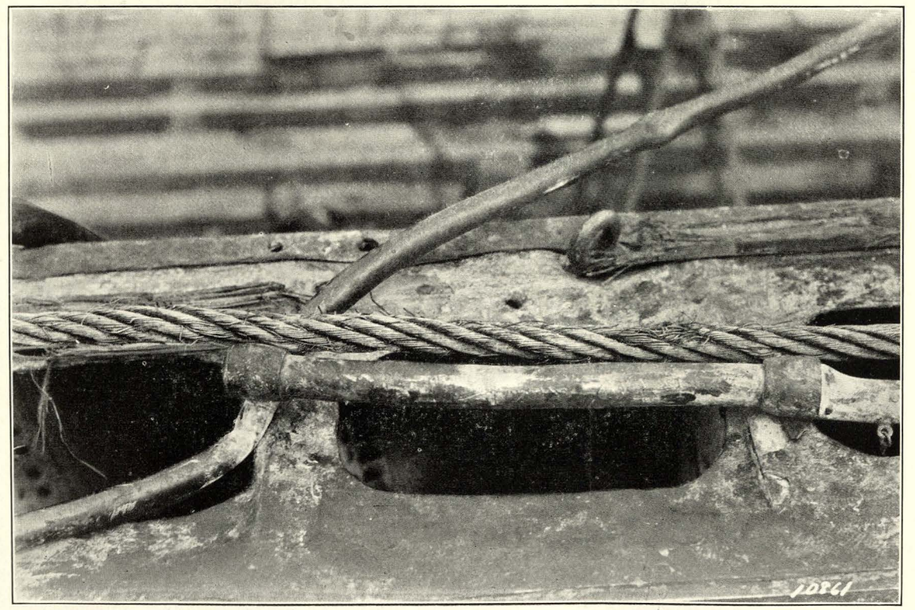


FIG. 131.—Stranded condition of 1⅛-inch wire towing pendant after being chafed by forward end of starboard middle pontoon in heavy seas

Submarine *S–4:*

General operations report on salvage of U. S. S. *S–4*, forwarded by commander *S–4* salvage force, Capt. E. J. King, United States Navy, letter S–94 (S–1122) of March 25, 1928. This is on file in the office of the Chief of Naval Operations, File No. SS109/L11–1(9)(280325–1).

Part XVI.—Section 2. Logs and Records.

The complete salvage log and the data on work of divers, weather conditions, temperatures, etc., is too bulky to be included either in the body of this report or as an appendix. The originals of these papers have, however, been filed for reference as noted hereunder. This data has been divided into six parts, as described hereunder.

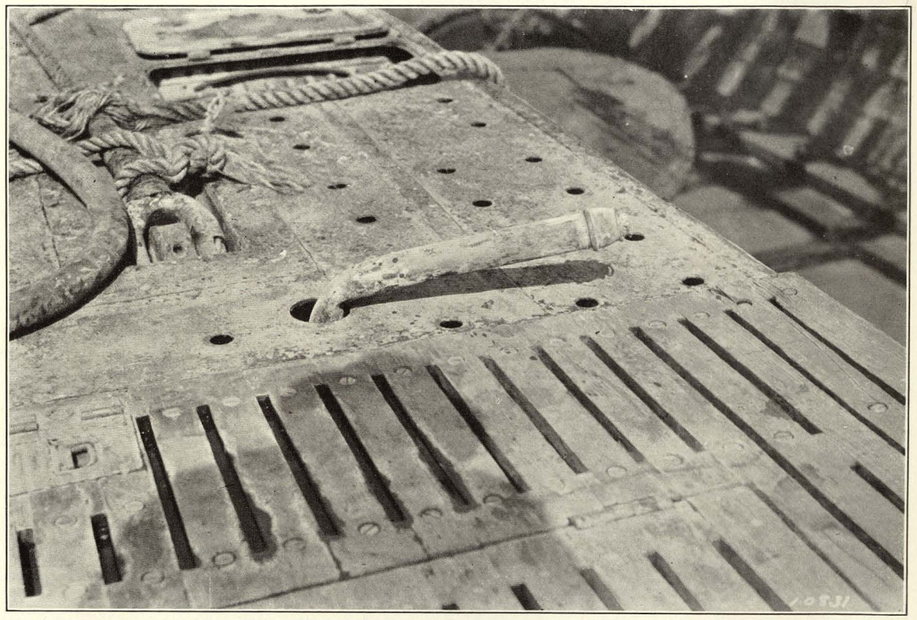


FIG. 132.—SC tube. Cross arm removed and stem capped to minimize possible damage, but stem was finally bent by pontoon in heavy seas

A. Summary of diving operations for the period December 17, 1927, to March 16, 1928, eight sheets in all. As an indication of the data recorded on these sheets, the entry for an average day is quoted.

Date	Diving	Number of dives	Work being done	Names of divers
Tuesday, Feb. 7, 1928	½ day *	8	Burning hole for torpedo-room spill pipe	Carr. Bailey.
	½ day †		Blanking outboard ventilation line in "cut"	Crilley. Mattox. Wilson. Kallinoski. Michels. McNulty.

* Signifies that diving was done. † Signifies that diving was prevented by weather and sea.

B. The salvage log complete comprises 138 numbered sheets, with 3 additional. As an example of the data recorded in this log, the following entry for Wednesday, January 4, 1928, is given:

"S–4" RESCUE OPERATIONS

SHEET NO. 20

WEDNESDAY, *January 4, 1928.*

Remained at anchor near *S–4*.

0700. Put dummy diver over and hauled up after 1 hour 10 minutes. Found air flow intermittent, but no ice upon disassembly of gear on deck. Decided not safe to send divers down.

Making alterations to three after starboard diving hose connections on 2-inch diving air line so as to have connections come off on top of main instead of on bottom, avoiding having the condensed water in the main drain down into the diving-hose connections and either freeze in the strainer sponges or else find its way into the diving hose.

Considered better to have 2-inch diving-air main run inside of deck house instead of outside, as at present, thus acting as a reheater for air to divers instead of a cooler, but see no practicable way to make this change at present.

Decided to fit a 1-inch drain and valve in after end of 2½-inch diving air line; work to be done when next the air can be shut off.

Moored over *S–4*. Put dummy down and found air supply O. K. Sent divers down to go into engine room.

1228. Applegate down to open engine-room hatch.

1359. Eiben into engine room; Wilson into engine room; Mattox on deck. Up at 1510.

Recovered two bodies on floor plates at foot of ladder on aft side. One body halfway back, between engines—found later to be not so far back. Forward engine-room door found closed. All three divers had helmets with new telephones. Operation very satisfactory. Bodies Nos. 1, 2, and 3.

1624. Campbell, Crilley, and Baker. Down to finish clearing up passage back to motor room. Campbell broke strap holding up his belt and had to come out. Darkness coming on, so decided to discontinue diving for night.

1800. Wind coming up from west, so unmoored.

C. The records show the following data as to diving days:

(A) Days when diving was done.
(B) Days when weather (sea) prevented diving.
(C) Days when weather (sea) permitted diving, but clogging of divers' air lines prevented diving.

Days	Week ending—	A	B	C	Remarks
1	Dec. 31, 1927	5½	½		1 day spent laying moorings, Dec. 25.
2	Jan. 7, 1928	2	3½	1½	Westerly gale, Jan. 1–2 and Jan. 5–6.
3	Jan. 14, 1928	4½	1½	1	
4	Jan. 21, 1928		3	4	SE. gale, Jan. 19–20; NW. gale, Jan. 20–21.
5	Jan. 28, 1928	1½	2½	1	Jan. 24–25 spent at navy yard, Boston. NE. gale, Jan. 28.
6	Feb. 4, 1928	5	2		NE. gale, Jan. 29; NW. gale, Feb. 2.
7	Feb. 11, 1928	6	1		
8	Feb. 18, 1928	5½	1½		NE. gale, Feb. 17–18.
9	Feb. 25, 1928	3	4		NE. gale, Feb. 19–21; SE. gale, Feb. 23.
10	Mar. 3, 1928	3½	3½		
11	Mar. 10, 1928	3	4		SW. gale, Mar. 4; NW. gales, Mar. 5–8; easterly gales, Mar. 9–10.
12	Mar. 17, 1928	5½	½		1 day spent raising the vessel on Mar. 17.
84	Total	45	27½	7½	4 days for other work, as described above.

D. The summarized record of weather conditions, three sheets in all. A typical record for one week is quoted:

Day of week	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Date	Jan. 29	Jan. 30	Jan. 31	Feb. 1	Feb. 2	Feb. 3	Feb. 4.
Wind:							
Direction	NE. to N	N. to NW	NW	S. to SW	W	N.-NW., SW.-S	SW.
Force	8 to 9 to 8	4 to 3	3 to 1	4 to 3	6 to 7	3 to 2 to 4	5 to 6.
Sea:							
Condition	8 to 6	3	3 to 1	3 to 2	6 to 5	2	4 to 5.
Swells	NE. to N	N	NW	S	W	NW to SW	SW.
Weather	NE. gale, snow.	Cool	Moderate	Snow, rain, warmer.	Moderate gale, clear.	Calm, cold	Choppy, warm.
Diving	No	Yes	Yes	Yes	No	Yes	Yes.

E. A fairly complete record was maintained of Hygrometric conditions, comprising six sheets. A specimen entry from these sheets follows:

Date	Hour	Dry bulb	Wet bulb	Corresponding humidity	Hygrograph	Water, surf	Water, bottom	Condensed moisture	Diving gear and test apparatus
					Per cent				
Saturday Feb. 4, 1928	0800	39	38½	85.6	100	34	34	Considerable	Satisfactory, though air not as dry as on other days.
	1200	41	38	76.5	86	34	35	Blowing down, cooler every 10 minutes.	
	1600	41	38	76.5	84	34	35		

Readings of the wet bulb on days when the atmospheric temperature was below 32° F. were somewhat unreliable and most of them were omitted.

F. The hygrograph records, a sample of which is shown in figure 13, are complete for the period January 2 to March 18; there is one sheet for each week, or 11 sheets in all.

The hygrograph was sufficiently sensitive to record passages of heavy cloud banks during days of overcast or rainy weather and to record passages of squalls of moderate duration.

For purposes of calculation, in connection with air-conditioning apparatus, the following is quoted in full from Table 138 on page 154 of the Smithsonian Tables:

TABLE 138.—*Weight in grains of the aqueous vapor contained in a cubic foot of saturated air*[1]

Temperature (° F.)	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0
−10	0.285	0.270	0.257	0.243	0.231	0.218	0.207	0.196	0.184	0.174
−0	.481	.457	.434	.411	.389	.370	.350	.332	.316	.300
+0	.481	.505	.529	.554	.582	.610	.639	.671	.704	.739
10	.776	.816	.856	.898	.941	.985	1.032	1.079	1.128	1.181
20	1.235	1.294	1.355	1.418	1.483	1.551	1.623	1.697	1.773	1.853
30	1.935	2.022	2.113	2.194	2.279	2.366	2.457	2.550	2.646	2.746
40	2.849	2.955	3.064	3.177	3.294	3.414	3.539	3.667	3.800	3.936
50	4.076	4.222	4.372	4.526	4.685	4.849	5.018	5.191	5.370	5.555
60	5.745	5.941	6.142	6.349	6.563	6.782	7.009	7.241	7.480	7.726
70	7.980	8.240	8.508	8.782	9.066	9.356	9.655	9.962	10.277	10.601
80	10.934	11.275	11.626	11.987	12.356	12.736	13.127	13.526	13.937	14.359
90	14.790	15.234	15.689	16.155	16.634	17.124	17.626	18.142	18.671	19.212
100	19.766	20.335	20.917	21.514	22.125	22.750	23.392	24.048	24.720	25.408
110	26.112	26.832	27.570	28.325	29.096	29.887				

[1] See Smithsonian Meteorological Tables, pp. 132-133.

The originals of the records listed under A, B, C, D, E, and F above were forwarded to the Bureau of Construction and Repair with commandant, Portsmouth, first indorsement SS109/S94(0-06) of September 12, 1928, and filed with that bureau as inclosures having the same designation.

Bu. C. and R. File FS/L11-1 (23), vol. 4. Serial 43836.

Part XVI.—Section 3. Weekly Reports.

The weekly reports of progress of salvage on the *S-4*, as described previously under Part V, section 10, were forwarded as follows and can be examined in the files of any of the offices addressed.

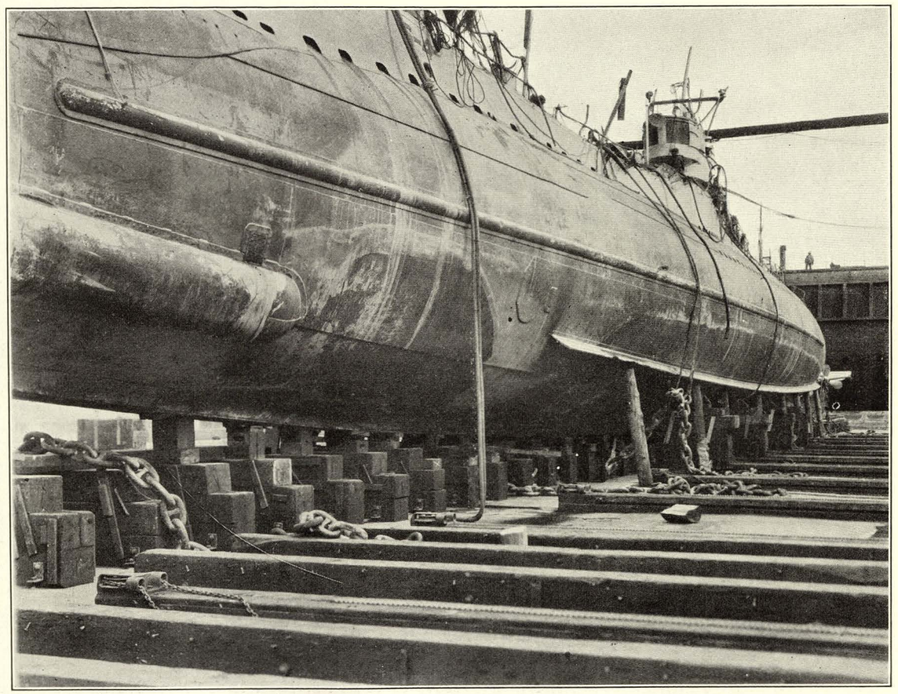


FIG. 133.—General view of forward underbody, with chains for forward and middle pontoons. Note mud line underneath forward end of bilge keel where tunnel was originally dug at frame 39

I. Commander *S-4* salvage force letter S94/(S-1034) of January 28, 1928, to Chief of Naval Operations; copies to—

Commander in chief, United States Fleet.
Commander control force.
Commander submarine base, New London.
Commandant, first naval district.
Commandant third naval district.
Commandant navy yard, Boston.
Bureau of Construction and Repair.
Bureau of Engineering.

II. Commander *S–4* salvage force letter S94/(S–1047) of February 4, 1928, to Chief of Naval Operations, copies as above and to Bureau of Navigation.

III. Commander *S–4* salvage force letter S94/(S–1051) of February 11, 1928, to Chief of Naval Operations, copies as for I and II above.

IV. Commander *S–4* salvage force letter S94/(S–1065) of February 18, 1928, to Chief of Naval Operations, copies as for I and II above.

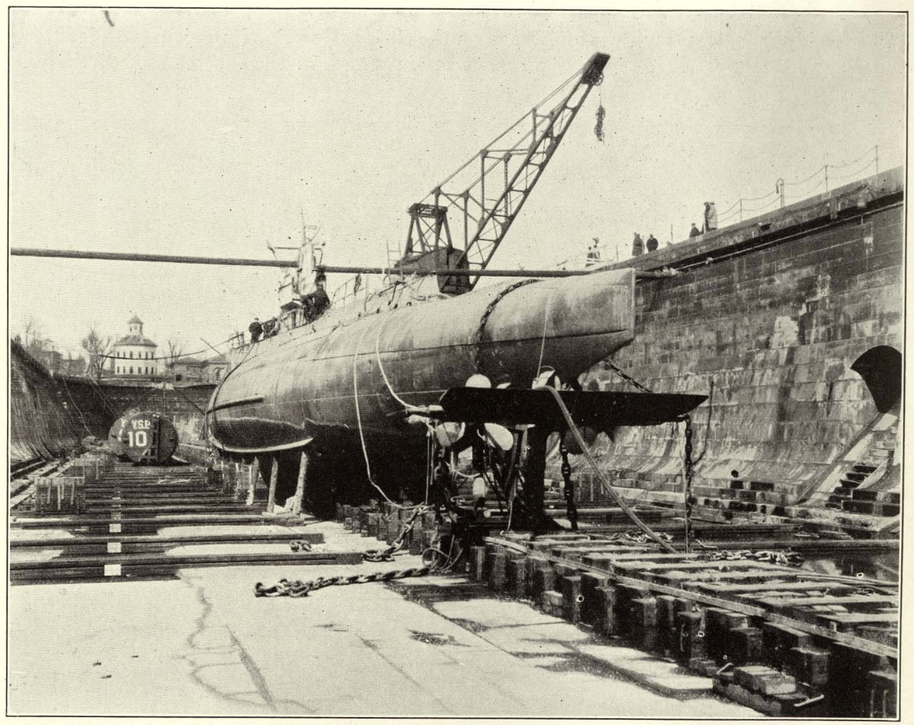


FIG. 134.—General view of underbody aft with mud line very clearly defined

V. Commander *S–4* salvage force letter S94/(S–1076) of February 25, 1928, to Chief of Naval Operations, copies as for I and II above.

VI. Commander *S–4* salvage force letter S94/(S–1087) of March 3, 1928, to Chief of Naval Operations, copies as for I and II above.

VII. Commander *S–4* salvage force letter S94/(S–1094) of March 10, 1928, to Chief of Naval Operations, copies as for I and II above.

Part XVI.—Section 4. Underwater Work.

Items of work	Undertaken	Completed	Number of dives
1. Searching for vessel	Dec. 21	Dec. 21	2
2. Examination of vessel. Inspection for leaks	Dec. 18	Feb. 15	16
3. Attaching and shifting descending lines	Dec. 21	Mar. 15	9
4. Clearing up lines and wreckage	Dec. 26	Feb. 29	20
5. Testing cutting torches	Dec. 21	Jan. 15	2
6. Testing telephones	Jan. 10	Feb. 4	5
7. Opening up vessel	Dec. 31	Jan. 9	15
8. Recovering bodies	Jan. 4	Jan. 11	30
9. Washing tunnels, frames 12, 19, 39	Dec. 22	Feb. 24	58
10. Attachment of air hoses and blowing hoses. Blowing tanks and compartments	Dec. 18	do	38
11. Sealing up, torpedo room	Jan. 12	Feb. 12	50
12. Blowing battery room	Feb. 12	Feb. 13	5
13. Sealing up, control room	Jan. 8	Feb. 12	46
14. Sealing up, conning tower hatch	Feb. 5	Feb. 14	5
15. Preparing for and cementing	Feb. 1	Feb. 5	4
16. Sealing up, engine room	Feb. 16	Feb. 16	6
17. Sealing up, motor room	Jan. 8	Feb. 3	10
18. Blowing main ballast tanks	Jan. 31	Feb. 5	22
19. Blowing normal fuel-oil tanks	Feb. 6	Mar. 2	53
20. Blanking ventilation outboard line	Feb. 7	Feb. 11	28
21. Fitting bow plane guards	Mar. 4	Mar. 4	4
22. Fitting towing bridles	Feb. 17	Feb. 24	19
23. Washing tunnel, frame 70½, port	Mar. 1	Mar. 1	18
24. Washing tunnel, frame 46	Mar. 4	Mar. 6	30
25. Cleaning out tunnel, frame 19	Mar. 16	Mar. 16	4
26. Reeving lines in tunnels	Mar. 7	do	18
27. Preventer lashing on No. 4 chain for middle pontoons	Mar. 9	do	24
28. Inspecting pontoon chains	Mar. 13	do	5
29. Pontooning	do	do	23
30. Miscellaneous			1

NOTE.—As work was frequently performed on several items of work during a single dive, no special attempt has been made to have the above list tally with the official number of dives, 564. The above list is for comparison only, and it has been made accordingly.
Total number of dives on tunnel washing 110.

Work of divers

Name	Rate	Number of dives made	Names	Rate	Number of dives made
Anderson, J. T	T. M. 1c	1	Kallinoski, E	T. M. 1c	20
Applegate, C. L	Coxwain	25	Kelley, J. R	C. T. M	30
Bailey, H	C. G. M	2	Mattox, E. A	C. T. M	24
Baker, J. E	Coxwain	34	Michels, F. G	C. T. M	19
Bedford, H. H	C. M. M	1	Miller, F. B	T. M. 1c	1
Burns, G. P	E. M. 1c	2	Mott		1
Burd, D. E	T. M. 1c	29	McNulty, P. C	G. M. 2c	8
Campbell, T. M	C. B. M	15	McMullen, J. F	Sea. 1c	15
Carr, W. J	C. B. M	39	Nicol, J	Gunner, U. S. N	1
Crilley, F. W	C. G. M	48	Rogers, C. A	B. M. 2c	1
Davis, A. H	C. T. M	2	Scott, C. W	B. M. 2c	29
Eadie, T	C. G. M	34	Schmidt, C. J	C. T. M	1
Eiben, J	C. T. M	31	Sherwood, H	C. T. M	10
Ellsberg, E	Lt. comdr., U. S. N. R	1	Skumautz, V. J	Sea. 1c	4
Evans, G. L	Sea. 1c	1	Stanley, J	Mo. M. M. 2c Coast Guard	2
Grube, A. C	T. M. 1c	28	Smith, A. M	G. M. 3c	1
Harris, H. P	C. C. M	17	Von der Wall, F. G	C. T. M	13
Holden, G. F	C. T. M	1	Waltz, N. E	Sea 1c	2
Ingram, J. W	C. T. M	10	Wilson, R. C	C. T. M	36
Johnson, I	Sea. 2c	1	Wickwire, W. S	C. G. M	30
Johnson, W. C	C. T. M	4	Witters, T. S	T. M. 2c	1
Joy, E. S	T. M. 1c	1			

NOTE.—Crilley, F. W., had the maximum number of dives to his credit for the *S–4* job—a total of 48. The above list exceeds the official number of dives, 564, as given elsewhere, by reason of the fact that a number of what might be termed instruction dives are included in the foregoing.

Part XVI.—Section 5. Brief Chronological Record of Principal Events.

1927

December 17—*S–4* sank as a result of collision with *Paulding* (CG–17).
Falcon left New London.
Bushnell left Portsmouth.

December 18—First diving and rescue work began. Blowing hose connected to main ballast tank salvage line.

December 19—*Sagamore* arrived Provincetown with three pontoons and *Mohave* arrived with barge load of salvage gear.

December 21—Examination of *S–4* and fitting of hoses to SC tube for air supply to torpedo room. Began supplying fresh air to torpedo room.

December 22—Began washing tunnel at frame 19.

December 24 ..... Visit of Secretary of Navy and Chief of Naval Operations. Rescue work terminated and salvage work begun.
December 25 ..... *Falcon* permanent moorings planted.
December 26 ..... Began clearing away wreckage on *S–4*.
December 30 ..... Terminated washing of tunnel at frame 39. Three sets of reeving lines under *S–4*, at frames 19, 39, and 135.
December 31 ..... Began opening access hatches (engine room).

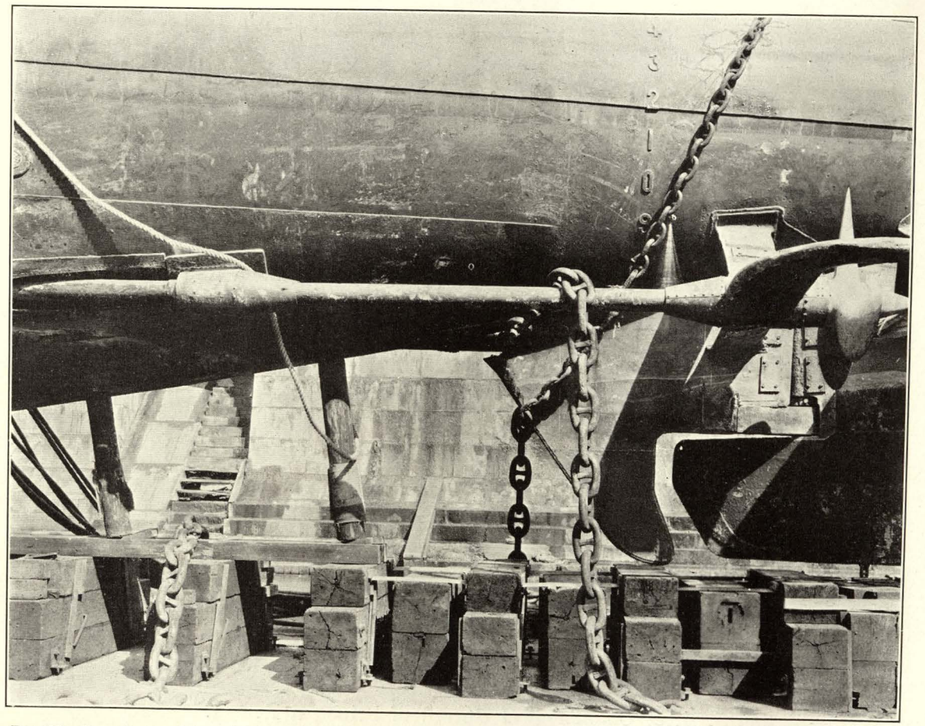


FIG. 135.—General view of stern showing mud line, after pontoon chains, after towing bridle, and special shores set by divers in dry dock. The cut in the forward end of the skeg was made by No. 6 chain of the after pair of pontoons during heavy weather encountered en route to Boston. The shackle used to connect the two ends of the girth chains for the sternfast is shown almost directly behind the point where the pontoon chain lies over the shaft

1928

January 2–3 ..... Freezing of diving air encountered. Began tests to solve freezing problem.
January 4 ..... Opened engine-room hatch and removed first bodies.
January 7 ..... Opened control room.
January 8 ..... Began sealing control room.
January 9 ..... Opened motor-room hatch.
January 11 ..... Completed removal of bodies from engine and motor rooms.
January 12 ..... Began sealing torpedo room.
January 16–23 ..... No diving on account of freezing of air lines.

January 23–25 ..... Installation of special cooler, heater, and air-conditioning apparatus at Boston yard.
January 27 ..... Began burning hole for torpedo-room spill pipe.
January 31 ..... Began work on main ballast tanks.
February 1 ..... Began preparations for cementing main induction.
February 3 ..... Began blowing main ballast tanks. Placed motor room salvage hatch.
February 5 ..... Blew main ballast tanks dry. Completed cementing.
February 6 ..... Began work on blowing of fuel-oil tanks.
February 7 ..... Began blanking outboard ventilation line.

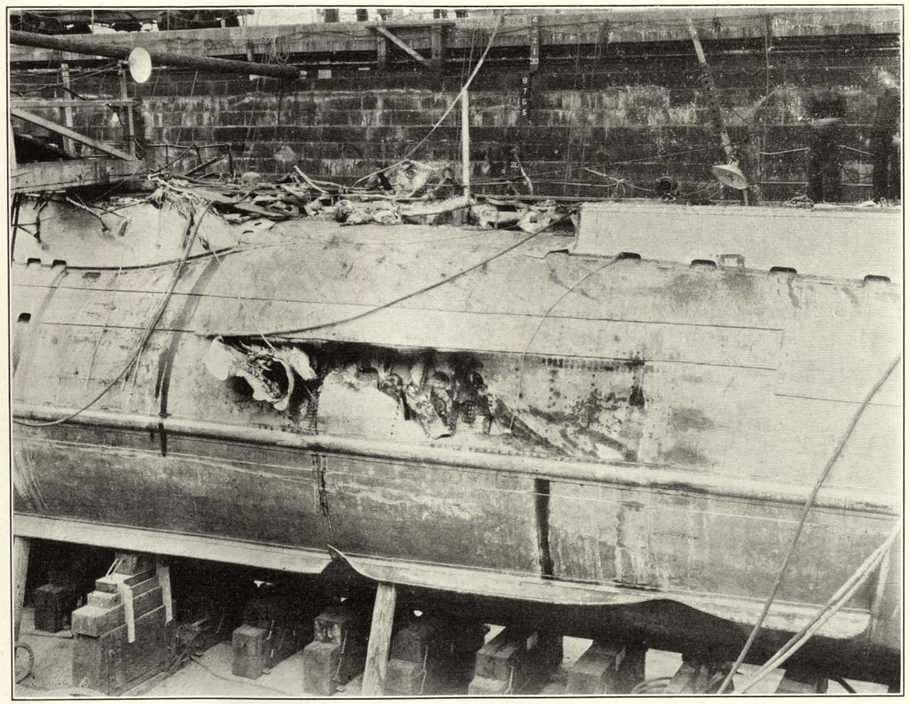


FIG. 136.—General view of damage to *S–4*. Note dents in bilge keel made by chains of middle pair of pontoons

February 11 ..... Completed cutting hole for torpedo-room spill pipe. Completed blanking outboard ventilation line.
February 12 ..... Placed torpedo-room spill pipe. Began blowing control room.
February 13 ..... Battery room blown. Five divers down at once on this date. Began blowing torpedo room.
February 14 ..... Began preparing pontooning gear.
February 15 ..... Control room blown dry.
February 16 ..... Placed engine-room salvage hatch. All work inside *S–4* completed and vessel sealed.

February 17 ..... Engine room blown dry. Began placing towing bridles.
February 18–21 ..... No diving on account of heavy weather.
February 24 ..... Completed placing and assembling towing bridles. Torpedo room blown dry.
February 28 ..... Blew bow buoyancy tank. Dropped mushroom anchor.
February 29 ..... Blew forward trimming tank. Lashing blowing hoses. Brought up last wreckage.
March 1 ..... Excavated tunnel at frame 70½, port, for access to fuel-oil-tank manhole.
March 2 ..... Began blowing normal fuel-oil tanks forward and fueling from *S–4*.
March 4 ..... Placed bow plane guards. Began washing tunnel at frame 46.
March 6 ..... Completed fueling from *S–4*.
March 7 ..... Completed tunnel at frame 46.
March 8 ..... Rove chains for middle pair of pontoons through tunnel at frame 46.

FIG. 137.—Group of divers prepared to make examination of interior of *S–4* after docking. Standing, left to right; Michels, Eadie, Wilson, Carr, Eiben. Kneeling, left to right; Crilley, Mattox, Doherty

March 9 ..... Began securing preventer on No. 4 pontoon chain.
March 13 ..... Lowered middle pontoons into place, *YSP–7* and *YSP–9*.
March 15 ..... Rove wires and chains under stern and lowered stern pair of pontoons into place, *YSP–6* and *YSP–10*.
March 16 ..... Finished securing preventer on No. 4 pontoon chain. Washed out old tunnel at frame 19 and passed reeving wires and chains under bow. Lowered bow pair of pontoons into place, *YSP–3* and *YSP–4*.
March 17 ..... Raised *S–4*. Began towing to Boston.

March 18 ..... Arrived at navy yard, Boston, and righted ship by using middle pair of pontoons.
March 19 ..... *S–4* docked. Salvage work completed.
March 19–20–21 ..... Postdocking examination and photographs.
March 23 ..... *S–4* salvage force disbanded.

Part XVI.—Section 6. Photographs.

Every endeavor was made as the work progressed to obtain photographs and records of the work that was being done and the manner of doing it for the benefit of those who could not view it or who might have to do similar work in the future.

It is regretted that the stress of work and darkness prevented taking many photographs of interesting stages and that wind and weather conditions and the inexperience of amateurs prevented some others from being first class in every respect.

The services of the yard photographers of both the Boston and the Portsmouth Navy Yards were available from the time the *S–4* arrived at the navy yard, Boston, until all postdocking examinations were completed. In this manner it was possible to get a complete and accurate photographic record of the condition of the *S–4* when first unwatered and the manner in which the work of the divers was performed.

The remainer of the four or five hundred photographs which were taken during the *S–4* rescue and salvage operations and not included in this report will be placed in the official files of the Bureau of Construction and Repair, Navy Department, Washington, D. C., for possible future reference.

File No. FS/L11–1 (23), vol. 4, Serial No. 43869.

Part XVII.—Suggestions and Recommendations Regarding Provisions for Possible Future Submarine Rescue Situations.

As was to be expected, there were a number of developments in the course of the rescue and salvage operations on the *S–4* which clearly point out the need of improvements and changes in ways and means of effecting rescue and for salvage.

The suggestions and recommendations made as a result of the experience gained during the *S–4* rescue and salvage operations and the study which the salvage force was able to give these matters during the course of and since the conclusion of the operations, chiefly during the course of a series of conferences in the Navy Department from March 29 to April 4, 1928, are set forth in the form of a technical memorandum on the pages following. Practically all the suggestions and recommendations contained herein were embodied in a letter from commander *S–4* salvage force to the Chief of Naval Operations, dated April 12, 1928.

The trend of these comments is that the first and greatest attention should be given to means whereby the crew of the submarine can help themselves and that the second and less efficient means of rescue lies in arranging for help from outside the vessel.

Part XVII.—Section 1. Submarines; Escape and Rescue.

Nothing which has been suggested or discussed since the casualty to the *S–4* would appear to alter the general principle which has been used in the past as a guide in the design, construction, and operation of our submarines—that is, that the best safeguard of the vessel and her crew is the provision of means whereby the personnel can most surely and safely handle their own ship. Neither is there reason to alter the thought generally prevalent among those acquainted with submarine affairs that submarine crews or personnel can not be rescued with any probability of success unless they find it possible to bring at least one end of their vessel to the surface by employing means within the vessel itself.

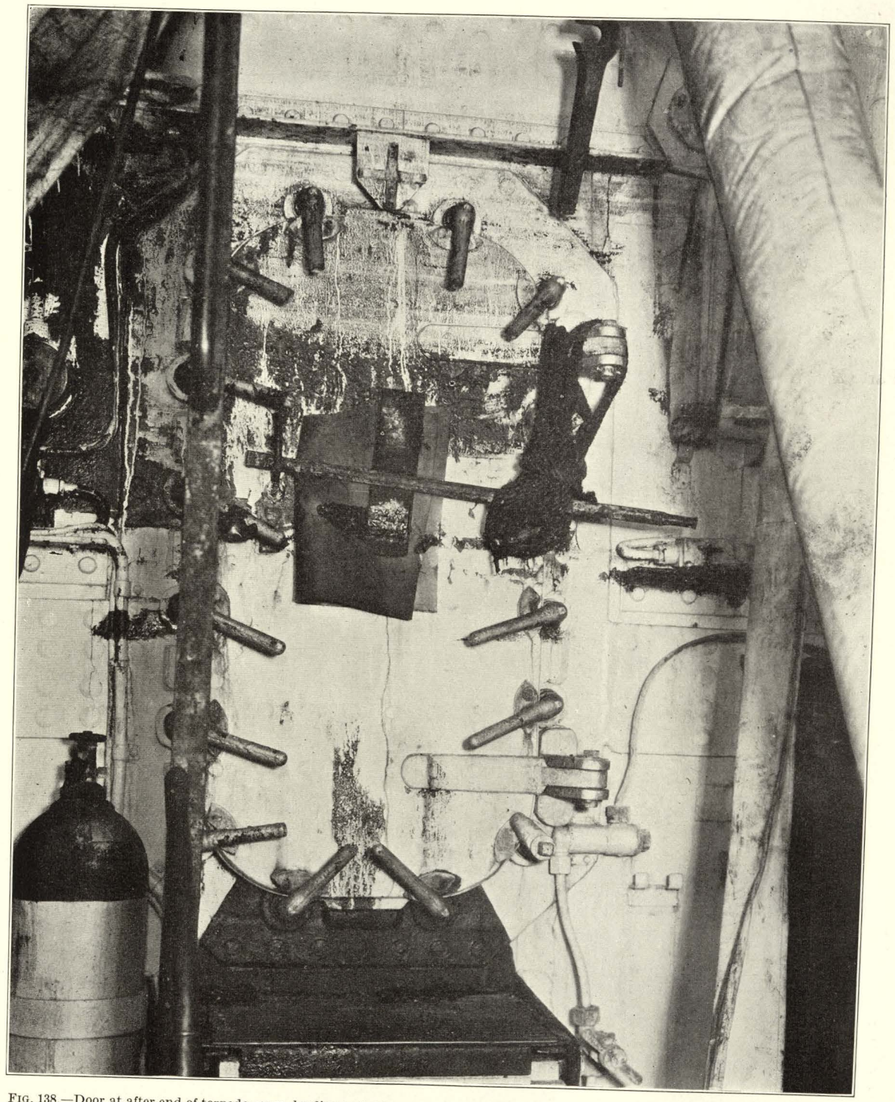


FIG. 138.—Door at after end of torpedo room, leading to battery room, with gear improvised by *S-4* crew to stop leaks around eye port. Oxygen flask in left foreground

The fitting and use of escape locks, combined with the possible development and use of a satisfactory rescue helmet, might suffice under certain conditions of shallow water, favorable temperature, etc., but it must be understood that even this means of enabling the crew to effect their own escape has severe limitations.

The same remarks apply to the provision of pads, hooks, lifting shackles, etc., for the attachment of derricks, pontoons, or other lifting gear, since the preparation and utilization of these lifting appliances depends upon so many circumstances which may not be favorable.

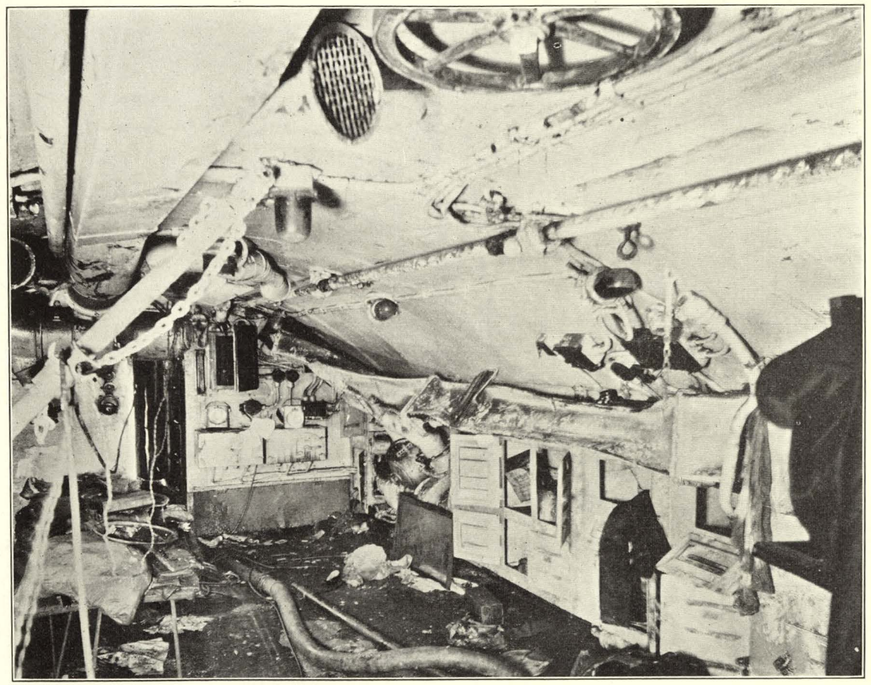


FIG. 139.—Port after corner of battery room, showing battery exhaust ventilation duct at right collapsed by external pressure

Part XVII.—Section 2. Submarines; Alterations and Additions, Applying Especially to Vessels of the "S–3" to "S–17" Class.

Consideration of certain alterations and additions, as listed herein, is recommended.

(*a*) The installation of valves or manifolds whereby any or all of the principal groups of main ballast tanks can be blown from the end compartments as well as from the control room is recommended, although it must be understood that the effectiveness of these arrangements will depend upon the maintenance of a supply of air from the ship's tanks to the manifold where the blowing is being done. The blowing valves and pipes need not be particularly large, as the rapid blowing feature available in the control room is necessary only to check the movement of the vessel when actually traveling downward. This recommendation is to include the

fitting of valves or a manifold in the deck erection whereby selective blowing of the forward, middle, and after main ballast tanks (or groups of tanks) can be accomplished by a diver at the main ballast tank salvage air connection.

(*b*) The fitting of a line or lines whereby it would be possible to blow the normal fuel-oil tanks from the control room were all other valves properly set beforehand is recommended for consideration if it can be accomplished without too much complication. However, the general provision of blowing valves, manifolds, and lines which would permit blowing of variable

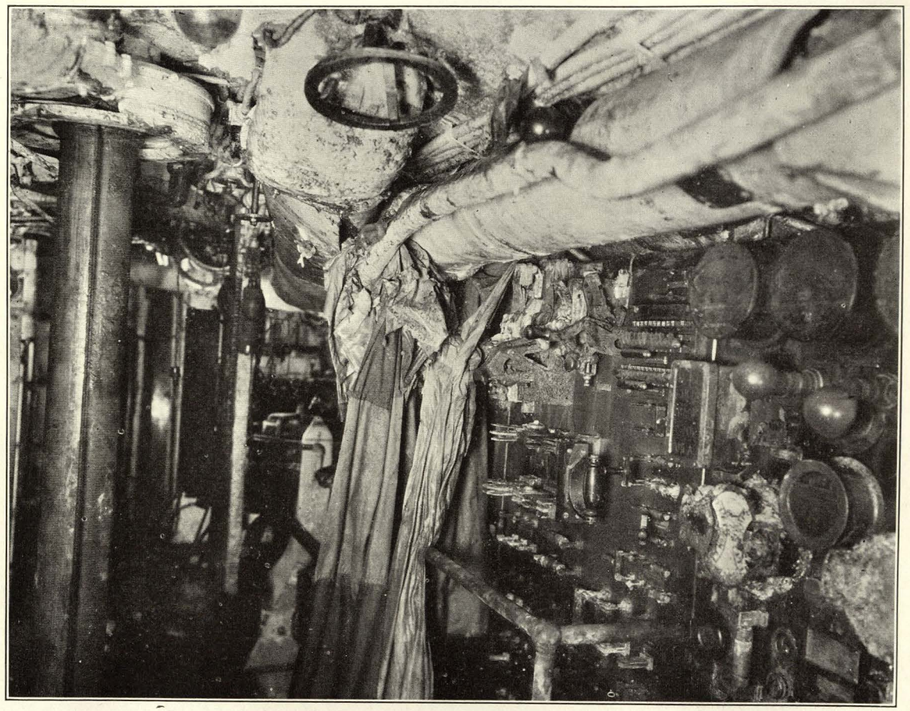


FIG. 140.—Control room, starboard side at main switchboard. The cloth lying on the switchboard rail originally covered the front of the switch-board but was moved back in the position shown by the divers. Note rupture in battery exhaust ventilation duct and débris which came through from battery room

ballast, fuel-oil, and other miscellaneous tanks from more than one location is considered not advisable on account of the tremendous complication involved.

(*c*) Fitting of individual compartment air valves and transformation of the present compartment air salvage line into a compartment air supply line, as on the V class. The changes recommended would follow in general the arrangmenet developed for later vessels of the V class except that the construction of the individual air valves might be simplified somewhat to reduce weight and expense. The fitting of two air valves, one for supply and one for exhaust, is considered justified only for the end and middle compartments, since it is likely that the crew in adjacent compartments could take refuge in these end or middle compartments, or else that it

might not be necessary to close off the adjacent compartments from the "refuge" compartments. The supply pipe in the refuge compartment could be run well down, to serve also as a spill pipe for salvage work.

(*d*) Some consideration should certainly be given to the fitting of individual connections over each main compartment whereby food, water, electrical power, high-pressure air, and a number of useful articles could be transferred with facility from a rescue vessel at the surface to the interior of a compartment with the submarine submerged. This can not be done through the present individual compartment valves. Members of the salvage force have examined one such device which shows promise, submitted by an inventor who is also a diver by profession. It is in the nature of a simple and compact fitting whereby a flexible reinforced rubber hose about 4 inches in diameter may be attached to the submarine by a diver working from the outside. Incidentally, it is possible to supply and exhaust air through this fitting while the hose is in use for other purposes. Although it is true that food, water, flash lights, and other gear may be kept stored in individual compartments on a submarine, it is conceivable that the use of a fitting whereby a supply of fresh material and a line of efficient communication could be kept up for several days might permit a submarine crew to exist in reasonable confort until such time as preparations could be undertaken and completed for raising the vessel to the surface. It will be recalled that the crew of the British submarine *K–13* were supplied with air, water, and food through an ammunition hoist trunk and an improvised tube until arrangements could be made for lifting one end of the vessel to the surface and cutting a hole in the hull for the escape of the personnel.

(*e*) The access hatches on submarines prior to the V class, with the exception of the battery room hatch on the *S–48* to *S–51* class, are operable only from the inside and are in general secured by devices which leave much to be desired from a mechanical standpoint. The fitting of single-action hatches operable from both above and below is possible on existing submarines, provided the necessary weight and vertical moment can be spared. Were the torpedo-loading hatches to be made operable in this manner and to be used as escape hatches, the deck hatches over should be cut away. The use of these hatches might under certain circumstances be of great assistance to the crew or to outsiders during rescue operations.

(*f*) It also appears feasible, provided the weight and vertical moment can be spared, to fit water-tight coamings and flanges around the hatches of the control room and of the end compartments to facilitate the attachment of a trunk, flexible pipe, or even of a sort of diving bell over the access hatch in order to permit the unwatering of the space above the hatch when it is not possible or practicable to bring the vessel or the access hatch all the way to the surface. The fitting of access trunks as escape locks, following the arrangements on the *V–4*, *V–5*, and *V–6*, appears practicable only on large vessels of perhaps 2,000 tons displacement and above.

(*g*) The water-tight doors of submarines previous to the V class are secured by numerous swinging dogs, in some cases as many as 16 in number. These dogs must be thrown in exactly the proper sequence and the operation of the closing and securing a door is necessarily slow. Even when fully closed absolute water-tightness of the door may not be attained, if the experience of the salvage force on the *S–4* and the *S–6* is to be taken as a guide. The substitution of a new type of light and compact single-action door for the present multiple-dog door on vessels of the S class and preceding classes seems entirely practicable, although previously it did not seem feasible on account of the greater bulk of the original single-action door. The provision of means for mechanically closing and opening the doors, making them operable from a central point, is not recommended for the same reason which governed the removal of doors of this type from naval vessels in the past.

(*h*) That the presence of valve openings in bulkheads, which may become clogged with débris upon the flooding of a compartment, is an undesirable condition can scarcely be denied.

Although the *S–4* is the first vessel, so far as known upon which the entrance of débris actually prevented the full closing of a valve under emergency conditions, there have been occasions in the past where difficulties have been experienced in making tight the ventilation valves on bulkheads bounding flooded compartments, and it is for this reason that special attention has been given on recent submarines to the design and construction of these valves. There remains, however, the likelihood that valves of the swinging-gate and swinging-flapper type as installed on practically all submarines may become jammed by wreckage floating into the ventilation duct through a screen opening which carries away or through a break in the duct itself, as on the *S–4*. The provision of a substantial grating of a type similar to armor gratings is submitted for consideration by the material bureaus. This grating must allow for easy passage of the air, must prevent foreign matter from finding its way into the valve body or under the valve seat, and must at the same time withstand full bulkhead pressure without giving way in case it becomes completely clogged with débris.

(*i*) The presence of voice tubes passing through hulls and bulkheads on submarines requires additional openings and necessitates the fitting of valves which must be closed when the hulls or bulkheads are to be made water-tight. Although voice tubes are fitted in surface vessels as a stand-by means of communication in addition to the telephones, there is a question, now that a satisfactory telephone system has been made available for installation in submarines, whether the voice tubes could not well be omitted in this class of vessels.

(*j*) On vessels of the *S–3* to *S–17* class the flap valves in the battery exhaust ventilation line at bulkheads 72 and 93, bounding the control room, are quite inaccessible. In addition, the valves at the forward bulkhead are so placed that one man can not close and secure them while another man closes the water-tight door. In other words, only one man can work in the narrow passageway at this bulkhead and he can not very well close and secure the bulkhead door and the flap valves at the same time. Provided some arrangement could be made whereby the battery could be ventilated inboard directly into the battery room or even into the control room, it might be possible to lead the ventilation exhaust line through the inner hull forward of the control room and thence through the superstructure to the outboard ventilator, thus removing entirely the ventilation duct from the control room and the valves from the bulkheads.

(*k*) The fitting of lifting eyes or rings in the upper part of the vessel, perhaps along the outer hull just above the surface water line at about the main ballast tank top, would greatly facilitate the work of attaching pontoons or other lifting appliances and would eliminate the necessity for the troublesome, laborious, and rather intricate work of tunneling under the vessel and reeving chains for the pontoons. It is considered that eyes or rings could be dispensed with at the ends of the vessel on account of the relative ease of passing pontoon chains underneath the bow and stern where little or no tunneling would be required. Could the necessary weight and vertical moment be spared, duplicate sets of eyes should be fitted over each of the main intermediate compartments on vessels of the S class—namely, battery room, control room, and engine room. Each set would consist of four eyes, two port and two starboard, for the double chains of the horizontal pontoons.

The eyes or rings would have to be fitted in such manner as to offer the least resistance when submerged and the minimum obstruction when passing through wires or nets; at the same time the working space around the eyes would have to be sufficient for the diver. Cover or patch plates over the eyes should not be fitted unless in the form of sturdy hinged doors such as are used over the salvage connections on the V class submarines.

It is obvious that the eyes should be ruggedly secured to the structure of the vessel, since the pulling out of an eye might open up a main ballast tank and cause the loss of buoyancy in that tank. On account of the enormous dynamic loads to which the eyes may be subjected, it would seem that, if fitted at all, they should be designed for maximum loads of about 150 or 160 tons each.

The most satisfactory form of attachment for a pontoon chain to a lifting eye, from the point of view of work to be performed by the diver and strength and security when lifting, appears to be the use of a detachable link which can be lowered in the open position on the bottom of the pontoon chain, hooked into the lifting eye by the diver with one operation and then held securely in place by taking a strain on the pontoon chain while the link is assembled by the diver. The taper locking pin type of detachable link recommended and the type mentioned elsewhere in this report is that described in article 3320 and illustrated in Plate 4 of the Bureau of Construction and Repair Manual.

Part XVII.—Section 3. Rescue Vessels and Gear.

Except for the fitting of a new steam capstan on the forecastle, the installation of roller chocks, new bitts and bolsters for pontooning, and the provision of a second motor surfboat for the 30-foot motor launch, practically all the changes recommended by the *S–51* salvage force for rescue and salvage vessels and embodied in Appendix B and Plate 10 of the salvage report on the *S–51* operations, by Lieutenant Commander Ellsberg, were effected on the *Falcon* after the conclusion of the *S–51* operations and before the work on the *S–4*.

The *S–4* salvage work afforded ample demonstration of the value of the changes on the *Falcon* previously recommended by the *S–51* salvage force, and quite naturally indicated the need for some additional alterations, of which the installation of the new air-conditioning apparatus, of the arc cutting torch, and of the flood lights and switches, were accomplished during the *S–4* operations, as described elsewhere. Recommendations concerning these changes were submitted by the commander *S–4* salvage force to the Bureau of Construction and Repair in letter S94 of March 24, 1928, and the subject matter of the three paragraphs following has been taken from that letter, amplified to include developments up to July, 1928.

Diving-air plant.—The diving-air plant of the *Falcon* is limited at present (July, 1928) to work at depths not exceeding 225 feet, exclusive of diving under extremes of temperature, since under these conditions the reducing valve would be by-passed. See the table of pressures on diving air system, under various conditions, Appendix I, section 4.

The diving-air and air-conditioning plants should be capable of supplying air for divers working at a depth of 300 feet and for divers working under the most extreme conditions of temperature and moisture that will permit of rescue or salvage work being carried on at sea. Detail figures and tabulated data relating to these features will be found in the latter part of Appendix I of this report.

The air-conditioning plant, if practicable, should be developed along the lines followed in the past two years, of mechanical deposition of the moisture by passage through coolers, without the use of chemicals. This for the reason that the chemical gear is likely to require more careful and expert attention, to be more uncertain and erratic in performance, and to produce harmful rather than beneficial results if something goes slightly wrong. The silica gel apparatus is included under the latter category.

The following points should be observed in the design and construction of the air-conditioning apparatus, all of which have been discussed with representatives of the navy yard, Boston, who have prepared designs for a plant operating at 400 pounds per square inch:

(1) The new 400-pound compressors should have "after coolers" attached which will deliver air at not more than 100° F. These coolers should be low in the vessel so as to be cared for by the engine or fire room forces which run the compressors.

(2) The special cooler should be in the open air, of the same general type as the existing one, which operated so well on the *Falcon*. The cooling effect of the atmospheric air on cold

days, when the cooler, connecting piping, and main air receiver are exposed, is very marked. The colder the atmospheric air the more moisture is condensed from the diving air. Care should be taken, however, that the cooler is so designed and placed that the deposited moisture does not freeze. This was accomplished on the *Falcon* by placing the cooler in a vertical position, so that the water collected from the tubes and waiting to be drained out would rest on top of the relatively warm lower tube sheet.

(3) Reducing valve and moisture eliminator (if fitted) should both be in a location where the temperature will always be well above 32° F.

(4) A recording hygrograph, as now carried on the *Falcon*, should be placed in a chamber in the diving air line or main beyond the reducing valve. Chamber should have a glass port and a door that can be conveniently opened for adjusting the hygrograph and clearing the glass. The chamber should be large enough for a wet and dry bulb thermometer as well, the latter for check purposes.

(5) The diving main or the parts of it outside the deck house should be completely lagged. Thermometers and drains should be conveniently placed.

(6) The main air receiver should hold sufficient air to permit supplying three divers, in the event of casualty to a compressor or to the steam plant, for the length of time required to get these divers on deck of the diving vessel, with 50 per cent to 100 per cent excess capacity.

Silencers of proved efficiency should be fitted to the vent pipe from the recompression chamber to the drains from the special coolers and separators, and to any other opening where air or steam exhausts on the topside, as the hissing noises at these points are troublesome when telephoning to the divers.

Pontooning gear and mooring gear.—(*a*) There should be an additional steam capstan on the forecastle (covered in previous recommendations and correspondence).

(*b*) There should be horizontal rollers and suitable cast-steel fair-leads worked into the foundations of the after pair of bitts abreast the after capstan for taking a pull on lines leading to submerged objects without the excessive chafe and friction that exists at present.

(*c*) There should be permanent pontooning chocks of cast steel, fitted with rollers wherever practicable, to increase the efficiency of the hauling gear. There should likewise be roller fair-leads for the reeving wires to replace the original snatch blocks.

(*d*) Fuel-oil tank vents and other fittings should be located to keep the deck clear for efficient handling of hose and lines.

Pumps and piping.—(*a*) Wrecking pump and connecting piping should be capable of continuous work at pressures up to 175 pounds per square inch.

(*b*) There should be a permanent voice tube with call bell between the after deck and the fireroom station where the pressure on wrecking pump and salvage air compressors is generally controlled.

General.—The design, size and type of recompression chamber as now installed on the *Falcon* and shown in Figure 37 serves fairly well for all practical purposes. It was frequently very crowded and more than once the work was slowed down on account of lack of accommodations in the chamber. Were there more room on vessels of the bird class it would be advisable to consider the installation of a longer tube, having a chamber at each end with a vestibule in the center, the latter with an outer door opening in the side. Some refinements in the detail design of the present recompression chamber could be used to save weight without sacrificing efficiency.

There should be additional staterooms provided, so far as practicable, for the diving supervisors, diving medical officer, and salvage officer, of relative importance in the order named. There should also be additional quarters for the accommodation of the divers and special crews who are living aboard during rescue or salvage operations.

Concerning the conversion and employment of vessels of the Navy as submarine-rescue vessels, it is considered that there should be at least five such craft fitted out and stationed—

(*a*) With the submarine forces, Atlantic;
(*b*) With the submarine forces, Pacific;
(*c*) At the Canal Zone;
(*d*) In the Hawaiian Islands; and
(*e*) In the Philippine Islands.

It is understood that—

(1) The *Falcon* is now well fitted out for this work.
(2) The *Widgeon* to a somewhat lesser degree.
(3) The *Ortolan* is now (July, 1928) being fitted out at the navy yard, Mare Island.
(4) The *Mallard* is now (July, 1928) being fitted out at the navy yard, Boston.
(5) The *Pigeon* is to be fitted out similarly in the not distant future.

These vessels should be capable of performing routine duties for the submarines and their tenders and they should, of course, accompany the major portion of the submarine force when it moves about from place to place.

Except for an increase in normal displacement and a decrease in freeboard, a lack of deck space and a slightly inconvenient arrangement of gear, the mine sweepers of the bird class make admirable rescue and salvage vessels when fitted out as recommended in the paragraphs preceding.

Were a submarine-rescue vessel to be designed primarily for this purpose it is possible that the same gear could be placed on a vessel having somewhat greater deck space and a more convenient arrangement of working compartments and quarters without a material increase in size or over-all dimensions above the present characteristics of the bird class. Certainly such a vessel should be not much larger than the *Falcon;* otherwise it will be difficult to moor her over a wreck and to maintain her in proper position for diving. The displacement should not exceed 1,500 tons, nor the principal dimensions 200 by 45 feet.

The question of fitting up or constructing large vessels as seagoing floating derricks for the purpose of lifting the ends of sunken submarines bodily to the surface appears just as inadvisable and impracticable now as at the times when this matter has been brought up for discussion in the past or when it was again brought to the fore for consideration by the members of the *S–4* salvage force in December, 1927. Such a vessel would have to have a lift of at least 1,000 tons to be of service, and she would be so large and unwieldy as to require particularly favorable weather conditions for her utilization.

Part XVII.—Section 4. Pontoons and Gear.

The 1928 model of three-compartment, horizontal pontoon, having drop pipes for blowing the end compartments, proved quite satisfactory as to size, shape, arrangement of valves and fittings, and general handiness. The drop pipes on the present pontoons should be relocated so that the lower ends of these pipes lie at the center of the compartments instead of toward the middle of the pontoon, as at present, for the reasons explained in Plate 6. These pontoons are likely to require overhaul after each time that they are lowered and blown to the surface, since the internal bulkheads are at present not sufficiently rugged to remain air-tight if the center compartment is filled with air when the pontoon is submerged to a sea pressure of more than 25 pounds per square inch and is blown to the surface without first releasing the pressure in this compartment. On all future pontoons of this type the internal bulkheads bounding the center compartment should have double angles to keep the calking intact when pressure is applied to the bulkheads from either side.

During May, June, and July, 1928, much time has been devoted at the navy yard, Boston, and in the Bureau of Construction and Repair to a complete redesign of the salvage pontoon as well as to improvements in the present 3-compartment design.

(*a*) An effort is being made to provide 90 or 100 tons of buoyancy on a maximum dead weight of 40 tons.

(*b*) There seems to be no reason why the diameter can not be increased accordingly, perhaps 2 feet, but the length has been limited to 32 feet for the present.

(*c*) A buoyancy compartment sufficient to carry the dead weight of the pontoon can be provided wholly within the outer shell and can be built so as to permit building up the air pressure in it to bottom pressure before it leaves the surface, thus avoiding a shift of blowing hoses, as on *S–4*.

(*d*) The pontoon design provides for a working depth of 300 feet. Additional relief valves, with tail pipes for relieving air, are to be fitted in each end compartment.

(*e*) All flood and relief valves are inside the inner shell or are recessed; likewise all pads for towing and lifting shackles are off the end bulkheads, leaving the ends of the pontoons clear for close spacing on the wreck.

(*f*) Sheathing is fitted in single lengths, with flat iron hoops instead of wire-rope bands.

(*g*) All blow and vent valves are fitted in recesses in the top, leaving the pontoon cylindrical, for rolling.

(*h*) Hawse pipes are flared at the bottom and smaller at the top, to reduce the span of the toggle bars.

The two 60-ton pontoons now on hand are being altered to 3-compartment pontoons, with all changes developed up to May, 1928. These smaller pontoons could have been used at the stern of the *S–4* and can likely be used to advantage in future salvage operations of this character.

The matter of providing a suitable number of lifting pontoons and their accessory gear and storing this material at strategic points has been given extended and careful consideration. It is felt that there should at least be an outfit of pontoons, chains, and gear on the west coast somewhat similar to that now available on the east coast; such an outfit, in view of possible demands from outlying stations, should probably consist of not less than 10 of the 80-ton pontoons. Similarly, additional pontoons might be stored at Pearl Harbor, Cavite, and the Canal Zone.

Although it was demonstrated during the *S–4* rescue operations that it is possible, with proper attention to detail and careful supervision, to tow these pontoons from place to place, even in bad weather, the most satisfactory and rapid method of transporting them from the place of storage to the place of rescue or salvage is undoubtedly by carrying them on a large naval vessel or on a cargo steamer, so placed and secured that they can be rolled or launched overboard upon delivery at the scene of operations. The necessary outfit of pontoon chains, detachable links, lowering lines, reeving lines and wires, fairing cones, toggle bars, tools, and blowing hose, *together with a complete outfit of plans and instructions,* should be stored with the pontoons and should accompany them when they are shipped.

Part XVII.—Section 5. Divers and Diving Supervisors.

The divers now in the Navy who have been proved and who are available for work at depths of 100 feet and over are relatively few in number, perhaps not exceeding 25 or 30. Many of these are veterans of long and useful experience, but, on the other hand, they are reaching ages where their remaining years of useful work are becoming more and more limited. The necessity of augmenting the force of divers on the *S–4* salvage operations led to the deliberate "breaking in" at depths exceeding 100 feet of divers who had been given the standard course and who had qualified at depths up to 100 feet. At the same time advantage was taken of

the opportunity to work in a number of young men so as to form what might be termed a "new generation" of trained and proved deep-sea divers.

A certain number of such trained divers should form a portion of the working complement of each of the five submarine-rescue vessels which are to be fitted out; this number should be in no case less than six per vessel, and should preferably be eight or nine, as one of these divers may be required as a diving supervisor and one or two of the others may not always be available due to leave, sickness, etc. The filling of the complements of these five vessels will, in this manner, require the services of almost twice as many trained deep-sea divers as are now available in the Navy; hence the great need for the establishment and maintenance of a deep-sea diving school or of a course of instruction wherein divers may be given proper training and wherein new men may be trained to take the place of those who leave the service. It has been the experience of the salvage forces on the *S–51* and on the *S–4* that very few recruits to the ranks of trained deep-sea divers may be expected from civilian firms or outside sources, and those recruits who are of real value are the exceptions rather than the rule.

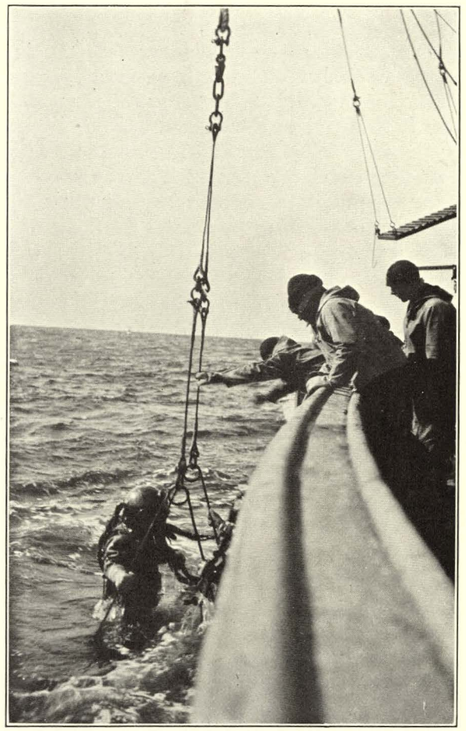


FIG. 141.—Bringing in a pair of divers, Burd and Scott, on the *Falcon*

Coincident with the need of training deep-sea divers comes the need of establishing a group of officers who are competent to act as diving supervisors in deep-sea salvage operations. To the limited number of officers who are already available may be added a few of the veteran divers who are no longer competent to carry on efficient work under water. This group should be further augmented by the addition of officers, preferably those who have had considerable diving experience and who demonstrate a liking for the diving game. Since at least two, and perhaps three, of these expert diving supervisors are necessary to stand watches during an emergency rescue operation or to supervise the complicated underwater work during an extended salvage operation, there should be a number of them available in the parts of the world where the submarine-rescue vessels are stationed.

Part XVII.—Section 6. Training and Experimental Work.

It is desired to emphasize the fact that no matter how ambitious, how complete, and how well developed a program may be established and carried out toward the training of divers, the conversion or building of rescue and salvage vessels, and the assembling of salvage gear at strategic points, the Navy can only consider itself in complete readiness to undertake rescue and salvage operations in an emergency by following with sincerity a well-defined plan for maintaining the ability of these forces by periodic training and frequent rehearsal of the special work

which they may be called upon to do. This requires that time and opportunity shall be set aside and given for experimental or actual rescue and salvage work and that employment schedules for the forces to which the rescue and salvage vessels are assigned shall provide for this training as a part of their regular work.

Salvage work, even when of an experimental nature, is always sufficiently interesting and intensive to bring out the full capabilities of the men engaged upon it as no other work can do, and it is firmly believed that all of the work which a submarine rescue or salvage vessel would be called upon to perform during the course of a year would benefit by the advantages to be gained in setting aside a portion of that year for the special work described.

There are now available at least two submarines of the S class which would require large sums of money for placing in service but which could be overhauled and made ready for experimental rescue and salvage work at reasonable expense. While a great deal of careful thought has been given to the suggestions and recommendations contained herein, it is felt that only by actually installing and testing these features on a submarine submerged can the relative value or usefulness of them be determined. In the case of alterations which must be done to a great number of submarines and which involves the sacrifice of weight or other features a certain amount of experimental work should certainly be undertaken before the alterations are carried out on a large scale.

APPENDICES

Appendix I.—Diving Procedure. Section 1. Statement of General and Fundamental Rules for the Most Efficient Performance of Work of Divers on Deep-Sea Salvage Operations.

The Bureau of Construction and Repair Manual, chapter 36, covers in great detail the correct practices and procedure to be observed when diving. The work for which these instructions were prepared and issued is necessarily general, hence an amplification of the text of the Diving Manual, covering deep-sea diving operations successfully carried out on the *S–4* salvage, may form a useful part of this report. Many of the notes following have to do particularly with ship salvage work, a feature which does not really come within the province of the Diving Manual.

Divers' work is no exception to the general rule that a task is half accomplished when it is properly studied and planned and when all necessary preparations have been made and all preliminary work done.

The plan which will prove most efficient is generally the one which provides for the maximum of work on the surface and the minimum by the diver. The preparations for that line of action require that each and every operation be carefully studied and planned, and that the work to be done by the diver be not only reduced to a minimum but restricted to operations which can most efficiently be performed under the circumstances.

An outstanding feature of the *S–4* salvage work was the manner in which the various phases of the work were laid out, then divided into operations, and each operation assigned to a diver or a group of divers as a definite task, upon the completion of which he would be brought to the surface with the satisfied feeling that he had accomplished his work for the day, even though he had not remained on the bottom for the full duration of his dive.

However, the satisfactory prosecution of work in this manner is based upon certain premises and rules, which may be set forth briefly as follows:

(*a*) The best of judgment, backed up by the advice and comments of the diving supervisors and checked constantly with the work being performed, must be employed in setting the amount and kind of work for each task and in picking the divers for the tasks, especially when the depths of water are considerable and the working periods limited.

(*b*) In the case of difficult and intricate work the tasks should be prepared and assigned well in advance and the divers given a preliminary description and a certain amount of what might be termed preparatory instruction.

(*c*) Having a definite task assigned, the diver may think of it and turn it over in his mind, as a result of which he may devise some better method, make suggestions as to improved methods or more efficient tools, or, best of all, ask questions which serve to fix the conditions to be encountered and the work to be accomplished more clearly in his mind.

(*d*) It will be found, and naturally so, that the diver, when consulted, will be very optimistic about the job and operations which he feels that he can execute under water, and equally pessimistic about those which he feels are difficult for a diver to perform, all of which should be considered when laying out the tasks and operations. He may also have a tendency to overestimate the amount of brute force which he can apply to a job under water, judging it more by his enthusiasm than by his abilities, when in a heavy diving suit, in cramped quarters, and so on.

(*e*) Therefore, the suggestions submitted by the divers must be tempered by the judgment of those in charge of the work and considerable tact must be employed in talking over the suggestions and ideas submitted by the divers and working them into a definite plan of action. This is especially true should the final decision as to methods to be employed differ from the ideas of the divers who are to carry them out, as a failure to carry out the instructions given invariably delays the work. For example, divers in the middle tunnel on the *S–4* were told to bend together their manila reeving lines under the ship by the use of a double becket bend; on the spot, they perhaps thought a hitch was good enough and made it so, with the result that when the reeving lines were hauled around the hitch almost immediately slipped off, whereupon the work had to be done all over again. The effort to obtain strict obedience of explicit instructions must not, however, be carried to the extreme—to the point where it may tend to suppress suggestions on the part of the diver and information as to the manner in which he has done his work.

(*f*) Each diver of a group, in addition to his own specific instructions, should be given a general idea at least of what the other divers of the group are to do, where they will be, what their likely movements are, etc. It was generally possible on the *S–4* job, when giving the instructions for the last time, just prior to placing the helmets on the divers, to have the remaining divers of a group "listen in" on what was told to each diver individually. Too much stress can not be laid upon the necessity for having the final instructions given to the divers by one person and one person only, such as the salvage officer. His assistants or others working with him may, in perfectly good faith and with the best of intentions, endeavor to help out by making suggestions to or by instructing the divers, but this practice, if continued, will almost invariably result in complications. For the same reason the giving of "long-winded" instructions should be avoided, as they tend only to confuse the minds of the divers, who have plenty to think about as it is.

(*g*) It must always be expected that a certain diver or group of divers can not perform or complete the task assigned to them due to circumstances often entirely outside their own control. For this reason it is the part of wisdom to give preliminary instruction to more than one diver or one group, provided it can be done without confusing their minds about another task in which they have already been instructed.

(*h*) This is especially true in the case of special gear which, when once sent to the bottom, is out of sight completely and can no longer serve for instruction purposes. For example, when the girth chains and bull ring of the bow towing bridle on the *S–4* were laid out, as shown in photograph (fig. 78), it was foreseen that not only would these chains have to be lowered to the proper position but they would have to be secured around the vessel, the bull ring would have to be shackled to the fore-and-aft wire towing pendant and the whole assembly hauled well to starboard and lashed there, perhaps continuing off and on for several days. The whole crew of divers were accordingly instructed simultaneously in what was to be done, they were shown all the parts and tools, and each operation was explained to them. It could be expected, therefore, as actually proved to be the case, that any of the first-string divers could be sent down as opportunity permitted and that they could perform their work on this towing bridle in intelligent fashion.

(*i*) Handling himself in delicate situations under water very frequently requires such intensive concentration on the part of the diver that it will be found not uncommon for him suddenly to forget important parts of instructions given to him. A diver properly indoctrinated will telephone up to the salvage vessel for instructions under such circumstances just as soon as he has straightened himself out; when the specific instructions are given him they will serve as a sort of index to his mind and he will generally recall all that has been told him on the surface.

(*j*) It is to be on hand at just such moments and to insure that the proper instructions are given that make it so extremely important for the salvage officer to be close by in the vicinity of the tenders and talkers when work is going on under water. Even though temporarily absent for a moment, those on deck will invariably call for him before sending word to the divers.

(*k*) It is considered the part of wisdom to avoid altering the task to be performed by a diver while he is on the bottom, unless circumstances make it unavoidable; also, to add to the tasks in which he has been instructed and of which he has been told. Doing this necessitates delivering instructions in the form of a message to the diver. Even though such a message may be transmitted, the satisfactory transfer of its meaning to the mind of the diver varies inversely as about the square of its length.

(*l*) Should a change in procedure or work be found necessary during the course of a dive, it is almost without question the most expeditious plan to instruct a new diver and to send him down to replace the one on the bottom.

Without detracting in any way from the excellent, laborious, and courageous work performed by deep-sea divers under conditions that most humans do not care to experience, it must be admitted in all frankness that their opportunities for observing conditions and obtaining information are comparatively limited and their observations are likely to be affected by their imagination, in their eagerness to make as complete a report as possible. While there are a few divers who are exceptions to the above, it may be accepted as a safe rule that the testimony of one diver should always be corroborated by that of another unless other observations, conditions, and data check the information supplied by the diver in a conclusive manner. In this, of course, as in all other things, the mind of the one in charge will have to be the best judge of the exact amount of information supplied by each diver which can be used in piecing together the story, remembering always that every story must somewhere have a logical foundation.

Several lines of work should, if practicable, be kept going simultaneously, so that in case the diving vessel is required to lie in a certain position, or a diver with special mechanical ability is not available or some gear has to be altered or completed, there will remain some other useful work which can be done. In other words, if the weather is such as to make it advisable to work under or inside a submarine, there should be work already planned and prepared for which can be done on the topside.

It should be borne in mind first, last, and all the time that, in the words of a salvage officer on a former job of this kind, "Under water on a wreck the diver's power is small, his chances for making mistakes in observations are excellent, his ability to think clearly is radically reduced, and his power to send or receive messages from the surface is rotten, in spite of the best telephone equipment." Furthermore, that the diver is only the means of accomplishing a certain portion of each task under water and that he is not the one who must be called upon or expected to perform the whole task by himself. The disadvantages under which he works are sufficiently great and his time is so valuable that an efficient plan calls for only the use of his vision or his sense of feel and for the performance of such manual labor as can not possibly be performed on the surface or by those who are at the surface.

Appendix I.—Section 2. Change of Scene and Leave.

In the case of long salvage jobs, especially when the work is constantly delayed by the weather or when it is slowed up to such an extent as to cause the divers and others to begin to lose interest in their work, it is most important that they be given a change of scene to prevent them from going stale. Also, when the work is being pushed hard, the divers and salvage crew, as well as the work, will benefit by periodic leave for the personnel when they may relax and catch up on sleep. The salvage crew quite frequently will be assembled as an emergency measure and

many of its members will be drawn from their homes or their regular employment on short notice without leaving them time to make proper provision for their families or their regular work while they are away.

On the *S–4* job periodic leave was granted to all members of the salvage crew who could be spared. First, they were given two days per month and later three days per month. Additional personnel was obtained in many cases to enable the work to go on just the same while they were absent. The divers were finally given one week off in every three; in other words, they were divided up into three sections, two of which were working sections and one a leave section. Although the work on the *S–4* proceeded at such a rate that these rest periods were not imperative to prevent staleness or fatigue, they should form the basis of any planning done on long salvage jobs in the future.

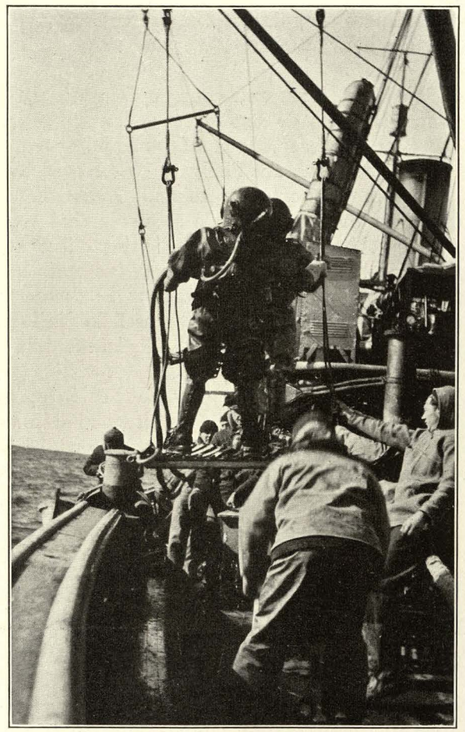


FIG. 142.—Divers coming in over the rail. Note construction and rigging of diver's stage with bails and slings

Appendix I.—Section 3. Observation of Divers' Work.

During the work on the *S–4* it was possible to follow the operations of the divers and to know where they were and what they were doing by one or more of several methods which may briefly be described here to advantage. Whether these methods would still be applicable in depths in excess of 120 feet could only be determined by experiment.

(*a*) A pneumatic drilling machine in operation could be detected by feeling the supply-air hose at almost any point due to the peculiar variation of pressure within the hose when the machine was actually running. The operation of the machine could generally be checked by listening on the telephone of the divers who were close to it.

(*b*) The operation of a pneumatic hammer could be detected with greater ease in the same manner. As a matter of fact, it was perfectly possible, when divers were working on the *S–4* with pneumatic hammers, or with hand hammers and chisels of fairly large size, to go down into the after hold of the *Falcon* where it was quiet and to hear every blow that was made. The noise of the pneumatic hammer could also be heard up through the water by simply leaning over the rail of the salvage vessel.

(*c*) The best guide as to the operation of the arc torch was the ammeter connected in series with it. The ease with which the diver was maintaining his arc and the exact periods when he was doing cutting were plainly indicated by the instruments.

(*d*) When the gas torch was in operation the fact that gas was flowing could be noted at the reducing valves and the adjacent gauges and it was possible in this manner to form an idea of the approximate proportions of each gas which was being used by the diver. When the torch was

lit the noise of it could almost invariably be heard over the telephone of the diver who was operating it and the large bubbles of gas from the torch would break on the surface and emit small bubbles of smoke.

Appendix I.—Section 4. Air Pressure on Diving-Air System.

Concerning pressures to be carried in the diving main of the rescue vessel, it is to be noted that this consists of several parts about as follows:

(*a*) Pressure in pounds per square inch gauge corresponding to the depth in feet of sea water where the divers are operating.

(*b*) Drop in pressure in the diving-air hose from the diving-air main to the diver's control valve. With the standard diving hose now in use, having an internal diameter of one-half inch, fitted with couplings which have an internal diameter of three-eighths inch, this drop will vary from 10 to 15 pounds per square inch for 400 feet of hose to 20 or 25 pounds per square inch for 800 feet of hose, depending upon the rate of flow of the air.

(*c*) An excess pressure of from 30 to 50 pounds per square inch above water pressure (at the depth of the dive) is required to be carried in the testing tank by the provisions of the Bureau of Construction and Repair Manual, article 3628, paragraph 2 (c). When feeding air from a diving main, as on the *Falcon*, this excess pressure is assumed to be taken at the diver's air-control valve. This figure includes, for all practical purposes, the increased pressure within the diver's suit and above the sea pressure outside.

(*d*) Pressure on diving-air main.

(*e*) Drop in pressure from diving-air compressors to diving-air main.

(*f*) Delivery pressure of diving-air compressors.

A summary of the component pressures as employed on the *S–4* operations and as would probably be utilized on any future operations of the *Falcon* may be set down as follows:

Subdivision of pressure in diving-air system, pounds per square inch, following tabulation above	A Sea pressure	B Drop in hose	C Excess pressure	D Air-main pressure	E Drop in system	F Air-compressor pressure
Falcon on S–4 salvage using diving-air plant as modified by the navy yard, New York, during 1927	48	14	86	148	2	150
Falcon on S–4 salvage with governors reset to deliver a lower pressure in the diving-air main	48	15	41	104	1	105
Falcon on S–4 salvage with the first Boston air-conditioning plant in operation and improved hose couplings	48	12	45	105	45	150
Falcon on rescue or salvage work at limit of present capabilities, with no extremes of temperature	100	18	30	148	2	150
Falcon on possible rescue work at 300 feet depth, with proposed 400-pound diving-air plant and 800 feet of diving hose	135	25	50	210	190	400

As an indication of what it should be possible to accomplish in the way of lowering the dew point with the new diving-air systems having 400-pound compressors, performing diving operations at 300 feet, the following is quoted from inclosures of commandant, Boston, letter SS109/L11–1 of February 4, 1928, to Bureau of Construction and Repair, copy to commander *S–4* salvage force and commanding officer *Falcon*. The method of determing the dew point of the air which has previously been compressed, then cooled, and then expanded, was described in Part VI, section 6, of this report. The figures given hereunder are approximate only; exact figures may be made up from the table in Part XVI, section 2F.

A. Moisture content at 35° F., as delivered from special cooler, 2.5 grains.

Compressor pressure		400
Reduction in pressure		200
Air-main pressure		200
Absolute humidity		1. 25
Relative humidity at 30° F	(per cent)	67
Dew point at air-main pressure		20° F.

B. Moisture content at 40° F., as delivered from special cooler, 2.9 grains.

Compressor pressure		400
Reduction in pressure		200
Air-main pressure		200
Absolute humidity		1. 45
Relative humidity at 30° F	(per cent)	75
Dew point at air-main pressure		24° F.

C. Moisture content at 50° F., as delivered from special cooler, 4.1 grains.

Compressor pressure		400
Reduction in pressure		200
Air-main pressure		200
Absolute humidity		2. 05
Relative humidity at 30° F	(per cent)	100
Dew point at air-main pressure		30° F.

It was customary to have from 130 to 145 feet of diving hose in the water when the divers were working at the average depth of about 100 feet. When working inside a little more slack was allowed than the actual distance from the diver to the rail called for because there was a diver at the hatch of the submarine whose sole duty was to tend the divers inside. When divers were working on the pontoons the slack was reduced to the absolute minimum in order to insure that the divers would not drop suddenly should they lose their footing on the pontoon; in fact, it was the practice to keep their lines so taut when working on the pontoons that they were required frequently to call for slack from the *Falcon*.

Appendix I.—Section 5. Limitations on Deep-Sea Diving Operations.

Based upon experience with deep-sea diving in rescue and salvage work on submarines, including both personal experience on the *S–4* and a careful study of reports and testimony of those who conducted rescue and salvage operations on the *S–51*, and having in mind the present limitations in the art of deep-sea diving, it may be stated that effective rescue work can be performed on submarines by only a limited number of divers working simultaneously. This for the reason that on rescue work the divers are subject to entanglements due to movements of the rescue vessel which can not always be properly moored, to the presence of loose lines and wreckage which have not yet been cleared from the submarine, and to incomplete knowledge concerning the location and position of the vessel and the condition of gear upon which the diver's work will have to be done.

The limiting number of divers actually engaged in work upon the submarine may be established approximately as follows:

Four divers at 100 feet.
Three divers at 150 feet.
Two divers at 200 feet.
One diver at 300 feet.

For purposes of calculating and adjusting the divers' air supply, it must be assumed that a number of divers equal to that given above will be in process of decompression in the water on

the divers' stages and that the recompression chamber on the rescue vessel will be in operation simultaneously.

The diving-air system of the rescue vessel should provide a sufficient reserve of diving air so that in the event of casualty to the compressors or to the rescue vessel such as to cause complete stoppage of the power-driven compressors, there will be sufficient air stored in the diving-air plant to supply the divers in the water until such time as they can be brought from underneath or from within the submarine and taken abroad the deck of the rescue vessel, with a margin of from 50 to 100 per cent. With the divers clear, this operation should require not more than 15 minutes or at the most 30 minutes. With the divers fouled, its duration may be indefinite; from experience on the *S–4*, it is known that as much as three hours may be required for this work.

Appendix II.—Decompression Tables as Used on " S–4 " Salvage for Work in Cold Water.

The report of the *S–4* diving supervisor, Chief Gunner C. L. Tibbals, concerning revised decompression tables for work in cold water, is included for information and guidance on future work. These tables are constructed on somewhat different principles than those used in the preparation of the decompression tables listed in article 3670 of the Bureau of Construction and Repair Manual, and their efficacy under the conditions encountered on the *S–4* salvage is proved by the fact that in 564 dives, all told, there were encountered only 10 cases of caisson disease, none of them serious. No divers missed more than one consecutive day of work on this account.

File No. JJ–12D1.

U. S. S. "FALCON,"
Provincetown, Mass., January 28, 1928.

From: Diving Supervisor *S–4* Salvage.
To: Bureau of Construction and Repair.
Via: Commander *S–4* salvage force.
Subject: Decompression tables used to date during *S–4* salvage operations.

1. The following tables have been devised for use in decompressing divers during the *S–4* salvage operations.

2. The time given in these tables are calculated for cold water and are somewhat lengthend over those required for tropical waters.

3. To date 170 dives have been made and divers decompressed, using these tables, with only one case of caisson disease, this being a mild case of skin bends.

4. During extremely cold weather, as now encountered, divers will not decompress in the water. Decompression is accomplished by remaining on the stage to do the first two stops, then being brought directly from the water. Helmet, shoes, and belt are removed, diver then placed in the decompression chamber as soon as possible, the elapsed time being not over three minutes. Pressure is raised to the point of the last stage completed in the water and decompression is then completed as per schedule.

5. New type tables constructed for *S–4* salvage, depth of water 86 feet, are as follows:

NOTE.—These tables are not to be used in treatment.

Depth of water, 86 feet:

Up to 45 minutes—	
50 feet, 25 pounds	2 minutes
40 feet, 20 pounds	5 minutes
30 feet, 15 pounds	18 minutes
20 feet, 10 pounds	16 minutes
10 feet, 5 pounds	10 minutes
	51
45 minutes to 1 hour—	
50 feet, 25 pounds	3 minutes
40 feet, 20 pounds	6 minutes
30 feet, 15 pounds	23 minutes
20 feet, 10 pounds	19 minutes
10 feet, 5 pounds	10 minutes
	61
1 hour to 1¼ hours—	
60 feet, 30 pounds	4 minutes
50 feet, 25 pounds	8 minutes
40 feet, 20 pounds	20 minutes
30 feet, 15 pounds	23 minutes
20 feet, 10 pounds	17 minutes
10 feet, 5 pounds	10 minutes
	82
1¼ hours to 1½ hours—	
60 feet, 30 pounds	5 minutes
50 feet, 25 pounds	9 minutes
40 feet, 20 pounds	26 minutes
30 feet, 15 pounds	29 minutes
20 feet, 10 pounds	27 minutes
10 feet, 5 pounds	10 minutes
	106
1½ hours to 2 hours—	
60 feet, 30 pounds	5 minutes
50 feet, 25 pounds	11 minutes
40 feet, 20 pounds	29 minutes
30 feet, 15 pounds	33 minutes
20 feet, 10 pounds	28 minutes
10 feet, 5 pounds	15 minutes
	121

Depth of water, 102 feet:

Up to 45 minutes—	
50 feet, 25 pounds	3 minutes
40 feet, 20 pounds	8 minutes
30 feet, 15 pounds	21 minutes
20 feet, 10 pounds	18 minutes
10 feet, 5 pounds	10 minutes
	60
45 minutes to 1 hour—	
60 feet, 30 pounds	5 minutes
50 feet, 25 pounds	10 minutes
40 feet, 20 pounds	22 minutes
30 feet, 15 pounds	23 minutes
20 feet, 10 pounds	17 minutes
	87
1 hour to 1¼ hours—	
60 feet, 30 pounds	5 minutes
50 feet, 25 pounds	10 minutes
40 feet, 20 pounds	25 minutes
30 feet, 15 pounds	30 minutes
20 feet, 10 pounds	26 minutes
10 feet, 5 pounds	18 minutes
	114
1¼ hours to 1½ hours—	
60 feet, 30 pounds	6 minutes
50 feet, 25 pounds	11 minutes
40 feet, 20 pounds	28 minutes
30 feet, 15 pounds	33 minutes
20 feet, 10 pounds	28 minutes
10 feet, 5 pounds	20 minutes
	126
1½ hours to 2 hours—	
60 feet, 30 pounds	6 minutes
50 feet, 25 pounds	12 minutes
40 feet, 20 pounds	30 minutes
30 feet, 15 pounds	35 minutes
20 feet, 10 pounds	30 minutes
10 feet, 5 pounds	20 minutes
	133

6. There follows the Navy standard or Admiralty type table, Bureau of Construction and Repair Manual, article 3670, lengthened considerably for use in decompression chamber when the diver is brought directly out of the water. This table is subject to modifications by the diving supervisor, to suit particular conditions. (Subsequent to the date of this report, when sea-water temperatures dropped to 35° F. and below, all decompression in the water was abandoned, the stops at 50 or 60 feet being limited only to the time necessary for both divers to get on the stage and to get the stage unshackled.)

NOTE.—This table is not for use in treatment.

Depth of water, 102 feet:

Up to 45 minutes—	
50 feet, 25 pounds	4 minutes
40 feet, 20 pounds	6 minutes
30 feet, 15 pounds	11 minutes
20 feet, 10 pounds	16 minutes
10 feet, 5 pounds	25 minutes
	62
45 minutes to 1 hour—	
50 feet, 25 pounds	4 minutes
40 feet, 20 pounds	6 minutes
30 feet, 15 pounds	13 minutes
20 feet, 10 pounds	20 minutes
10 feet, 5 pounds	30 minutes
	73
1 hour to 1¼ hours—	
60 feet, 30 pounds	5 minutes
50 feet, 25 pounds	9 minutes
40 feet, 20 pounds	12 minutes
30 feet, 15 pounds	18 minutes
20 feet, 10 pounds	23 minutes
10 feet, 5 pounds	30 minutes
	97

Depth of water, 102 feet—Continued.

1¼ hours to 1½ hours—	
60 feet, 30 pounds	5 minutes
50 feet, 25 pounds	12 minutes
40 feet, 20 pounds	21 minutes
30 feet, 15 pounds	25 minutes
20 feet, 10 pounds	30 minutes
10 feet, 5 pounds	35 minutes
	128
1½ hours to 2 hours—	
60 feet, 30 pounds	6 minutes
50 feet, 25 pounds	13 minutes
40 feet, 20 pounds	24 minutes
30 feet, 15 pounds	30 minutes
20 feet, 10 pounds	35 minutes
10 feet, 5 pounds	35 minutes
	143

C. L. TIBBALS.

Appendix III.—Section 1. Diving Hose Couplings.

The following is paraphrased from commander *S–4* salvage force letter S94 (S–1003) (File JJ–12D1) of January 13, 1928, to commandant, New York, on the subject of couplings for diving hose.

1. In the course of an examination of parts of the Navy standard diving gear and an exhaustive study of its performances during the salvage work on the *S–4*, it was brought out that the design and construction of the hose coupling (shown in fig. 143) was susceptible of improvement. The following defects and shortcomings were noted with gear then on the *Falcon:*

(*a*) The bore of the coupling is less than the bore of the hose, resulting in a pressure drop at the coupling and a constriction which causes a certain amount of refrigeration.

(*b*) The bore is in most cases cored, probably to obtain a tighter casting, but the internal surface of the bore is often rough and the irregularities of the sand-cast surface form projections to catch snow or ice particles and to cause them to collect.

(*c*) The ends of the internal hole are not tapered so as to cause the internal surface of the hole to merge easily into the interna. surface of the hose when the coupling is in place.

(*d*) In this connection it is to be noted that on Plate 16, page 36–12, of the Bureau of Construction and Repair Manual, the last barb is shown as being five-eighths inch in diameter, whereas all the others are apparently eleven-sixteenths inch in diameter, although the only one so marked is about midway of the shank of the coupling. *Actually*, on many of the hose couplings now on hand, the barb about midway of the shank and one of the barbs near the end are materially greater in outside diameter than the remainder and they are so placed that the second and third clamps on the hose come inboard of them, near the coupling proper. In this manner the coupling is locked in the hose and even though it may, as occasionally happens, become loose enough on the hose to turn, it can not pull out.

2. Following the inquiry made by the salvage force in its despatch of January 6 to navy yard, New York, there was forwarded by that yard to the *S–4* salvage force, a print of New York plan, Hull Division No. 78713, type plan, couplings for air hose for diving apparatus, marked up, dated January 6, 1928, which showed the following improvements:

(*a*) Couplings were made of copper-nickel alloy, machined from the solid bar, so that they would be much stronger. (The use of this material had been proposed some time previously.)

(*b*) Hole was to be bored (and reamed, although not so stated) so as to insure a smooth internal surface.

(*c*) Bore at outer end was to be tapered to seventeen thirty-seconds inch diameter. This should be for a distance of one-fourth inch to five-sixteenths inch.

(*d*) Bore at inner end was to be tapered to fifteen thirty-seconds inch diameter, for a distance of three-eighths inch or so, to avoid the effect of the sharp edges on the adjacent parts of the two couplings in case they did not pull up exactly in line.

(*e*) Internal bore was made seven-sixteenths inch instead of three-eighths inch.

(*f*) It was assumed that tests would be made to insure that the copper-nickel parts would not drag on each other when screwing them up tight. This tendency exists and can be eliminated by careful machining.

3. However, the following shortcomings still existed in the design shown, New York plan 78713, dated January 6, 1928, and they were considered of major importance:

(*a*) Not only are there no rings of greater diameter for holding the hose back of the clamp but there are no longer any rings or barbs of saw-tooth form.

(*b*) In place of them are shallow grooves which are considered entirely inadequate to hold the coupling in place on the hose in case it becomes loose enough to turn.

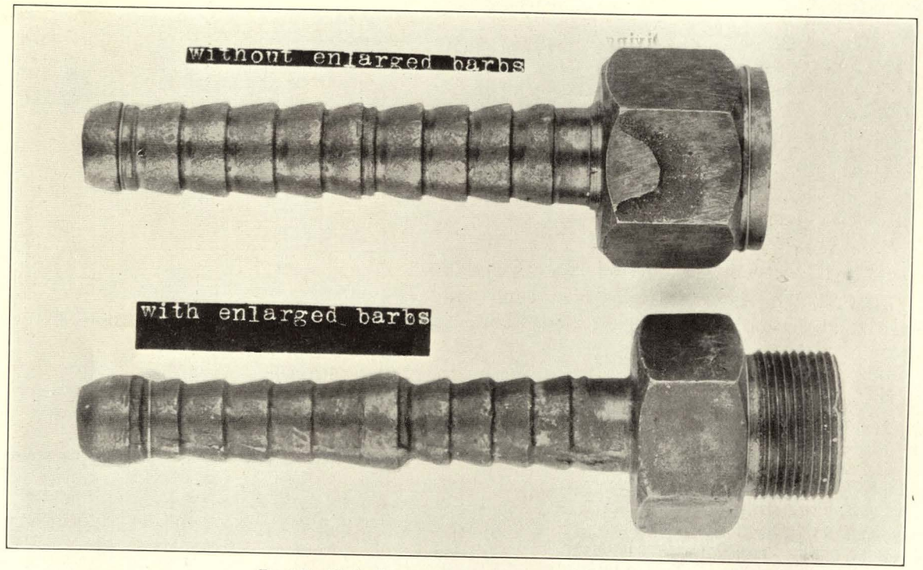


FIG. 143.—Diving-hose couplings, old style, cast composition

(*c*) The fact that the shank on the new coupling design is larger than the old shank is considered not sufficient reason for omitting the barbs.

(*d*) On some of the old-style couplings there are two barbs adjacent to the hose clamps fully one-sixteenth inch greater in diameter than the remainder. (See fig. 143, lower view.)

4. It was recommended, therefore, that the design shown on New York plan 78713 be altered as described in paragraphs 2 and 3 above and that sufficient couplings be made up of copper-nickel alloy of the new design to equip one 600-foot length of Navy standard diving hose, which was shortly afterward ordered by the force.

The alterations so made are now shown on New York plan 78713, approved January 20, 1928, C. & R. No. 141478. The hose made up with these new type couplings was subjected to test pressures of 900 pounds per square inch, and it was found entirely satisfactory in service on the *Falcon*. Although there were no opportunities to determine quantitatively the improvements effected by the new design of coupling in regard to the flow of air, it has every appearance and indication of being immeasurably superior to the old cast type coupling for special and general service.

Appendix III.—Section 2. Diving Knives.

Certain improvements in the design and construction of diving knives were made, tending toward greater efficiency. Instead of the single-edged blade described in the Bureau of Construction and Repair Manual, chapter 36, article 3612 (1), one edge of the blade was made sharp for ordinary cutting and the other edge was made serrated, about 10 or 12 teeth to the inch, for more expeditious cutting of certain materials.

The recommendation is made that the blades of these knives be made in the future from corrosion-resisting steel, as is used for modern cutlery, to avoid the excessive corrosion which is now experienced.

FIG. 144.—Diving lamp, showing method of carrying lamp

The sheaths were made cylindrical instead of flat, and the knives were held in place, not by the friction of a spring of more or less uncertain behavior but by being screwed into the sheath with a thread on the lower end of the handle.

Appendix III.—Section 3. Diving Lamps.

The new type of lamp developed on the *S–51* salvage job to replace the then standard diving lantern, as described and illustrated in article 1316 and Plate 30 of the Bureau of Construction and Repair Manual, had been perfected during 1926 and 1927 by the Westinghouse Co. and new lamps of the final design had been furnished to the *Falcon* as part of her equipment. These diving lamps were provided with a pressure-proof globe of 1,000 watts rating, made watertight in the plug by a rubber collar, cemented on. The reflector was of ample size, chromium-plated to resist surface corrosion, and covered with a substantial screen. The cable coupling was the same design that had been worked out on the *S–51*. The size and shape of the lamp, the manner of carrying it, and the details of construction are clearly shown in Figures 144 to 148, inclusive.

FIG. 145.—Diving lamp. Method of holding lamp

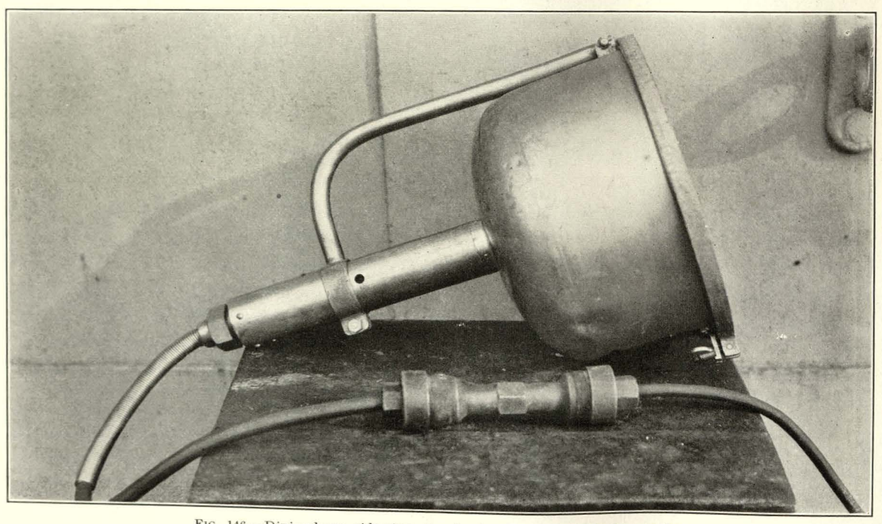


FIG. 146.—Diving lamp, side view, showing handle, barrel, and cable coupling

The performance of these diving lamps on the *S–4* job was admirable, and their design and construction leaves little to be desired in the way of improvement, save for a possible redesign of the coupling, which is now quite heavy.

In the course of the *S–4* operations efforts were made through the Naval Research Laboratory, Bureau of Standards, and large electric-lamp companies and others to obtain globes filled with neon gas or lamps of a different design which would throw their rays to a greater distance under water. A mercury vapor lamp was brought from the Naval Research Laboratory at Bellevue and tried on the *Falcon*, but it was complicated in operation and awkward to handle, so that it did not fill the needs of the salvage force. It was learned that neon lamps also would necessitate complicated equipment.

The correspondence relative to the investigations about improved diving lamps may be found in File S64–4, Serial 38566, of the Bureau of Construction and Repair.

Taking it on the whole, not much development was achieved along this line, and the problem, like the penetration of fog, remains yet to be solved.

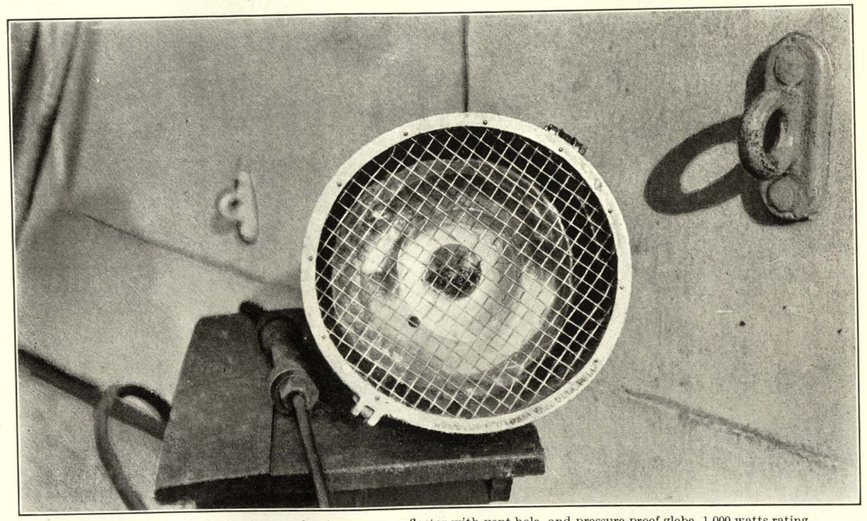


FIG. 147.—Diving lamp, front view, showing screen, reflector with vent hole, and pressure-proof globe, 1,000 watts rating

Appendix III.—Section 4. Diver's Tool Bag.

Although the Bureau of Construction and Repair Manual, article 3605 (4), and Plate 35 of the Manual describe and show a suit of overalls with pockets for slipping over a diving dress and for carrying small tools, it was found most advantageous on the *S–4* operations to place the tools needed and used by a diver in a tool bag of heavy canvas, as illustrated in photograph. (Fig. 148.) These bags were sufficiently sturdy to carry weights up to 100 or 150 pounds, as, for instance, a 2½-inch detachable link with all its parts and all of the tools necessary to assemble and disassemble it. The bags had large eyelets for flooding and draining. The tool bag was deep enough to carry any ordinary hand tool, except a crowbar, without danger of falling out, and yet it was not so deep but that a diver could find a small tool at the bottom of it. In the case of very small articles such as bolts and nuts, small drills and taps, lead pellets for shackles,

etc., these were secured to individual lengths of marline or rope yarn and tied to the handle of the bag or through the eyelets. When the tool bag was loaded normally it was carried over the arm of the diver; when it was heavily loaded it was generally sent down and brought up by the use of a small manila lowering line.

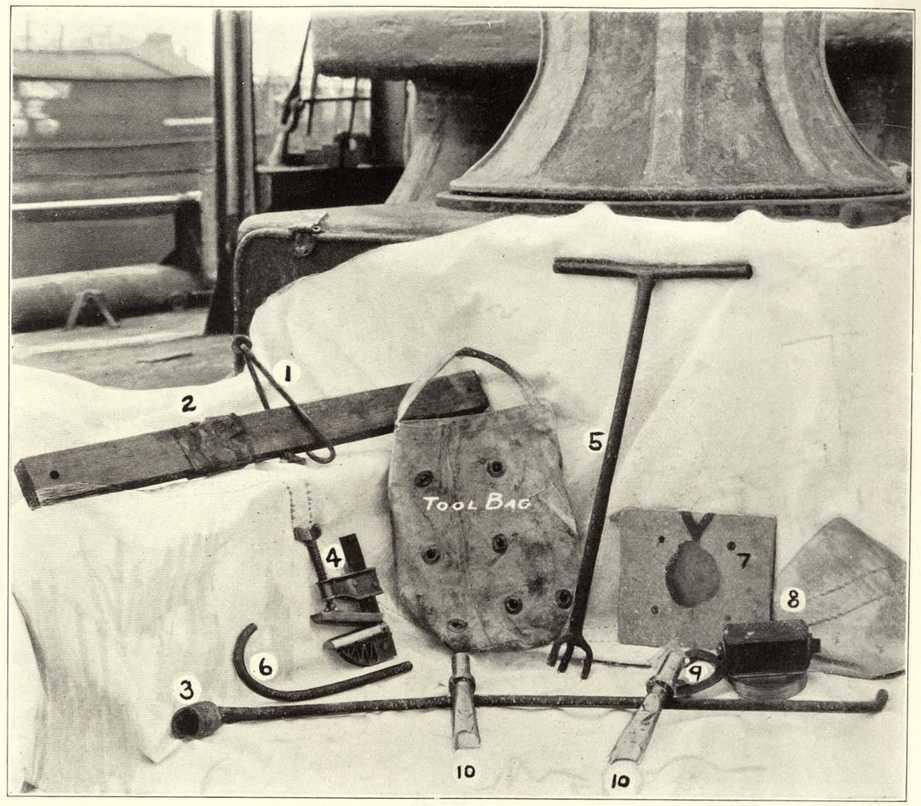


FIG. 148.—Miscellaneous tools and equipment used in *S-4* salvage operations. 1, Strongback and hook bolt, and 3, special pipe wrench used by Eadie, Carr, Eiben, and Wilson in closing and securing the levers of ventilation flap valves on forward control-room bulkhead. The hook bolt 1 was placed over the after lever so that lever could be held down by one diver while the other diver clamped it, since both divers could not reach the lever simultaneously in the narrow passage. The wrench 3 was slipped over the end of the forward lever so one diver in the passageway aft of the door could hold the valve lever closed while the other diver inside the door opening clamped and secured it. 2, Sheet lead wrapped around wood to make it sink. 4, Hose clamp for pinching and shutting off air when working on blowing hose. 6, Hook pipe for blowing bow buoyancy and forward trimming tanks on *S-4*. 5, Forked wrench for use on small handwheels of valves in control room. 7, Template of asbestos board used for burning spill-pipe hole in *S-4* torpedo room by means of arc torch. 8, Brass plug with double-ended pipe connection for fuel-oil filling connection on *S-4*, and 9, Lead gasket for this plug. 10, Splitting tools for pneumatic hammer, designed as a development and improvement on those shown in Figure 29

Appendix IV.—Diver's Telephones.

The substance of this appendix is copied from a report on telephones made by the commander *S-4* salvage force in his letter S94(S-1098) of March 13, 1928, to the Bureau of Construction and Repair, with some changes and additions as a result of a more careful survey of the situation since the conclusion of the operations on the *S-4*. In view of the promise which this

FIG. 149.—Diver Kallinoski with helmet removed, showing transmitter and jack box inside helmet, method of mounting and securing head phones to diver, and jack plug from head phones lying just in front of diver's left shoulder

type of telephone holds out for future development, the report is submitted in full so that the merits of this equipment may become common knowledge in the Navy.

The diving telephones of the improved batteryless type, as developed by the Pittsburgh Deep-Sea Diving Telephone Co., Pittsburgh, Pa., and employed during the diving operations at Provincetown, were designed to replace battery telephones as described in Bureau of Construction and Repair Manual, article 3617, and as shown on Plates 31, 32, and 33 of the Manual. The new phones were designed to obtain better acoustical properties, reduce upkeep, and increase reliability.

These telephones were still in the experimental stage at the time of rescue operations on *S–4* in December, 1927, but reports of their superior performance on preliminary test were so encouraging that it was decided to give them a trial in service, in view of the continued trouble and poor service with the then standard diving telephones, operating with dry cells.

An order for 15 sets of instruments was sent from the *S–4* salvage force about December 27, 1927, and the first instruments were delivered in about one week thereafter. Three sets of diving gear were fitted up with instruments and cable then available (the first cables were only 200 feet long) and placed in service on January 4, 1928.

The batteryless telephones were in continuous service on *S–4* salvage from that time, to the complete exclusion of the former standard battery telephones. Developments were later suggested by the salvage force and by the inventor, Mr. F. G. Troisi, and worked up by the Pittsburgh Deep-Sea Diving Telephone Co., in the form of double diaphragm transmitters, special mouthpieces, plated diaphragms, multiple talking systems, and so forth, all of which will be described later. Incidentally, it may be noted that as the use of this type of telephone is being extended, the name of the firm has recently been changed to the Batteryless Telephone Equipment Co.

DETAIL DESCRIPTION

The improved batteryless telephone consists essentially of the following parts:

(*a*) Diver's head set.
(*b*) Diver's transmitters.
(*c*) Talker's outfit, consisting of head set and transmitter.
(*d*) Telephone cable.
(*e*) Carrying case.

There are no batteries, transformers, condensers, magnetos, switches, or other devices such as form parts of an ordinary telephone equipment. The batteryless telephone is operated by currents induced in small coils through the vibration of the transmitting diaphragm. The coils of all transmitters and receivers are connected in series in a simple loop, so that transmitters may be used interchangeably.

The secret of the successful operation of this simple device, so far as can be learned, is the manner in which the standard current-carrying cables are assembled. By being laid up with a certain twist, the inductive effect is such that the very minute currents generated in the transmitters are maintained for effecting vibration of the receiver's diaphragm at the far end of the line.

(A) The diver's head set consists of an artificial leather cap laced in the back for adjustment, from which the telephone receivers are suspended. The cap is adjustable as to size and is held firmly in place on the diver's head by means of a chin strap, as shown in Figure 149. On only two occasions did the cap become misplaced on the diver's head with the helmet in place; in both cases the front edge was pulled down over his eyes and the diver was unable to see anything through his glass ports.

A single rubber-covered cable connects the two receivers over the top of the cap; the junction with the connecting cable is made in a very small aluminum tee fitting at the very top. A single rubber-covered cable with a single-point jack plug serves to connect the diver's receivers with the jack box in the helmet. (See fig. 150.)

When the diver's helmet is removed after he comes to the surface the cap is quickly slipped forward over his head and face and the chin strap cleared by a single movement of the tender's hand. The cap, with receivers, is then deposited in the helmet, ready for use by the next diver, without the necessity for pulling out the jack plug.

(B) The diver's transmitter is fitted in the usual recess in the helmet. (See fig. 149.) A jack box with but one opening is used, making the operation of plugging-in very simple and rapid.

The leads from the transmitter pass through the gooseneck at the back of the helmet (fig. 150) and attach to a specially formed fiber block upon which are mounted two copper contact springs, intended to bear on the two insulated portions of the jack plug on the main telephone cable.

The goosenecks on the Mark V helmets now in use were not designed for this type of plug, and it is therefore necessary to make the jack-box connection in the form of an adapter rather than a regular fitting, using washers or shims under its base to bring it in proper position relative to the gooseneck. Furthermore, the leather washer interposed between telephone-cable fitting and gooseneck, for securing a water-tight joint, has a tendency to compress and change the position of the jack plug relative to the contacts in the box. These features combined to cause much trouble during the second month of operation of these instruments on the *S–4* salvage, but as these defects have to do with purely mechanical features instead of with the electrical or acoustic features, it is reasonable to expect that a new type of jack box may be shortly developed which will prove quite satisfactory.

The precautions to be observed in the care of diving telephone equipment, as outlined in Bureau of Construction and Repair Manual, article 3634, paragraph 3, apply equally to the batteryless telephones, especially with regard to the transmitter diaphragms. The diaphragms quickly become wet and the mouthpieces partly filled with condensation from the breath, to say nothing of moisture, rain, and spray which may be deposited on them. If not cleared and dried before being put away after each day's work the diaphragms will rust and their efficiency be correspondingly diminished.

Diaphragms of other material more resistant to corrosion than enameled sheet steel have been tried by the Pittsburgh Deep-Sea Diving Telephone Co. For use in the immediate future gold-plated diaphragms have been ordered for the transmitters now in use and on hand.

(C) The talker's outfit consists of two receivers fitted to a spring headband, with rubber cables connecting in a very small cross junction box of aluminum to a single short lead to the transmitter and a single long lead to the telephone cable proper. (See fig. 151.)

The original plain transmitter without mouthpiece which was first used on the *S–4* was followed by the development of (1) a light aluminum mouthpiece to fit the face; (2) a handle on transmitter for more convenient holding by the talker; (3) a breastplate and bracket for holding transmitter, as on fire-control instruments (see fig. 151); and (4) a double diaphragm transmitter, with two separate transmitters set at an angle at 70° to 90° in front of the mouth to increase the strength of current and volume of sound. (See fig. 152.)

The long lead on the talker's outfit carries a jack box which receives the jack plug on the inboard end of the telephone cable, the connection being made by a female coupling which screws up by hand. The abuse which this small cable will withstand is shown in Figure 153, where knots are tied in it.

FIG. 150.—Rear view of helmet with gooseneck for telephone cable at left and inlet valve and gooseneck for air at right. Air-control valve lying on diver's left knee. Lack of requisite flexibility in the telephone wires just below the gooseneck connection caused these wires to carry away under the severe wear and tear to which the diving equipment was subjected

FIG. 151.—Diver in full diving dress. The three-finger gloves are cemented water-tight to the diving dress. The diver's left hand is on his air-control valve. Air hose at diver's left side; combined telephone cable and life line at his right side. Note lashing of face plate. Talker at right, with full telephone equipment

Cases and fittings for receivers and talker's instruments were of cast aluminum, coated with zinc. The company claimed that the parts had been thoroughly tested for resistance to corrosion by salt air, and, for the *S–4* job at least, the parts seemed to stand up well.

(D) The telephone cable consists of a composite assembly of four wires—two stranded flexible phosphor-bronze cables forming the life line proper and two special telephone wires, laid up with the bronze cables to form a rough square. The whole is made up with a sheath and a smooth rubber jacket to form a cable about thirteen-sixteenths inch in diameter, as shown in Figures 151 and 153.

The phosphor-bronze cable wires are secured to a socket at the outboard or helmet end of the cable in the same manner that a wire rope is attached to a socket. The telephone wires are attached to the two parts of a jack plug at each end of the cable.

FIG. 152.—Improved type of double-diaphragm telephone transmitter developed by Pittsburgh Deep-sea Diving Telephone Co. as a result of experiments and work on *S–4* salvage. Note police whistle for assistance in calling

A male coupling at the outer end of the cable screws to the gooseneck on the helmet; a similar male coupling at the inner end takes the fitting on the end of the talker's lead.

The two phosphor-bronze cables forming the strength part of the life line have a combined breaking strength of 5,000 pounds—over ten times the strength of the life line formerly used.

The service to which the combined life line and telephone cable is subjected is severe, especially adjacent to the helmet fitting, where the line is frequently hauled taut at an angle to the fitting and where the telephone cable is used as a handle to the helmet when moving the latter around. It is believed that there should be more slack left in the telephone wires when the cable is made up. A new type of cable designed to give greater flexibility for withstanding this bending is shown in the foreground in Figure 153.

In a considerable number of instances on the *S–4* salvage the outer end connection of the telephone cable has had to be reassembled on the *Falcon*, due to breaking of the telephone wires. This is an operation requiring considerable care and one which should not have to be performed in the midst of diving and salvage operations.

Helmet telephone connections and the inboard cable connections on the *Falcon* were painted in various colors, so that the proper cables could easily be picked up when shifting helmets and talkers.

It was a standard practice on the *Falcon* to test out all diver's telephone sets just prior to putting on the helmets, and this should be made standard practice in the future.

(E) Carrying cases are provided for holding a complete set of instruments for one diver, with the exception of the telephone cable. The cases for the first instruments were of fiber,

FIG. 153.—Samples of telephone cable as developed by Pittsburgh Deep-Sea Diving Telephone Co. Heavy cable on top consists of two phosphor-bronze stranded life lines and two telephone wires, laid up in smooth rubber sheath, as actually used during *S–4* salvage operations. Disassembled cable shows modifications recently proposed by company to improve flexibility, with six telephone wires. Small cable in background is used for talker's sets and shows abuse to which it may be subjected

with steel bands, trimmings, and fittings. These parts on subsequent sets should be made of a material which will be resistant to corrosion from salt water and salt air.

A control box, whereby three divers (or any fewer number) may talk together and be talked to by one or two talkers on the surface, was given a preliminary test, with promising results. This gear is shown in Figure 154. In this test and with this combination the transmitters and receivers of all those who are on the line are connected in series, so that the current passes through three times as many instruments and three times as much wire as when one diver and one talker are on their own line. While it was not always possible with this junction box to have one diver give a message directly to another diver without relaying it through their

two talkers, it was always possible for the one talker to get it through, and, what was most beneficial, the diver who sent the message could hear the talker (fig. 155) give it to the other diver, not only making sure that the message was correct but satisfying himself that the message had been passed.

FIG. 154.—Chief Gunner Loughman rigged as telephone or diver's talker with three-way control or jack box and improved double diaphram transmitter as developed by Pittsburgh Deep-Sea Diving Telephone Co.

MAINTENANCE

So far as weight, handiness, simplicity, and operation are concerned, the batteryless telephones are a distinct improvement over the present standard type.

Whereas it was found necessary on the *Falcon*, when the battery telephones were in operation, to keep two electricians constantly at work overhauling and maintaining the gear in an operating status, the services of these men were entirely dispensed with for the first month of

operation of the new telephones. During the second month mechanical difficulties were encountered, as previously explained, and it was necessary to spend a certain amount of time on the telephones. During the third month difficulties became more frequent and delays due to time spent in connecting troubles became embarrassing. In a few instances communication with the

FIG. 155.—The three-way jack box shown made it possible for one talker to converse with any one of three divers, for the three divers to hear what was said to one of them, and for one diver to talk to another without relaying the message through two talkers. The talker's set shown was the type used during the latter half of the *S-4* salvage operations. The three-way box was tested with divers but not actually used on the *S-4*

diver ceased entirely during his dive. Part of the difficulties were due to mechanical defects in effecting a complete metallic circuit through the phones and all connections and plugs; the greater part of the remaining troubles were due to corrosion and partial sticking of the diaphragms, principally in the transmitters installed in the helmets. It is perhaps too much to expect of a device, deliberately taken in its laboratory stage, that it shall function consistently

and continuously without regular attention under the extreme conditions of a winter on salt water. It should be said for the equipment that the defects are such as can undoubtedly be overcome by improvements in mechanical design and such as will amost certainly be overcome in the course of the present development work. One distinctive feature of these batteryless telephones is that, while they require a complete metallic circuit for operation, it is not mandatory that the parts of the circuit be insulated from ground. The telephones would continue to operate if all the divers and talkers wore bathing suits only and took to the water with their telephones on.

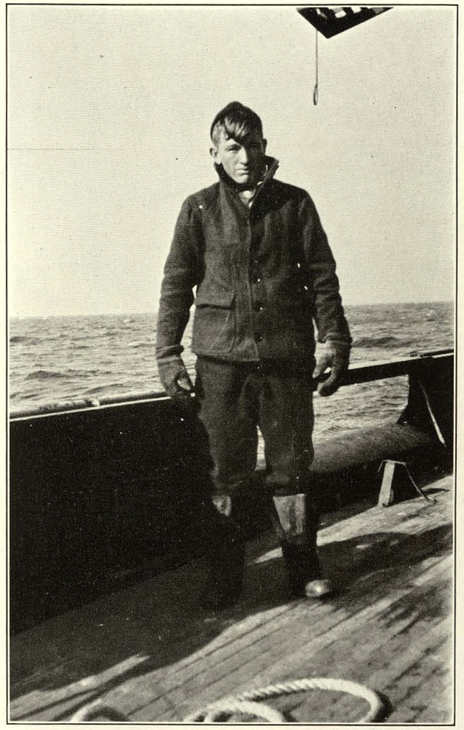


FIG. 156.—Submarine winter clothing dress with rubber arctics and woolen mittens

ACOUSTICAL PROPERTIES

The difficulties in talking as outlined in the Bureau of Construction and Repair Manual, article 3651 (4), caused by hissing air within the helmet and hissing or talking or other noises on deck, are ofttimes very real to diver and talker and frequently cause entire cessation of conversation between the two. The escaping air within the helmet prevents the diver from hearing plainly, and frequently prevents calling him on the telephone. In such cases resort was had to (1) blowing of a police whistle in the transmitter, each talker being provided with such a whistle; (2) loud and sharp calling into the double diaphragm transmitter (or into the two talkers' receivers held close together); and (3) giving the diver one pull on his life line, which not only signified "Are you all right?" but means "Answer the telephone."

It was found necessary on the *Falcon* to put mufflers and silencers on the decompression chamber vent pipe and on the drain from the diving-air cooler, because the noise of the escaping air was very troublesome. Talkers were placed in sheltered positions, as the noise made by the wind blowing past the receivers greatly reduced audibility.

Even with the improved performance of the batteryless telephones it became more or less standard practice in the *S–4* salvage force for the divers to shut off their air completely when it became necessary for them to listen to messages or directions involving more than a few words or when they were carrying on a conversation out of the ordinary, where stock phrases were not used.

As regards acoustical performance, the new telephones leave little to be desired. Inflections of the voice, variations in air coming into the helmet, and similar sounds are plainly heard. The improvement in communication over the old telephones has had the very agreeable result of making the divers in general more talkative, so that they will more readily ask for directions and so that those on the surface will have a better idea of what is going on.

As an example, it is possible for a talker to listen to the grind of a drill, the squeak of a tap, or the hiss of a torch which the diver is using, or for a talker on diver A to hear diver B talking to diver A under water, although the words of diver B in such a case can not be distinguished.

When all is said and done the operation of diving telephones depends upon "the man behind the gun." If the diver is willing to talk and exercise a normal effort to make himself heard and understood the cooperation between the diver and the talker can be just as close as if the diver were near by on deck but just out of sight.

Appendix V.—Winter Clothing.

It was necessary to provide personnel engaged in outside work with heavy clothing suitable for the weather encountered off Provincetown in the midwinter months.

Effort was made to confine use of such equipment as much as possible to those articles of apparel which were listed in the standard stock catalogue and which seemed most suited to the needs of the salvage force.

OUTER CLOTHING

Each man engaged in outside work was equipped with a suit of *submarine winter clothing*, as shown in Figure 156. This is the type of clothing regularly issued to submarine personnel when operating in cold weather. It is made of heavy 32-ounce woolen material and provides a very warm and comfortable dress. The trousers have laces at the bottom, which facilitate their use with arctics.

Members of boat crews were given *wind-proof clothing* in addition which could be pulled on over the winter clothing. Figure 157 shows the type of blue wind-prcof clothing issued to the *Bushnell's* boat crews. A particularly valuable feature of the wind-proofs is the protection which the hood affords to the entrance of spray and rain at the back of the neck.

Divers' telephone talkers and tenders were supplied with blanket shirts which could be used in conjunction with winter clothing, as shown in Figure 158. In more severe weather and in rain or snow khaki wind-proofs were pulled on over these. (See fig. 159.) Here, again, the hood attached to the blanket shirt and wind-proofs served the additional purpose of covering telephone receivers and shutting off wind noises. This was a very good combination and provided a warm outfit for the prevailing temperatures (10° F. to 35° F.).

A few sheepskin coats, as shown in Figures 160 and 162, were purchased on open order and issued to watch standers on the *Wandank* and *Sagamore* and to the *Falcon's* boat crew. These were also issued to officer personnel and to a limited number whose work in exposed positions for long periods without much exercise made it necessary to secure something warmer than the clothing regularly issued, as explained above. These coats are very warm and well suited for this purpose. The coats purchased, however, were not costly, and must be considered too frail for rough usage, such as handling lines or doing other deck work. In this connection it seems entirely possible to provide coats of this general type but with a more durable outside fabric, such as on certain types of aviation clothing, which would be suitable for general issue.

Twenty suits of yellow oilskins, similar to those used by local fishermen, were purchased as an experiment for use by boat crews and men on deck. Figure 161 shows these oilskins worn over a sheepskin coat. The yellow oilskins turn water much better than either type of wind-proof clothing and do not stick together as badly as the black oilskins which were formerly part of the regular Navy issue. The objection to the particular type purchased is the character of the trousers, which are held up by shoulder straps, and thus restrict the free movement of the arms. It is possible that a serviceable garment of the same kind of cloth could be made in the

style of the khaki wind-proof clothing. (Fig. 159.) While the latter do soak up a certain amount of water, they are generally backed up with sufficient clothing underneath to prevent getting wet through. Boat crews require something more like the oilskins to withstand the spray.

FOOTGEAR

The men in the accompanying pictures are shown wearing lace-type rubber arctics. These were found more serviceable for deck duty than the six-clasp cashmerette arctics regularly issued

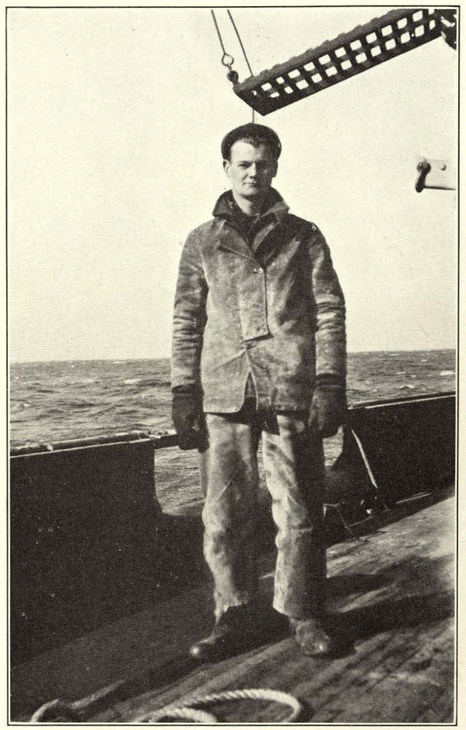


FIG. 157.—Blue wind-proof clothing pulled on over submarine winter clothing, with rubber arctics and woolen mittens. (Jones, coxswain of *Bushnell* surfboat)

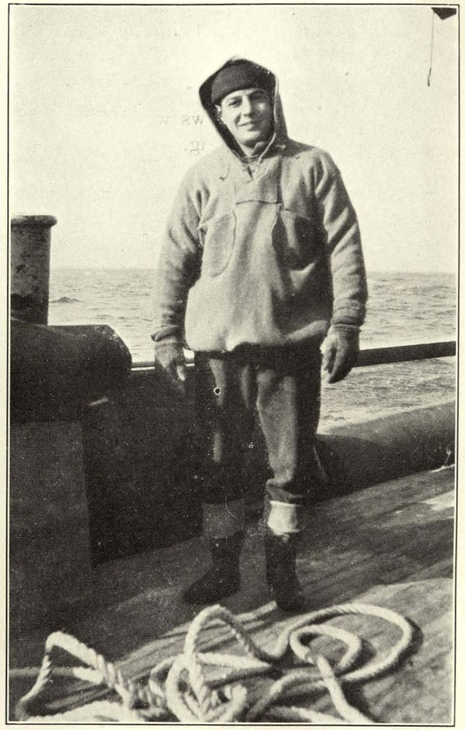


FIG. 158.—Blanket overshirt worn under khaki wind-proof clothing

to submarine personnel. The main advantage of the former is that they are waterproof. The cloth arctics are probably warmer and better for cold dry weather.

GLOVES

The problem of providing suitable gloves for men working on deck in cold weather was indeed difficult. A pair of woolen mittens, regular submarine issue, was furnished each man. These are shown in Figures 156, 157, 158, and 160. They are quite warm and serviceable until thoroughly wet. A number of three-finger woolen-lined leather gloves were purchased

and distributed to men in the *Falcon* working party. These gloves are more expensive than the woolen mittens and proportionally more serviceable.

Probably the best solution for handling wet lines in cold weather was found in the use of discarded gloves which had formerly been cemented onto diving dresses. These gloves are also of the three-finger type. The man shown in Figure 159 is wearing a pair of the type regularly used on diving dresses, while the man in Figure 161 is wearing a pair of rubber mittens of

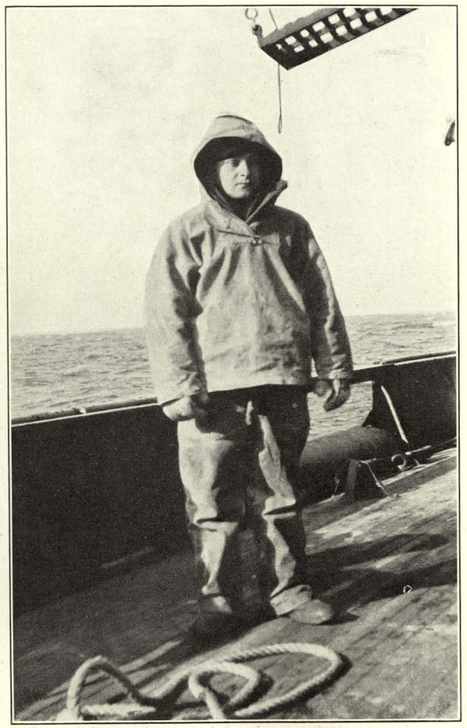


FIG. 159.—Khaki wind-proofs worn over submarine winter clothing, with rubber arctics and divers' tenders' gloves

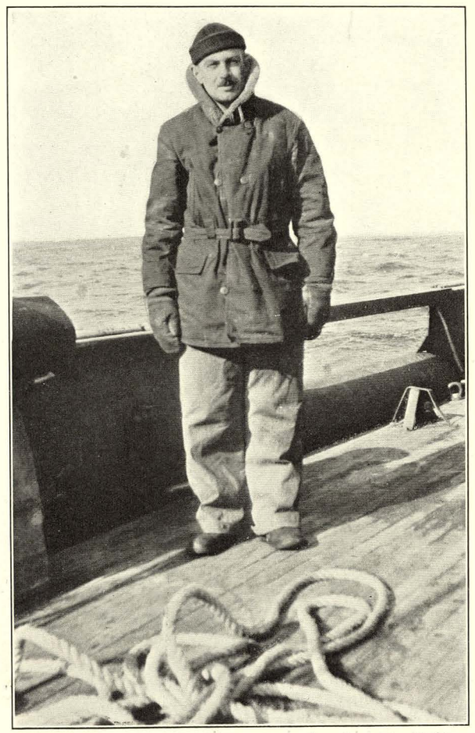


FIG. 160.—Heavy sheepskin coat worn over submarine winter clothing, with wind-proof trousers, rubber arctics, and woolen mittens

a type formerly issued to divers' tenders. The use of the glove shown in Figure 159 and a woolen five-finger glove underneath provided the most satisfactory combination for this difficult task of handling mooring lines and divers' life lines and hose.

UNDERWEAR

In addition to the above, men were supplied with heavy submarine winter underwear, and this was apparently well suited to their needs.

GENERAL

The above remarks apply particularly to those engaged more or less actively in outside work and whose exertions and movements assisted in keeping them warm. The clothing problem for officers and others whose work was of a supervisory character and required their presence

on deck all day long without much opportunity for exercise was somewhat more complicated and was solved in various ways, according to the individual. In general, however, the principle was the same—to wear enough clothes of whatever kind could be procured to keep warm and

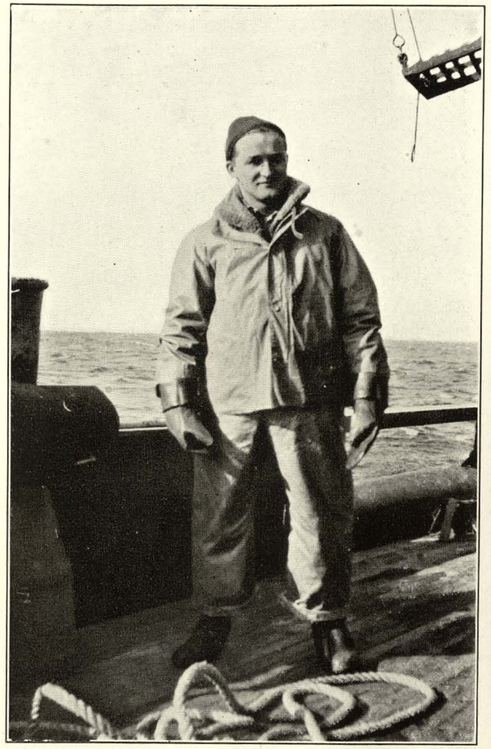


FIG. 161.—Yellow oilskins pulled on over sheepskin coat, and top clothes, with rubber arctics and rubber mittens. (Rogers, C. A., B. M. 2c., coxswain of *Falcon* surfboat)

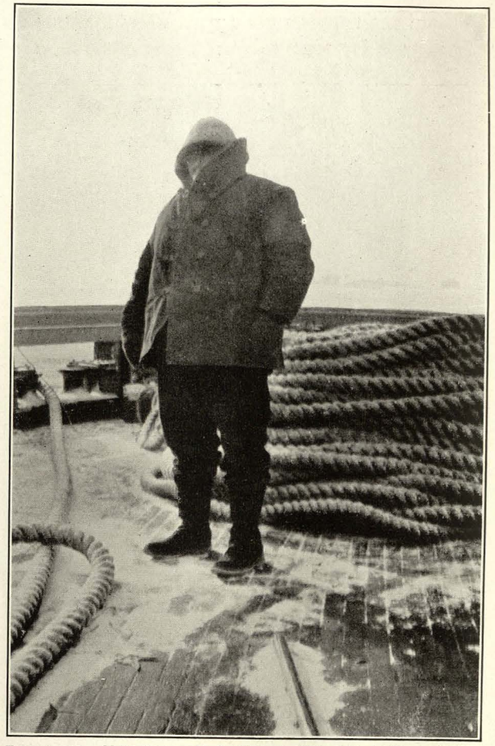


FIGURE 162.—Chief Gunner C. L. Tibbals, United States Navy, diving supervisor, in winter outfit

comfortable, so that one's mind could be entirely on the work instead of intermittently on the problem of keeping warm.

The salvage officer solved the problem for himself by the use of part or all of the following outfit, donned in the order given. The principle of this method of dressing is to wear the warmest articles of clothing on the *inside*, next to the body.

1 union suit; part wool, inside.
1 union suit; cotton, outside.
2 pair wool socks, light or medium weight.
1 blue flannel shirt, C. P. O. style.
1 service (uniform) trousers.
1 jersey, short sleeves.
Wool weatherproof submarine trousers.
Moccasins, sheepskin, fleece-lined.

Arctics, cashmerette tops, five-clasp.
1 service (uniform) blouse or coat.
1 medium scarf.
Wool weatherproof submarine coat.
Sheepskin coat (worn on very cold days only).
Knitted toque.
1 pair leather flannel-lined gloves, inside.
1 pair wool mittens, outside.

Although apparently cumbersome by reason of the many layers, the equipment was not heavy or tiresome to wear. With the addition of waterproof outer clothing on rainy or snowy days, and oilskins when in the surfboat in choppy seas, the outfit served very well for all sorts of weather throughout the winter.

Although frequently the butt of jokes and jests, the distinctive headgear worn by the commanding officer of the *Falcon*, the salvage officer, the diving supervisor, and others served a useful purpose other than keeping their heads and ears warm, in that it was possible to "spot" them immediately when they were wanted anywhere around the ship.

STOCK ARTICLES OF CLOTHING

The following table of items taken from the standard stock catalogue is added for ready reference and as an indication of the cost of equipping men for winter operations:

	Stock catalogue No.	Price		Stock catalogue No.	Price
1. Blanket overshirt of heavy wool material, complete with hood	37D42	$4.85	6. Underwear, wool, extra heavy	37U4	$4.34
2. Arctics, lace, rubber, heavy	37A1	3.81	7. Arctics, clasp, cashmerette	37A2	2.30
3. Mittens, wool, heavy	37N10	1.13	8. Coats, woolen, 32-ounce	37C22	7.00
4. Socks, woolen, extra heavy	37S53	.53	9. Trousers, woolen, 32-ounce	37T16	6.00
5. Suits, wind-proof	37S54	5.27	10. Mittens, leather	37M14	1.75

DIVING EQUIPMENT

Diving equipment, except as enumerated elsewhere in the report, conformed closely to the Navy standard. Divers were dressed in blue contocooks (woolen union suits with feet), and were given 5-finger woolen glooves similar to small-stores issue, for use inside the 3-finger water-tight rubber gloves cemented to their dresses.

One of the few innovations in diving dress was the use of sheepskin-lined moccasins over divers' heavy blue socks. These served to good purpose in the cold water in which diving operations were conducted (32° to 40° F.).

Appendix VI.—Section 1. Tools and Templates.

The use of the templates and drilling jigs shown in Figure 34 and in Figures 163 and 164 will be found more or less self-explanatory when combined with the titles on those photographs.

Appendix VI.—Section 2. Nozzles for Washing Hose.

There were available on the *Falcon* the reaction type hose nozzles developed during the *S–51* operations, as described on page 35 of the salvage operations on that vessel. (C. & R. Technical Bulletin No. 2–27.) One of these nozzles which did the greater part of the washing on the *S–51* and the *S–4* jobs is shown in Figure 166.

Four nozzles of the so-called "self-propelling" type were ordered from a firm in New York during the first day or two of the *S–4* rescue operations and were delivered for use on the

Falcon. One of these nozzles was tried out by Kelley during the early tunneling operations, but after endeavoring to wash with it for a few minutes he sent it up and had one of the *Falcon* nozzles sent down on the hose.

Four replacement nozzles were later supplied by the firm, one of which was used by Kelley during the tunneling operations in March. He reported that the nozzle was to a certain extent self-propelling, in that the force acting ahead, in the line of the jet, exceeded the reaction from the jet, but he stated that this was of no particular advantage in tunneling under the submarine and that he preferred the *Falcon* nozzle.

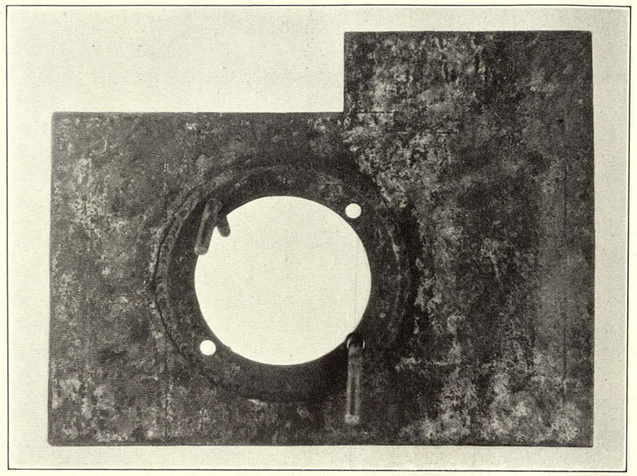


FIG. 163.—Steel template with centering pins used first by Carr for burning hole for torpedo-room spill pipe with gas torch and later by Crilley for drilling holes for spill-pipe flange. The upper right hole was drilled "double." The cutaway portion in the upper left-hand corner of the template was designed to fit over the cleat shown in Figure 53 and to locate the template in position

The self-propelling nozzles were a patented, proprietary article, of rather unusual form (see fig. 166), with a main jet 1¼ inches in diameter, as compared to the ⅞-inch jet of the *Falcon* nozzle. The self-propelling nozzle had eight ½-inch reaction jets, while the *Falcon* nozzle had five of 9/16-inch diameter. Tabulated data with respect to the two is given hereunder:

FALCON NOZZLE	SELF-PROPELLING NOZZLE
Main jet, diameter=0″.875. Area=0.601.	Main jet, diameter=1″.25. Area=1.227.
Rear jets, diameter=0″.5625 each; number, 5.	Rear jets, diameter=0″.5 each; number, 8.
Total area=5×0.2485=1.2425.	Total area=8×0.196=1.568.
Excess area, pushing nozzle ahead, 0.6415 square inches, or about 106 per cent.	Excess area, pushing nozzle ahead, 0.341 square inches, or about 27 per cent.
Total orifice area, 1.8435 square inches.	Total orifice area, 2.795 square inches.

While the *Falcon* nozzle had a main jet of less than half the area of the other and undoubtedly had less water issuing from it, the divers reported it as more efficient for washing tunnels, due, perhaps, to the more concentrated stream of water, clearly shown by a comparison of the photographs. (Figs. 167 and 168.)

Appendix VI.—Section 3. Cement Gun and Cementing.

Cementing the main induction valve trunk and the pig lead over the conning-tower hatch was accomplished by the use of the cement gun shown in Figure 169, originally made on the *Vestal* in 1926 and used on the *S–51* salvage operations. This gun has a two-piece reservoir with a total capacity of about 7 cubic feet and it will hold a mixture carrying 600 pounds of cement. Air is fed to the reservoir at 100 to 150 pounds per square inch through a diving-hose connection at the top, and the cement mixture is expelled at the bottom through a tapering nozzle, a gate valve, and 1¼-inch air hose, as described in the report on salvage operations, submarine *S–51*, page 33. The cement gun should be set up, made thoroughly tight by sub-

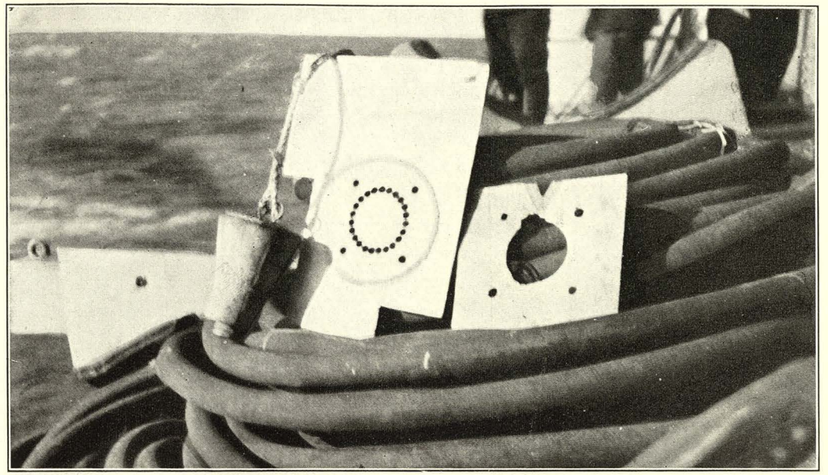


FIG. 164.—Tools and templates prepared for work around spill pipe over torpedo room. On left, wood plug with lead plates for sinking, used for insertion in hole in shell to insure sufficient diameter for passage of hose strainer. Center, steel template cut to fit around adjacent structure with a ring of guide holes for drilling outhole in shell plating and for drilling flange bolt holes. Right, template of asbestos lumber actually used for burning hole in shell of *S–4* with electric torch. Irregular notches in this template were made accidentally and were not caused by action of electric torch

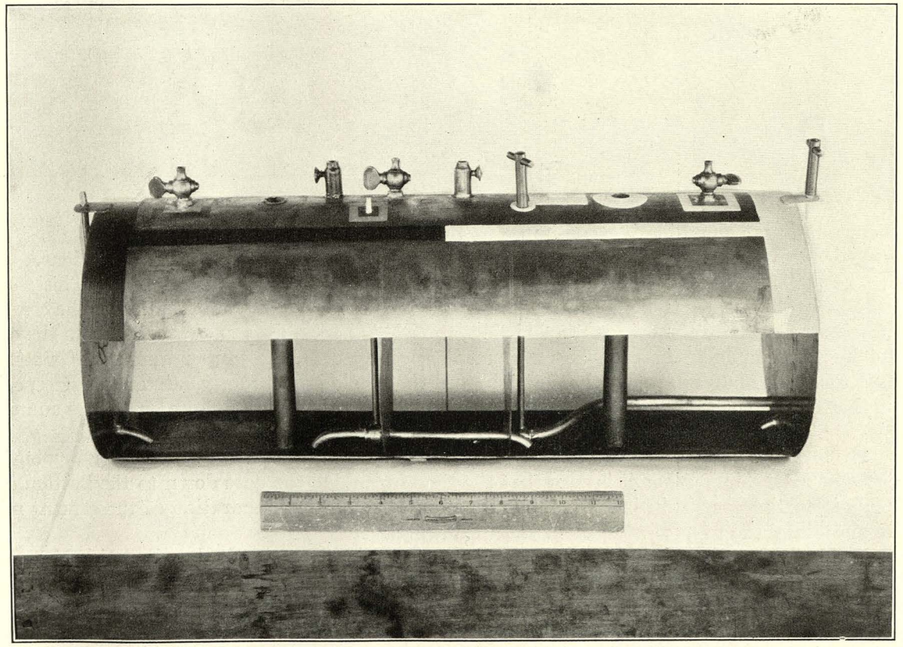


FIG. 165.—Model pontoon made up for instruction of divers. The pet cocks represent vent valves and the screw cocks represent blow valves

jecting it to air under pressure, and then tested by filling it with fresh water and expelling the water through the hose.

The cement used was a bauxite cement made by the Atlas Lumnite Cement Co. and furnished in 94-pound bags. More than ordinary care must be exercised in protecting the cement from water or moisture, as it is intensely hygroscopic. The neat mixture used on the *S–4* was 94 pounds of cement to 4 gallons of *fresh* water.

The cement gun being rigged and the 1¼-inch rubber hose prepared for taking down to the submarine, a wooden box of water-tight construction of a capacity at least twice that of the

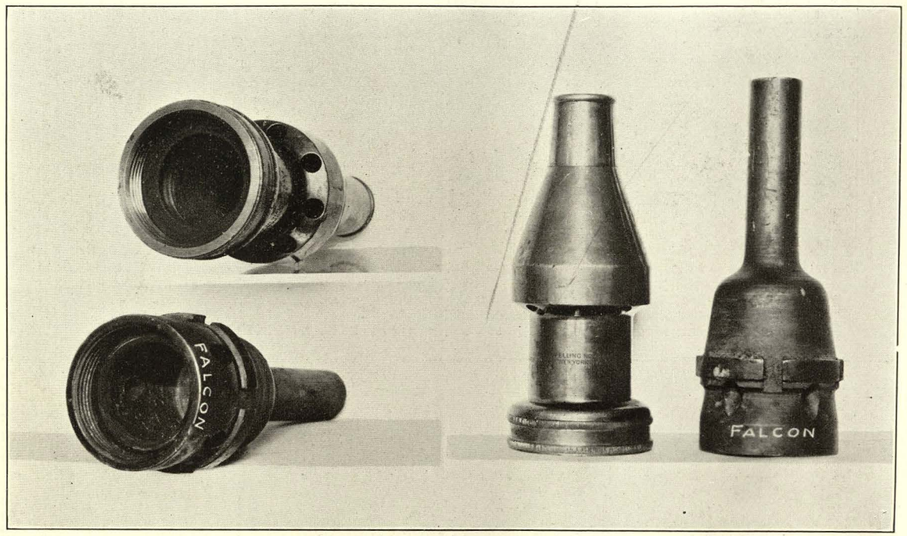


FIG. 166.—Side and rear views of washing nozzles, *Falcon* and self-propelling type

cement gun is set alongside it, together with three or four shovels and at least six pails. The cement is brought out and a crew of seven or eight assembled to carry out the operations.

The pails are filled with fresh water, so that each carries a certain volume. (This water had to be heated nearly to boiling before using on the *S–4* job, to prevent freezing of the cement before it reached the submarine. In addition, the whole apparatus was protected from the cold wind by a tarpaulin.) As each bag of cement is dumped in, the proper amount of water is added (one pail of 16 quarts on the *S–4* job) and the whole is vigorously stirred, with especial care that no lumps of cement are left which would lodge in the 1¼-inch hose or fittings and clog them.

While this is going on the diver is dressed and the hose is filled with fresh water by pouring it into the reservoir. When it is seen that the time for taking the hose down to the bottom and placing it on the wreck will just equal the time for finishing the preparation of the cement mixture and filling the reservoir the diver is sent down.

When the cement mixture is ready, a large funnel is placed in the handhole in the top of the reservoir and a bucket brigade is formed to pass pails of cement and to fill the reservoir as promptly as possible. The reservoir filled, the handhole cover is replaced and all is ready on deck. As soon as the diver reports the end of the hose secured, pressure is turned on the reservoir, the gate valve is opened, and the mixture ejected. The try cocks are opened as the level of the mixture drops in the reservoir, and as soon as all the cement is out the gate valve is quickly closed, the air turned off, and the reservoir vented, whereupon it is immediately filled with (hot) fresh water. If the gate valve is not shut off promptly and air is blown out of the hose at the lower end the cement mixture under water will be greatly agitated and it may be blown out of place.

The diver in the meantime has been instructed to remove the lower end of the hose from the pocket being cemented, and as soon as he reports having done so the hose is hauled up and

FIG. 167.—Washing nozzle, *Falcon* type, in action, showing the five reaction jets and the concentrated main jet

the charge of fresh water is ejected from the reservoir through the hose in order to flush out the apparatus and prevent the residual cement from solidifying inside it.

It may be assumed that the cement will set in 7 hours, harden in 12 hours, and that it will be as permanent as it is ever going to be in 24 hours.

The cement mixture issues from the hose as a grayish-brown smoke and it is so heavy that it does not cloud up the water in the immediate vicinity at all.

When preparing to cement on the wreck, a box or container or a pocket with a practically water-tight bottom must be provided in order to hold the cement; otherwise the heavy mixture will leak out and be lost before it sets. For instance, on the *S–4*, when cementing the main induction trunk, the 3-inch drain valve for this trunk was very carefully closed. When cement-

ing the pig lead on top of the conning-tower hatch the lead was laid in a waterproof lining made of heavy canvas.

No attempt has so far been made to force a cement mixture through a hose and set of orifices or fittings having a bore less than 1¼ inches, although a proposal to force cement through ¾-inch pipe fittings on the *S–4* was laid aside as impracticable, acting solely on the general opinion of those who did this work on the *S–51* operations. Further experiments along this line could be carried out to advantage.

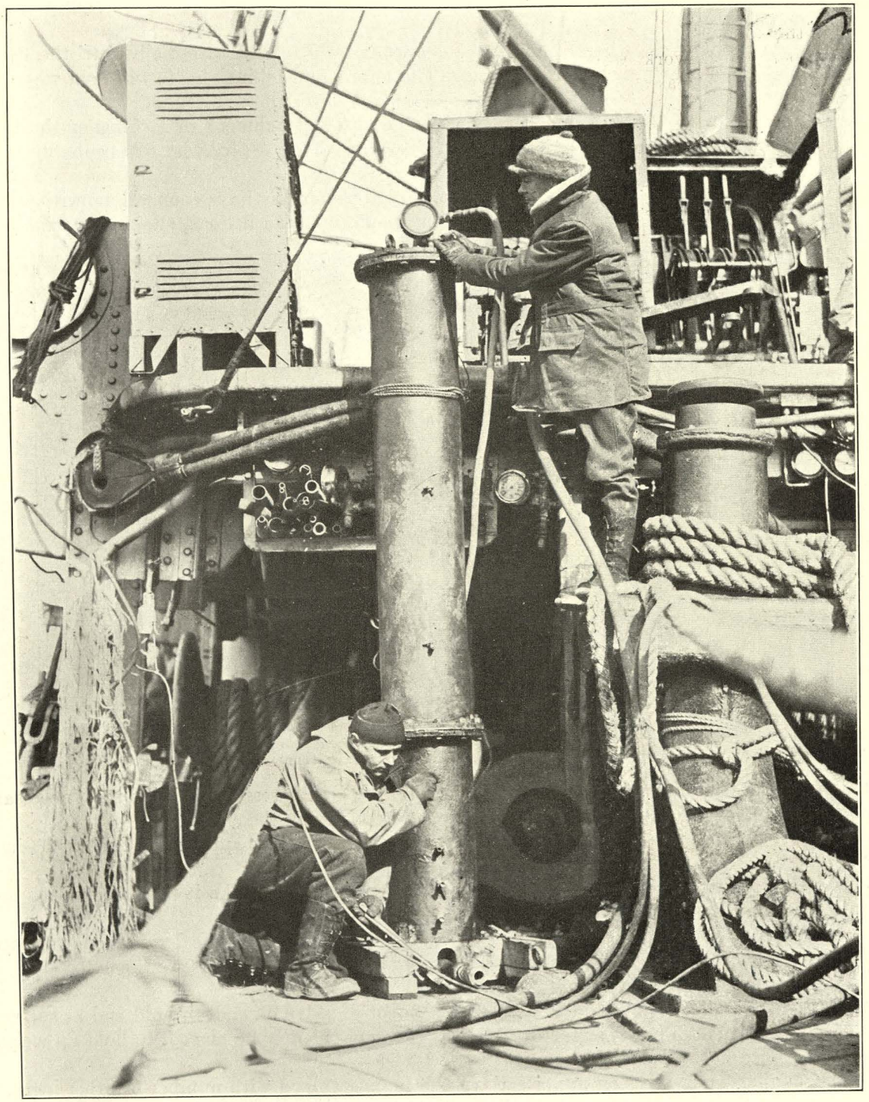
When the gear is rigged and all preparations made the actual operation of cementing takes almost less time than it does to describe it. The results obtained by its use, when the limitations of the cementing operation were carefully observed, have so far been quite satisfactory.

FIG. 168.—Washing nozzle, self-propelling type, showing the eight reaction jets and the main jet of more flaring form

Appendix VII.—Blowing Hose.

It is imperative that a rugged, substantial hose be used for transferring air from the rescue or salvage vessel to the vessel submerged. The best that money can buy is none too good, for the time lost on the delays incurred due to leakage or carrying away of hose will often involve many times the cost of the hose.

For temporary work, such as blowing the bow buoyancy and the forward trimming tanks on the *S–4*, where the hose will be used for only one or two dives or where it will remain in place only two or three days, second-hand diving hose can be used. The bore is only one-half inch



International Newsreel Photo.

FIG. 169.—Cement reservoir and gun on *Falcon*, showing air-blowing hose, pressure gauge, try cocks at various levels, and outlet-hose connection with gate valve at bottom; 1¼-inch hose attached to this valve conducts the liquid cement to the point where it is to be deposited

in diameter, but full salvage air pressure can almost invariably be used at the upper end to increase the air flow.

For permanent work, where a hose once connected is intended to remain until the termination of the job, a heavy air hose is required. The 1-inch and 1¼-inch hoses will float when full of air.

For depths up to 100 feet, measured to the point of attachment or lashing of the hose, 1-inch hose is adequate; for depths of 125 to 150 feet and over, 1¼-inch hose is probably to be preferred on account of its greater ruggedness.

All blowing hose larger than diving-air hose should preferably have connections with standard pipe threads. All lengths of hose, after being made up with fittings, should invariably be

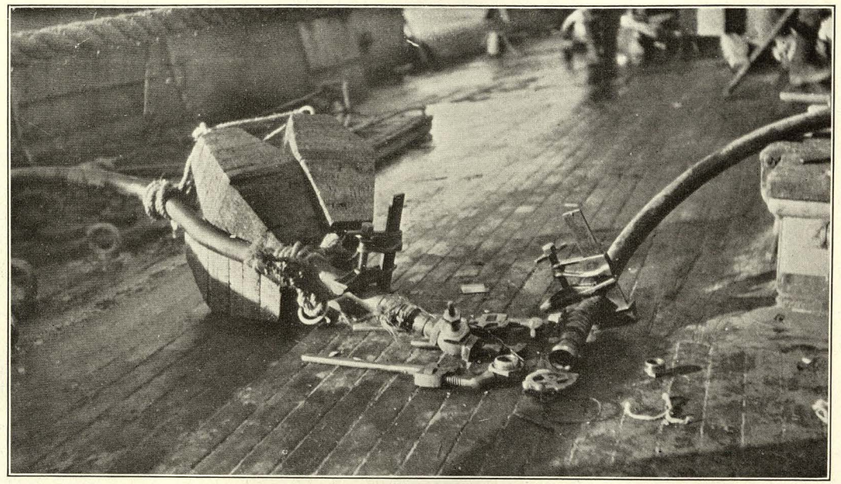


FIG. 170.—Gear for connecting blowing hoses. Buoyed end of hose taken aboard salvage vessel and closed by clamp, ready for valve to be removed and another section of hose coupled on. Note valve wheel removed from buoyed end of hose to prevent opening of valve by bumping on other buoys and hoses. Half-round jaws on clamps prevent damage to hose

tested under water *with air* before they are brought to the salvage vessel. This is a most necessary requirement and it will save much time, trouble, and expense in the end.

A blowing hose, properly buoyed off, is arranged as follows (this applies to 1-inch or 1¼-inch blowing hose):

(*a*) Hose full of air down to connection on wreck in order to make it float on surface and keep it taut when suspended.

(*b*) Valve (globe) fitted on upper end. Valve closed and handwheel removed, as wheel will bump against buoys and lines, and this action may open the valve. (See fig. 170.)

(*c*) Pipe plug inserted in open end of valve.

(*d*) Special cork buoys lashed to hose within 3 feet of valve on end, to hold end at surface.

(*e*) Spherical metal buoy, as far from end as can conveniently be placed, to hold up weight of hose and keep hose taut. (Fig. 171.)

(*f*) Coupling and valves on upper end of hose to be stamped with number or other identification marks, the stamping to be done clear of all places where wrenches may be used.

A detail of the blowing hoses for compartments and pontoons, as lashed for the trip from Provincetown to Boston, is shown on Figure 172.

Appendix VIII.—Lines and Buoys.

When working on a wreck, such as a submarine, the arrangement and the rigging of the lines leading from the diving vessel on the surface to the submerged wreck for the assistance of the diver are somewhat different from the standard or general methods illustrated on Plate 40 and as described in articles 3637, 3656, 3661, and 3662 of the Bureau of Construction and Repair Manual.

Due to the more intricate nature of the work on a wreck, the arrangement of lines is often complicated to a great degree, involving even more care on the part of divers and personnel on the diving vessel than is described in article 3663 of the Bureau of Construction and Repair Manual.

Not only does the diver have to handle these various lines, but he has to talk about them frequently in his telephone conversation, and it is very important that the surface crew pull and slack on the proper ones when so ordered by the diver. For this reason, it is very necessary that a logical nomenclature be established and employed. Descriptions, definitions, and names of the various lines which have been used and established as more or less standard equipment as a result of the *S–5*, *S–51*, and *S–4* salvage operations are set down here for information and guidance on future work.

Life line (*and air hose*) is the combination of the life line or telephone cable and the diving air hose, lashed together with a canvas sheath at the lower end, as shown in Figure 42, and secured together with marline at intervals for the remaining distance.

Descending line, generally of new 4-inch manila, although frequently of 2½ or 3 inch manila when it is for temporary use only, is the line which is attached to the wreck and taken to the diving vessel, down which the diver slides in his descent in order to reach the desired point on the wreck.

Lowering line, varying in size from 4-inch manila to 9 or 12 thread material, is the line attached to objects being sent to the bottom for the purpose of controlling the movements and position of those objects.

Hauling line, varying from ¾-inch wire to 1½-inch manila, is a line used when it is desired to have the surface crew assist the diver in lifting some object or moving it from place to place.

Stage line, of 4-inch manila, is the line or whip by means of which the diving stage is raised or lowered. It attaches by a shackle to the top of the stage slings.

Reeving line is the combination of 1½-inch, 2½-inch, 4-inch, and 6-inch manila and 1-inch wire rope which is passed through the tunnels preparatory to hauling through the pontoon chains. The operation of these lines is described in Part IX, and they are illustrated in Figures 83 and 99.

Lamp wire is the electric cable, less than one-half inch in diameter, as shown in Figures 146 and 147, carrying the copper conductors for the diving lamp. The words "light wire" as sometimes used are unsuitable, due to their great phonetic similarity to "life line."

Blowing hose, of sizes varying from the ½-inch diving-air hose to 1¼-inch air hose, is used solely for blowing and venting air to and from compartments, tanks, and so forth under water.

The method successfully employed on the *S–4* of attaching and buoying descending lines, where these were to remain in place for several weeks or months, was to pass a chain strap around a part of the vessel's structure, selecting a point which would insure the diver landing on deck even though the descending line tended one way or the other due to tide or position of diving vessel above. To the chain strap was shackled a wire strap, not less than one-half inch, about 3 or 4 feet long, to take the chafe on surrounding rails or structure. The manila descending line, with eye-splice and thimble, was shackled to the upper end of the wire strap. Actually, of course, the whole assembly was sent down together for securing.

The only disadvantage of this arrangement lay in the fact that the numerous shackles which were used to send gear down the descending line would frequently pile up on the permanent shackle at the top of the wire strap at some distance from the deck of the submarine.

This made it necessary for the diver to pass this string of shackles on every trip up and down, a rather awkward proceeding while hanging on the descending line with his feet clear of the deck.

To insure that the objects lowered to the bottom reached the desired point, they were generally slid down the descending line by the use of a heavy screw shackle, 1 inch to 1½ inches, as a runner. Lowering lines were attached to the objects and the objects secured to the shackle, so that by keeping the lowering line well off to one side and clear of the descending line it could not take turns around the descending line. Very frequently, by tending the lowering line in proper direction, the object could be deposited just where it was required by the diver.

The lamp wires, although rubber-covered, are fairly smooth and when wet will reeve around obstructions with reasonable facility. On one occasion a diver came up out of the control room, engine room, and engine-room hatch on the *S–4* only to find that his diving lamp had been

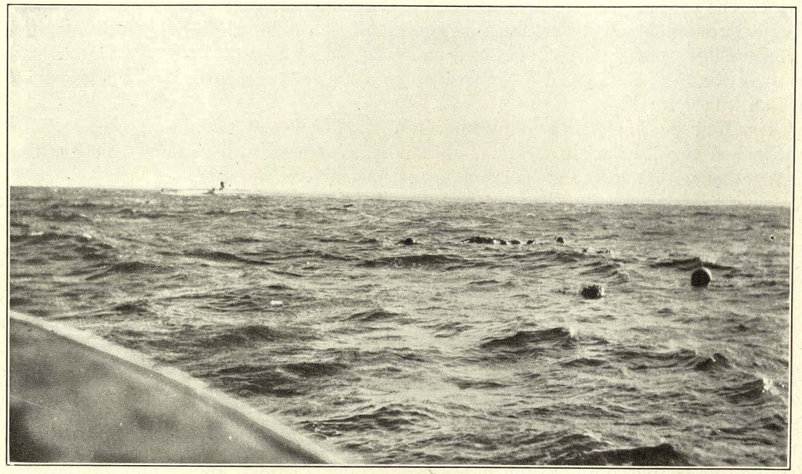


FIG. 171.—Collection of descending lines and blowing hoses with their buoys and floats, including log buoy for sternfast in background, through and by which *Falcon* had to maneuver when mooring and unmooring

inadvertently passed through a loop of the hoisting cable on No. 1 periscope. To have cleared it would have necessitated a trip back into the vessel when his diving time had already expired. He was instructed to cut the wire at the lamp; having done so, the free end was easily hauled around the cable in the control room, 38 feet distant.

Stage lines were marked with rags of different colors to signify depths to the stage platform for convenience in handling stages during decompression under water.

At times, with not more than two divers over the side, there might be as many as nine lines to tend and keep clear, comprising the following:

1. Descending line.
2. Life line and air hose for diver A.
3. Life line and air hose for diver B.
4. Diving lamp wire for diver A.
5. Diving lamp wire for diver B.
6. Lowering line for tool bag and tools.
7. Oxygen hose and arc torch electrode on negative lead.
8. Positive ground wire for arc cutting torch.
9. Blowing hose to compartment connection near point where divers A and B were working.

BUOYS

The buoys found most satisfactory for use were of two kinds—hollow metal and cork. These were used more or less interchangeably for markers and floaters, depending upon local conditions. The metal buoys were hollow spherical mine markers, of welded sheet steel, galvanized, with eyes welded on both top and bottom, of types largely used for seaplane moorings. Two sizes were employed, of diameters 20 and 16½ inches.

All cork buoys were of special type, having the shape of two square truncated pyramids placed together, base to base. The ends were 4 inches square and the center portion 8 inches square, with a length of 16 inches. A galvanized-steel bolt, with swivel eyes at each end,

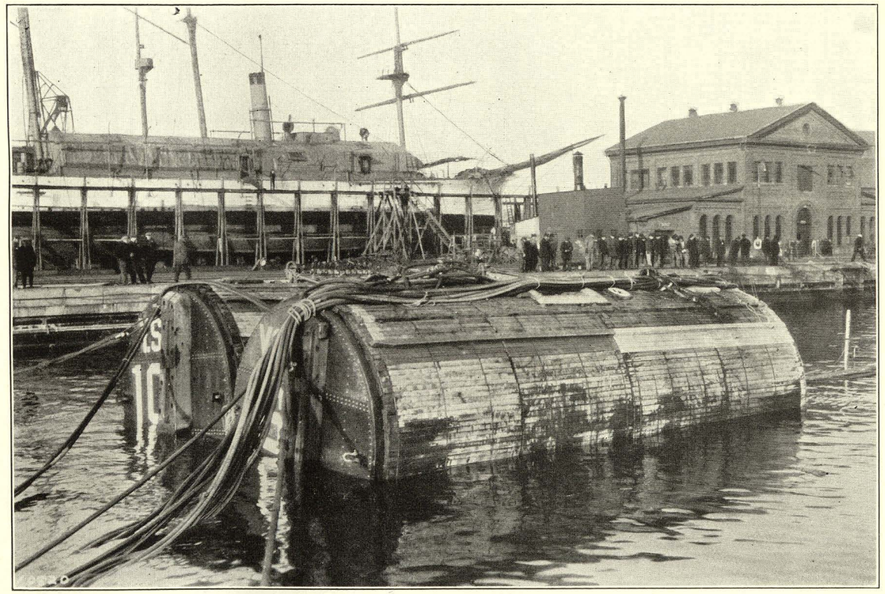


FIG. 172.—Stern pair of pontoons, with blowing hoses from compartments and pontoons, as lashed for towing

passed through the center of the buoy. These cork buoys were almost invariably used in sets of from two to four, as illustrated in Figure 168.

For what might be termed permanent descending lines one metal buoy was shackled to an eye-splice in the upper end of the line for a marker. A second metal buoy was attached to the line by a screw shackle running free. When buoying off the descending line, the shackle was run down the line as far as convenient and fixed in position by lashing the descending line in a loop around it. This second buoy acted as a floater and kept the descending line fairly taut. However, with the great range of tide at Provincetown, a line buoyed off at high tide would slack away at low tide and quite frequently the loop of the descending line would catch under some object on the submarine. For instance, Ingram went down the descending line at frame 40 on January 12, only to land on the breech of the gun, the loop of the line having caught there as it rose and fell with the tide in the interval since the line was last used.

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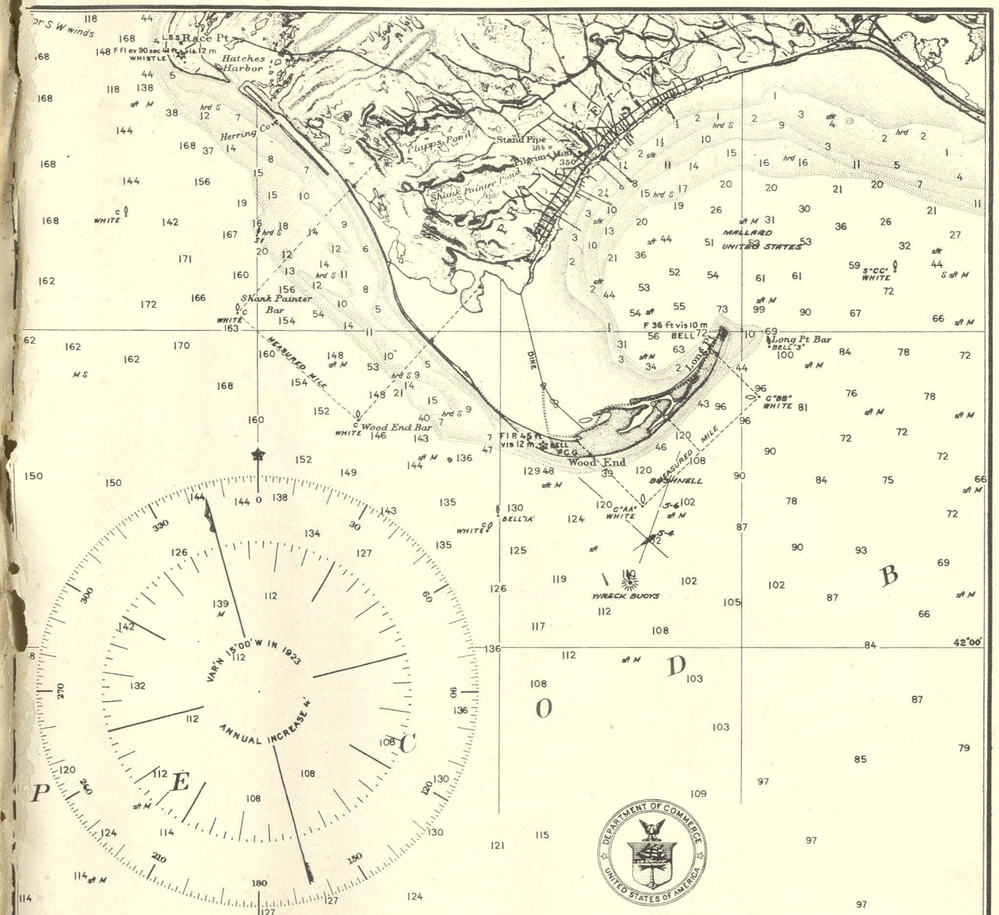


PROVINCETOWN HARBOR

MASSACHUSETTS

Scale $\frac{1}{5000}$

SOUNDINGS IN FEET
AT MEAN LOW WATER

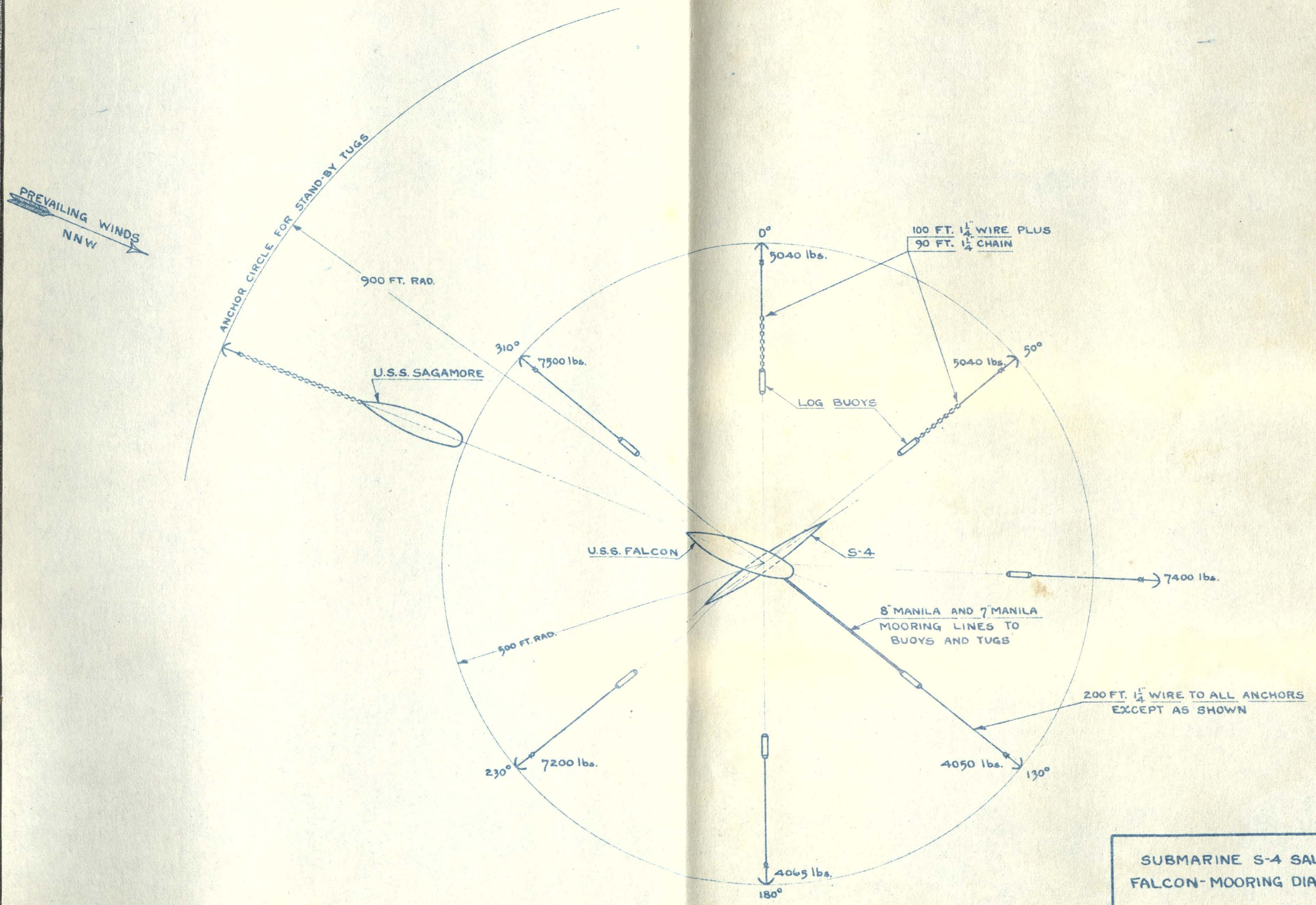
AMENDED TO SHOW POSITION OF U. S. S. S-4 AND WRECK BUOYS

FROM U. S. C. & G. S.
CHART NO.
341

PLATE 1.

Nautical Miles

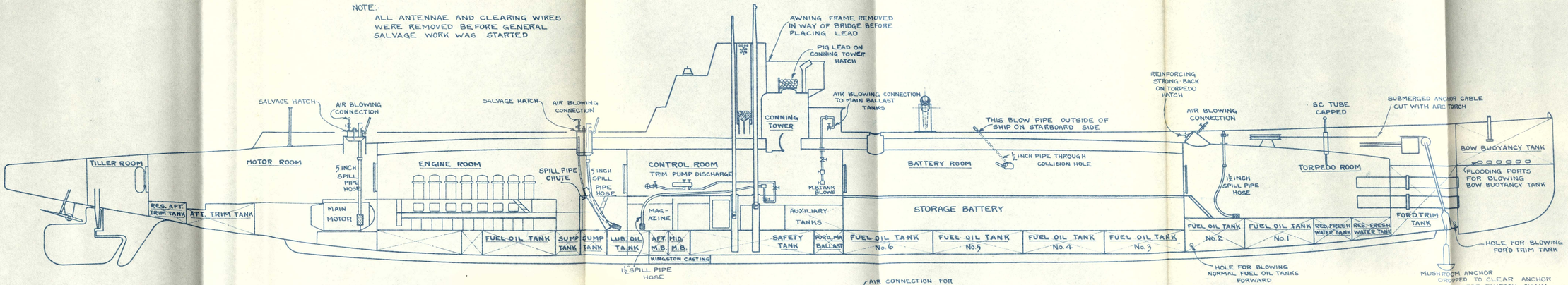
Yards



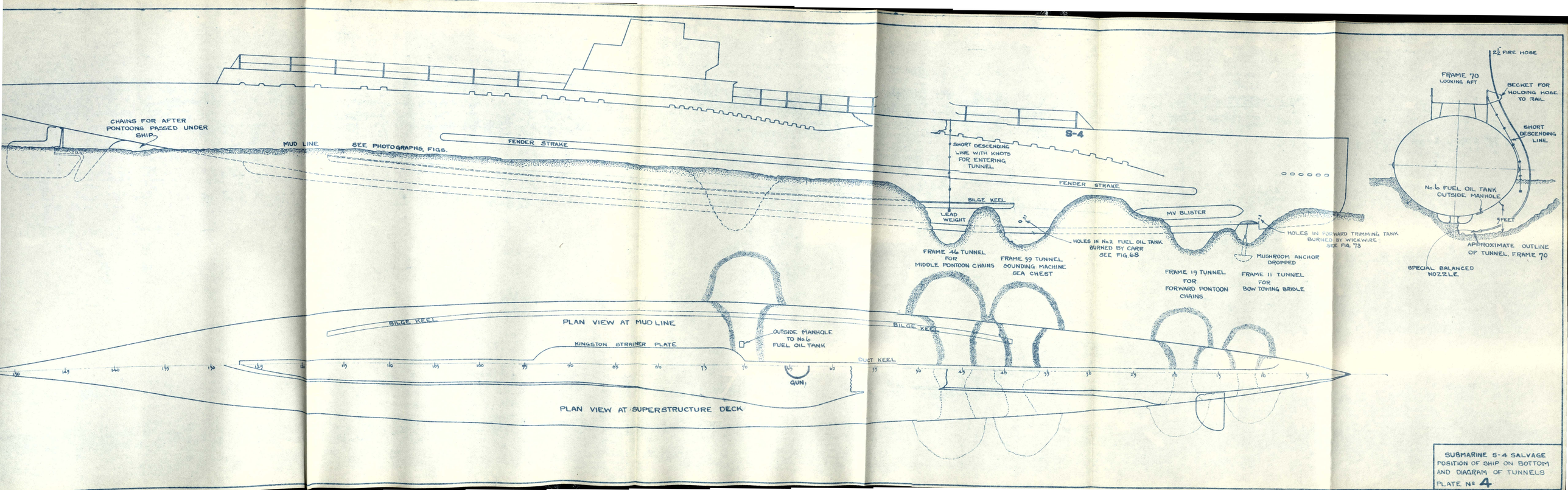
SUBMARINE S-4 SALVAGE
FALCON-MOORING DIAGRAM

PLATE Nº 2

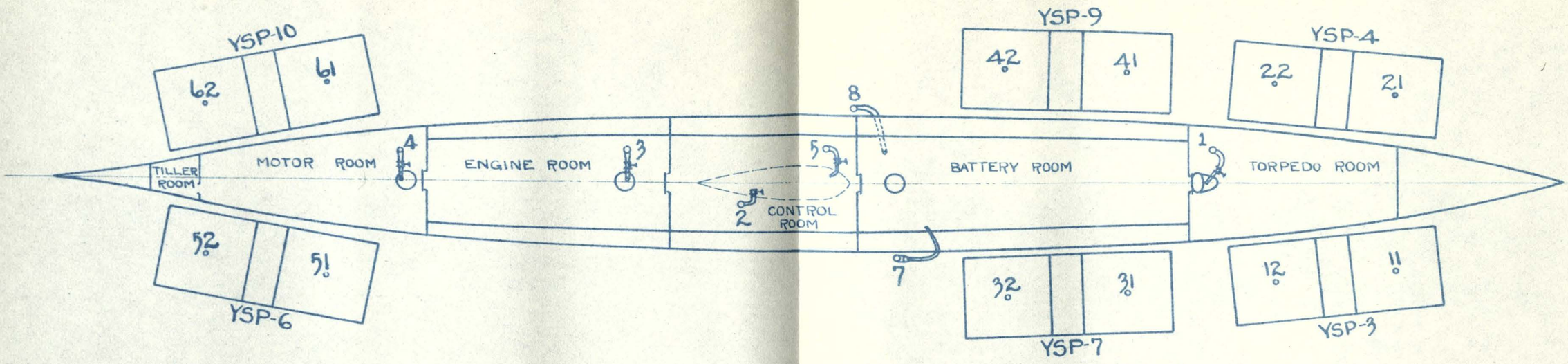
NOTE:-
ALL ANTENNAE AND CLEARING WIRES WERE REMOVED BEFORE GENERAL SALVAGE WORK WAS STARTED



SUBMARINE S-4 SALVAGE
GENERAL SALVAGE DIAGRAM
PLATE No 3



SUBMARINE S-4 SALVAGE
POSITION OF SHIP ON BOTTOM AND DIAGRAM OF TUNNELS
PLATE No. 4

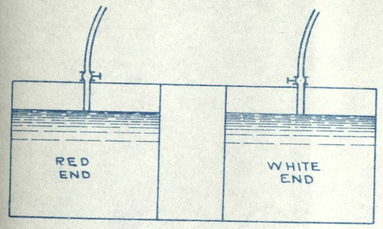


	HOSE Nº	SIZE CONNECTIONS	DESIGNATION	LOCATION
COMPARTMENTS	1	1¼" TO ¾"	TORPEDO ROOM BLOW	TORPEDO ROOM HATCH CASTING
	2	1¼" TO 1"	CONTROL ROOM BLOW	COMPARTMENT AIR SALVAGE VALVE
	3	1¼" TO ¾"	ENGINE ROOM BLOW	ENGINE ROOM SALVAGE HATCH
	4	1¼" TO ¾"	MOTOR ROOM BLOW	MOTOR ROOM SALVAGE HATCH
	5	1¼" TO ½"	MAIN BALLAST TANKS BLOW	H.P. EXTERNAL CONNECTION FOR CHARGING
	6	1¼" TO ½"	FUEL OIL TANKS BLOW	BLOW LINE FOR FORWARD GROUP OF OIL TANKS IN ENGINE
			THIS HOSE BROUGHT TO SURFACE BUT NOT USED. SEE TEXT OF REPORT	ROOM, THENCE TO ENGINE ROOM SALVAGE HATCH.
	7	1¼" TO ½"	BATTERY ROOM BLOW	PIPE INSERTED IN HOLE
	8	1¼" TO ⅜"	FUEL OIL TANKS BLOW	SPECIAL FITTING ON OUTSIDE OF TANKS
PONTOONS	11	1¼" TO 1¼"	FORWARD PONTOON STARBOARD	WHITE END BLOW
	12	1¼" TO 1¼"		RED END BLOW
	21	1¼" TO 1¼"	FORWARD PONTOON, PORT	WHITE END BLOW
	22	1¼" TO 1¼"		RED END BLOW
	31	1¼" TO 1¼"	MIDDLE PONTOON, STARBOARD	WHITE END BLOW
	32	1¼" TO 1¼"		RED END BLOW
	41	1¼" TO 1¼"	MIDDLE PONTOON, PORT	WHITE END BLOW
	42	1¼" TO 1¼"		RED END BLOW
	51	1¼" TO 1¼"	AFTER PONTOON, STARBOARD	WHITE END BLOW
	52	1¼" TO 1¼"		RED END BLOW
	61	1¼" TO 1¼"	AFTER PONTOON, PORT	WHITE END BLOW
	62	1¼" TO 1¼"		RED END BLOW

NUMBERING OF PONTOON HOSES FOLLOWS NAVY STANDARD NOMENCLATURE.
ODD NUMBERS OF UNITS TO STARBOARD, EVEN NUMBERS TO PORT.
CONSECUTIVE NUMBERS OF UNITS FROM FORWARD TO AFT

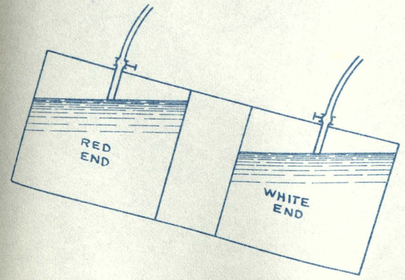
SUBMARINE S-4 SALVAGE
NUMBER, DESIGNATION AND LOCATION OF BLOWING HOSES

PLATE Nº 5

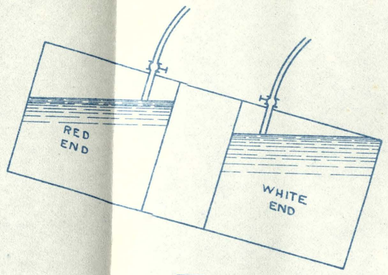


V

RELOCATION OF DROP PIPES IN PONTOONS Y.S.P. 1 TO 11 INCLUSIVE AS RECOMMENDED IN PART XVII SECTION 4 OF TEXT.

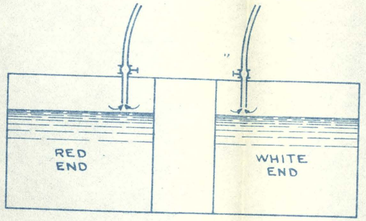


EQUAL AMOUNTS OF WATER BLOWN OUT OF BOTH ENDS WHEN PONTOON IS NOT LEVEL



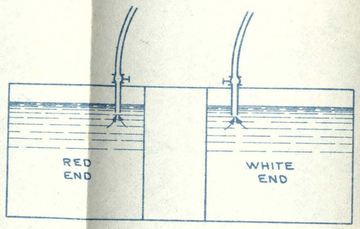
IV

WITH S-4 DROP PIPES MORE WATER WAS BLOWN FROM HIGH END WHEN PONTOON WAS NOT LEVEL



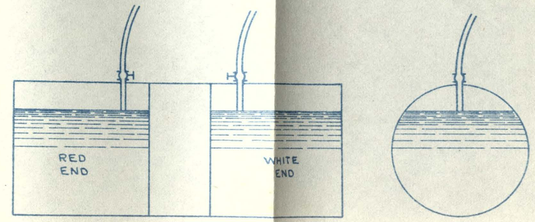
III

END COMPARTMENTS BLOWN DOWN TOO FAR.
AIR ESCAPES WHEN VENTED.



II

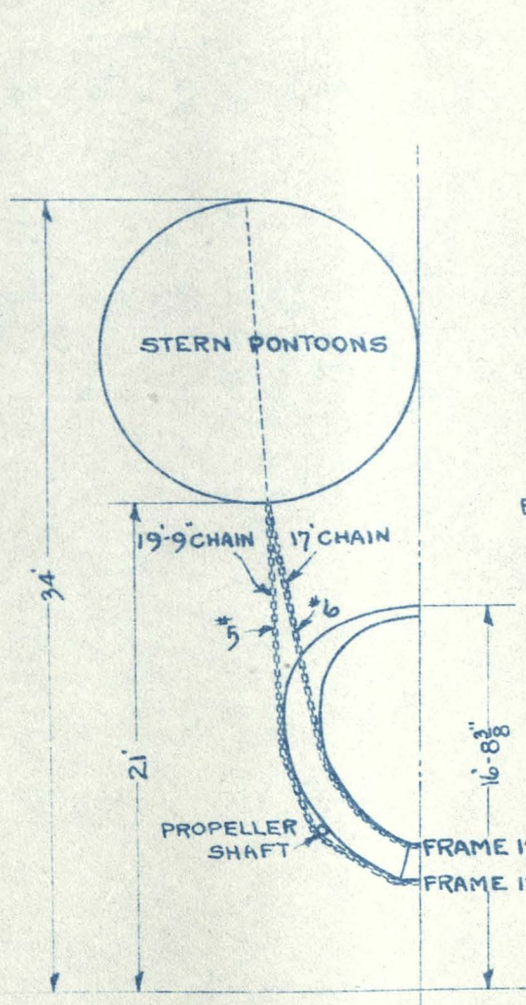
END COMPARTMENTS NOT SUFFICIENTLY BLOWN.
WATER ESCAPES WHEN HOSES ARE VENTED.



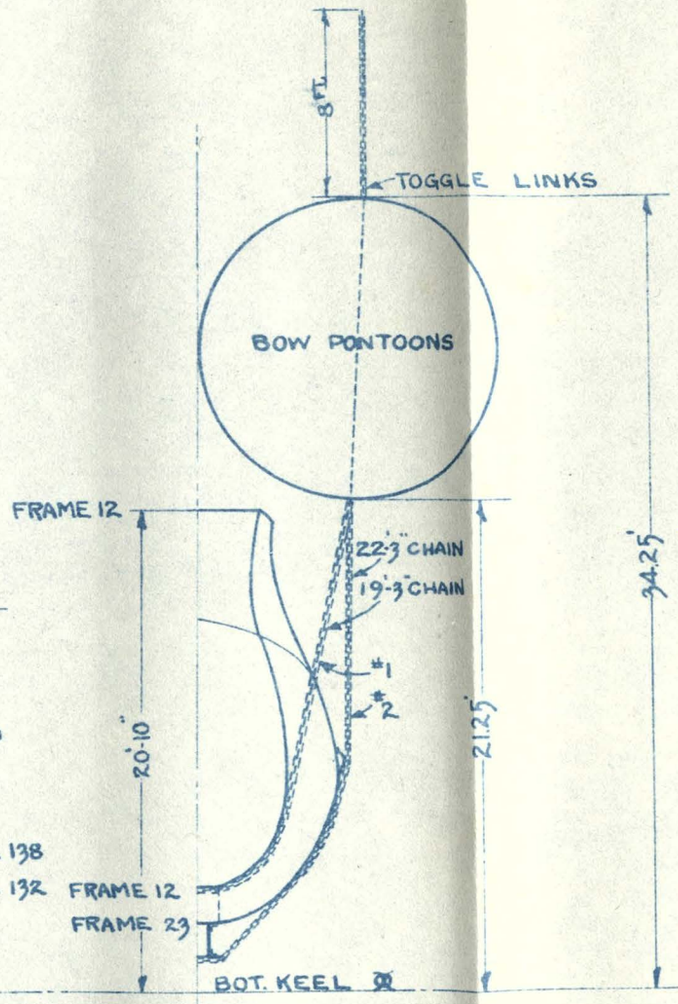
I

WATER LINE IN END COMPARTMENTS TO GIVE PONTOON 8 TONS POSITIVE BUOYANCY WHEN SUPPORTING CHAINS

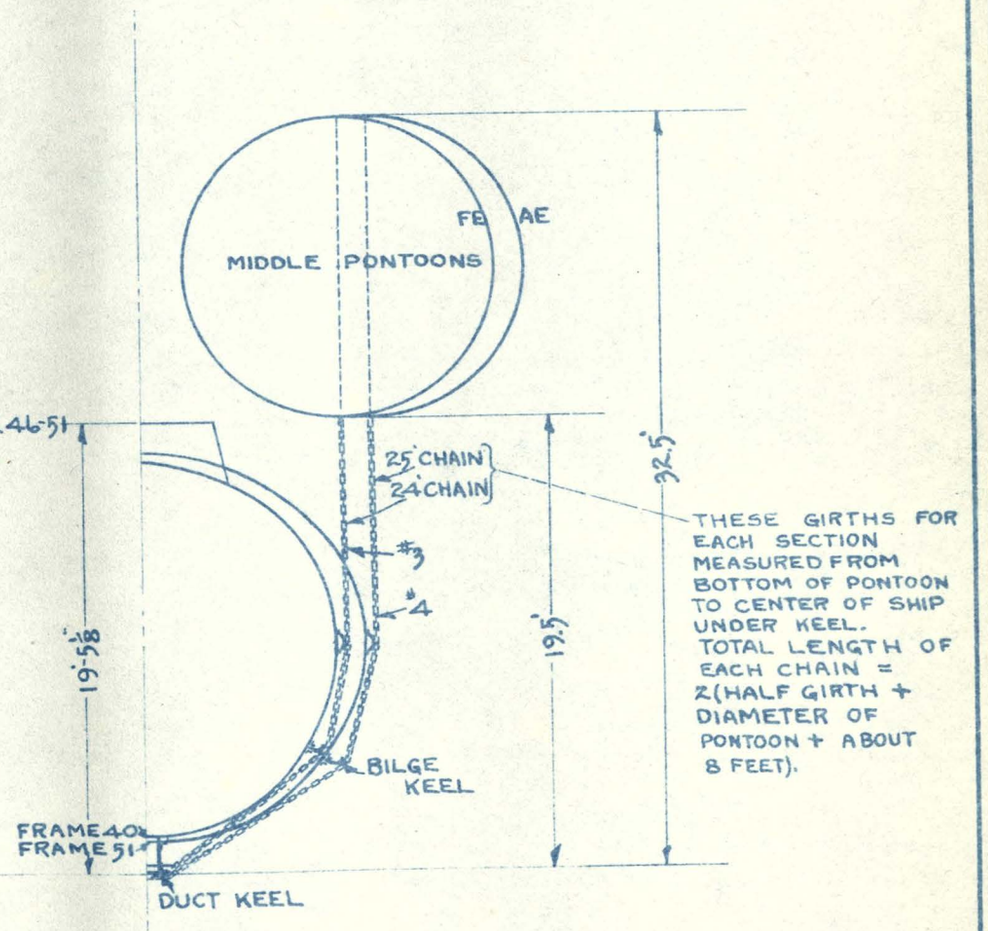
SUBMARINE S-4 SALVAGE
PONTOONS WITH DROP PIPES
PLATE Nº 6



SECTION
LOOKING FORWARD



SECTION
LOOKING AFT



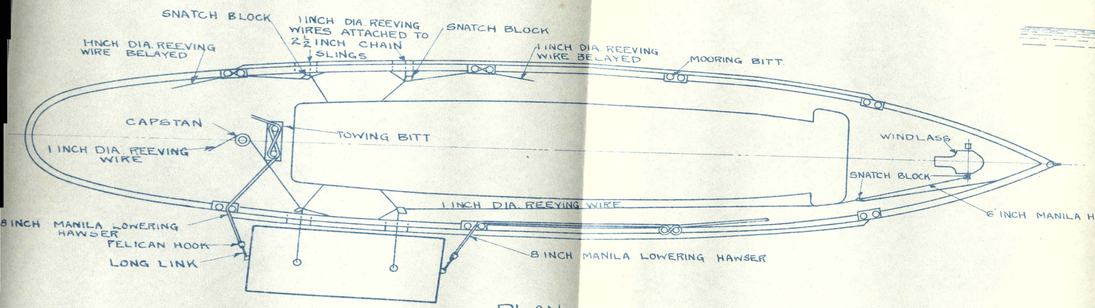
SECTION
LOOKING AFT

THESE GIRTHS FOR EACH SECTION MEASURED FROM BOTTOM OF PONTOON TO CENTER OF SHIP UNDER KEEL. TOTAL LENGTH OF EACH CHAIN = 2(HALF GIRTH + DIAMETER OF PONTOON + ABOUT 8 FEET).

STUDS WERE REMOVED FROM TOGGLE LINKS, ALL ALTERNATE LINKS BETWEEN TOGGLE LINKS AND ENDS OF CHAIN, AND FROM FOUR (4) ALTERNATE LINKS BELOW TOGGLE LINKS.

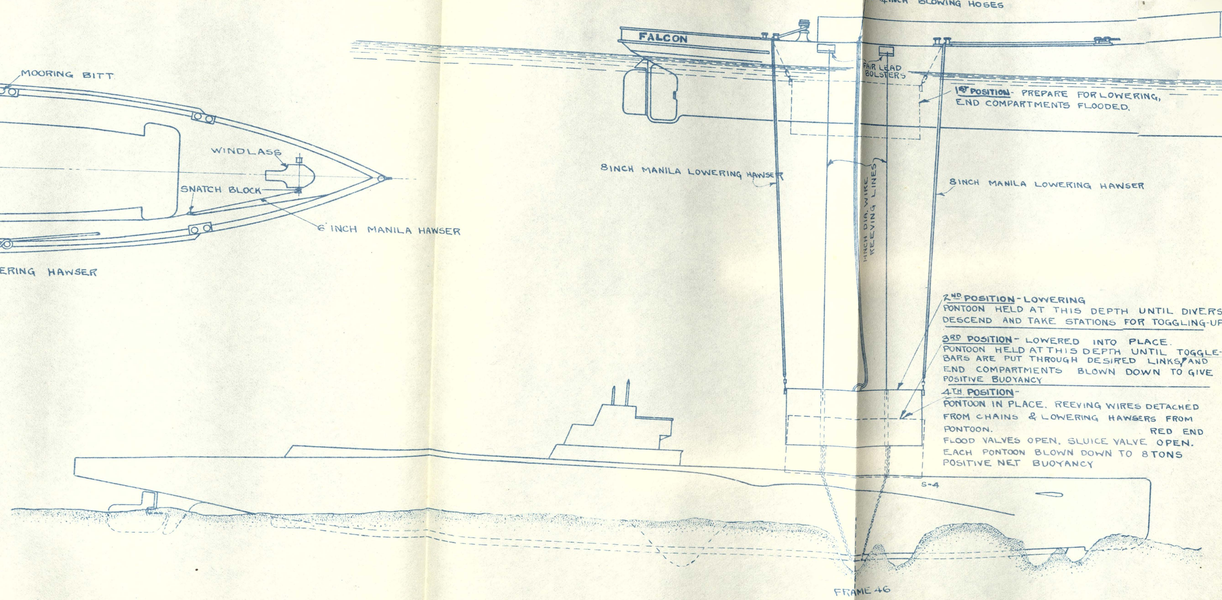
-SUBMARINE S-4 SALVAGE-
POSITION OF PONTOONS WITH REFERENCE TO HULL

PLATE Nº 7



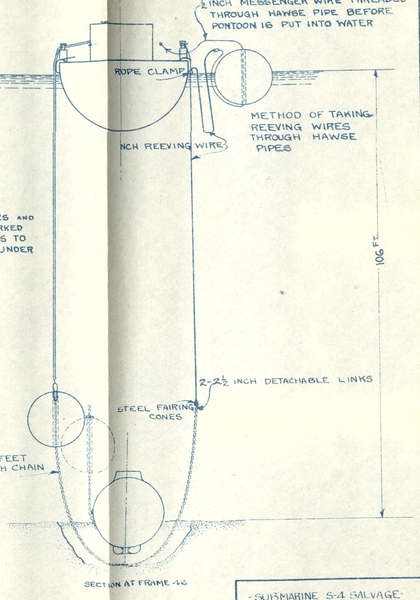
PLAN

NOTE:-
FOR SUBMARINE RESCUE VESSELS FITTED WITH PERMANENT PONTOONING CHOCKS, ROLLER FAIRLEAD AT FORWARD BITTS AND FORWARD CAPSTAN, OMIT ALL SNATCH BLOCKS AND 6 INCH TACKLE ON FORECASTLE.



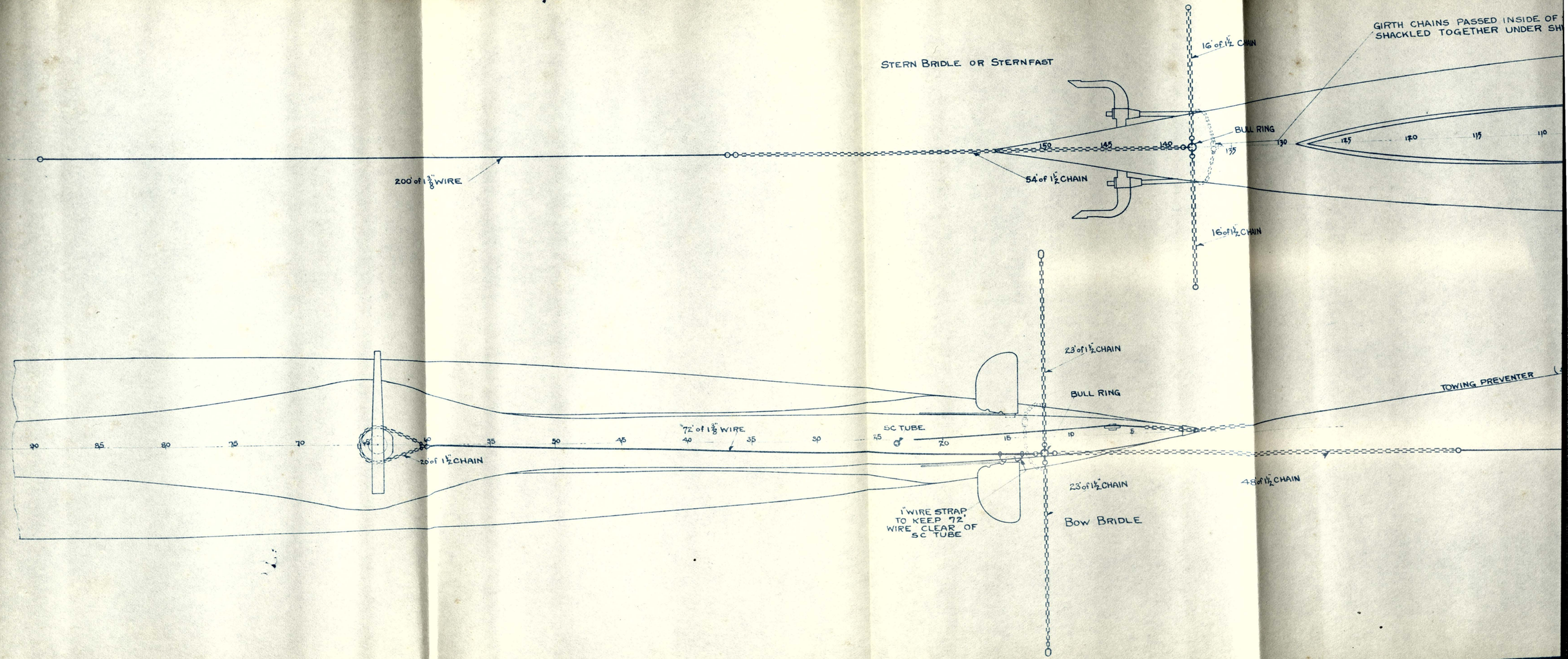
LOWERING HAWSERS AND REEVING WIRES		
MARK	FATHOMS	FEET
W	1	6
R	2	12
B	3	18
Y	4	24
W	5	30
R	6	36
B	7	42
YY	8	48
W	9	54
R	10	60
B	11	66
YYY	12	72
W	13	78
R	14	84
B	15	90
YYYY	16	96
W	17	102
R	18	108
B	19	114
WR	20	120
W	21	126
R	22	132
B	23	138
WRR	24	144
W	25	150
R	26	156
B	27	162
RRRR	28	168
W	29	174
R	30	180
B	31	186
RRRRR	32	192

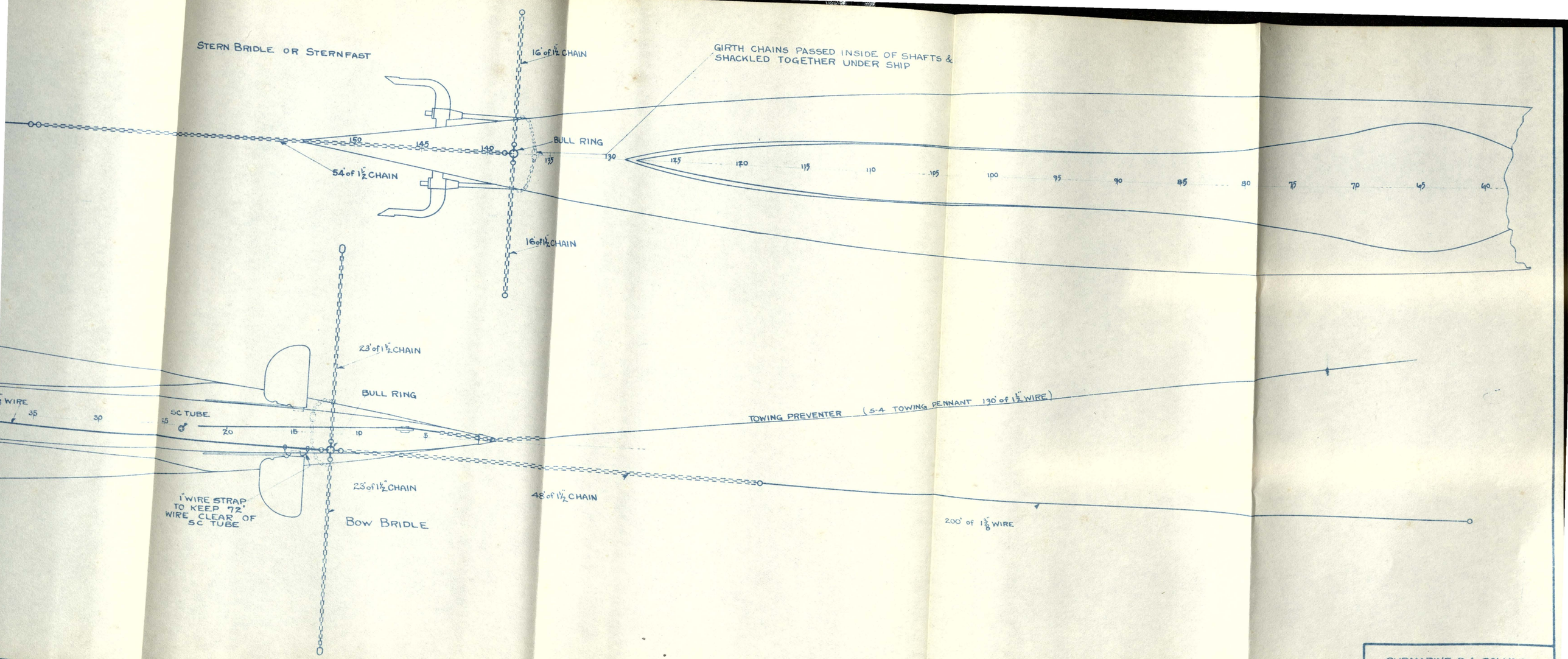
NOTE:-
LOWERING HAWSERS AND REEVING WIRES MARKED FROM LOWER ENDS TO SHOW DISTANCES UNDER WATER.



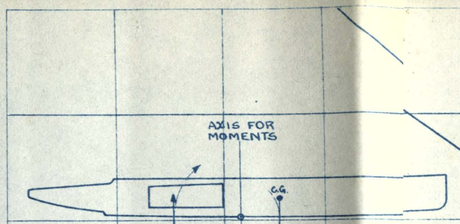
-SUBMARINE S-4 SALVAGE-
GENERAL PONTOONING DIAGRAM

PLATE No 8

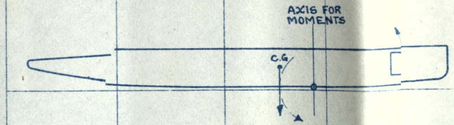

STERN BRIDLE OR STERNFAST
16' of 1½ CHAIN
GIRTH CHAINS PASSED INSIDE OF
SHACKLED TOGETHER UNDER SH
BULL RING
200' of 1⅜" WIRE
54' of 1½" CHAIN
16' of 1½ CHAIN
23' of 1½" CHAIN
BULL RING
TOWING PREVENTER
72' of 1⅜" WIRE
SC TUBE
20' of 1½" CHAIN
23' of 1½" CHAIN
48' of 1½" CHAIN
1" WIRE STRAP
TO KEEP 72'
WIRE CLEAR OF
SC TUBE
BOW BRIDLE



-SUBMARINE S-4 SALVAGE-
TOWING BRIDLES
PLATE NO. 8



ORDINATES ABOVE BASE LINE REPRESENT CLOCKW(+) MOMENTS. THUS.



ORDINATES V THE "0" BASE LINE REPRESENT COUNTER-CSE OR (-) MOMENTS, THUS

NOTE:- SLOPE AND POSITION OF EACH LINE FIXED BY POINTS A AND B.
POINT A IS FRAME LOCATION OF CENTER OF BUOYANCY OR GRAVITY.
POINT B IS 100 FRAMES FORWARD OR AFT OF A WITH ORDINATE EQUAL TO TONS BUOYANCY (OR V) TIMES 100

	BUOYANCY TONS	C.B AT FRAME	MOME FR (+
TORPEDO ROOM	77.0	30	
BATTERY ROOM BUBBLE	10.6	62	
CONTROL ROOM	73.5	83	1
ENGINE ROOM	105.7	104	5
MOTOR ROOM	87.2	125	6
ST. GEAR ROOM	4.0	143	
FUEL OIL	40.6	53	
CONNING TOWER	4.5	78	
SAFETY	14.0	81.5	
MIDDLE MAIN BALLAST	63.0	82	1
AFTER MAIN BALLAST	56.0	101	2
			18
TOTAL	536.1 TONS BUOYANCY		(+) 10 FR

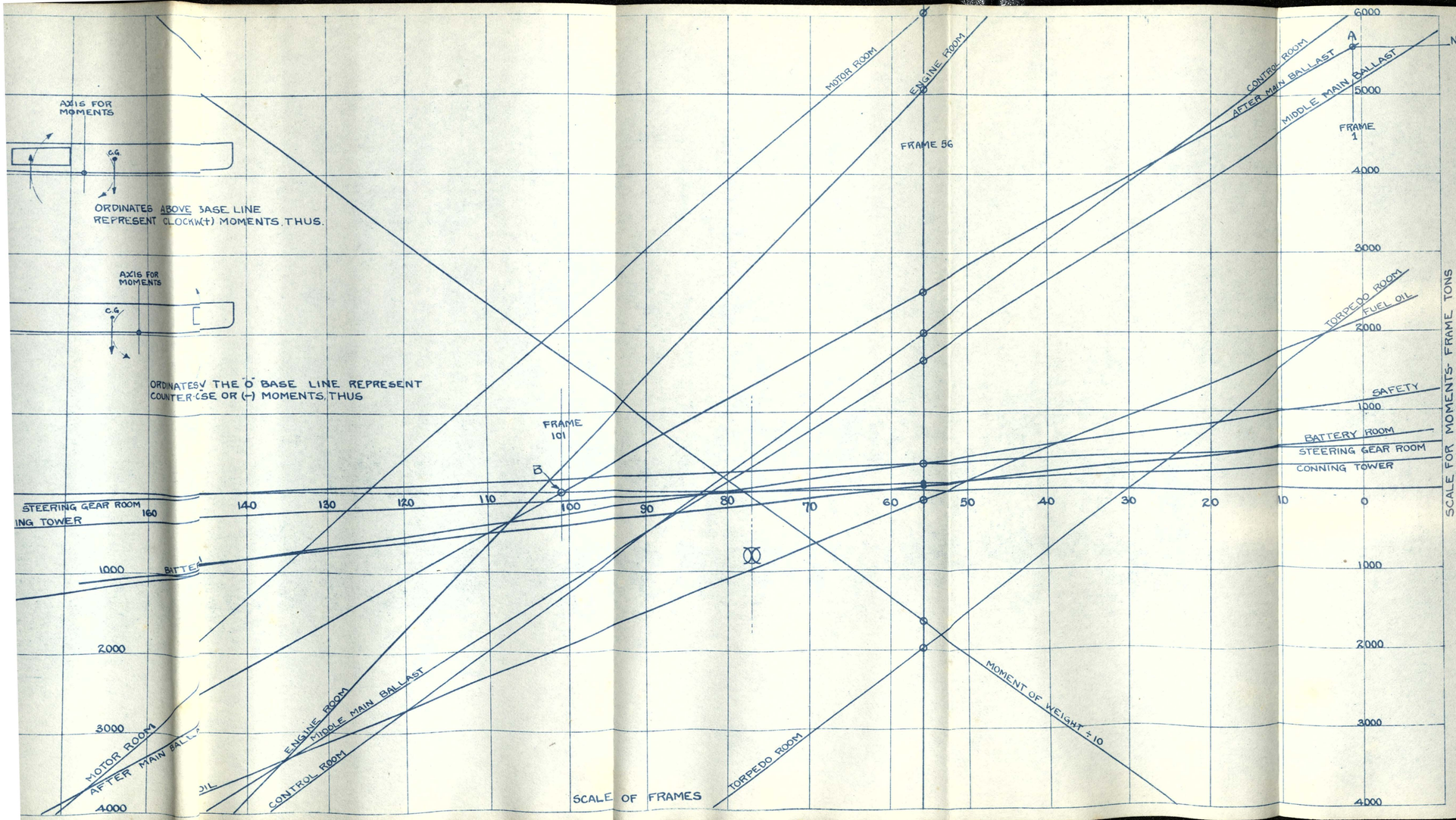
ASSUMED EXTREME CONDITION OF MAXIMUM WEIGHT - MINIMUM BUOYANCY
SHIP 2½° BY BOW
27. FEB., 28

SUBMARINE S-4
MOMENT DIAG
SHEET-1

PLATE Nº 10

SCALE OF FRAMES

SCALE FOR MOMENTS - FRAME TONS

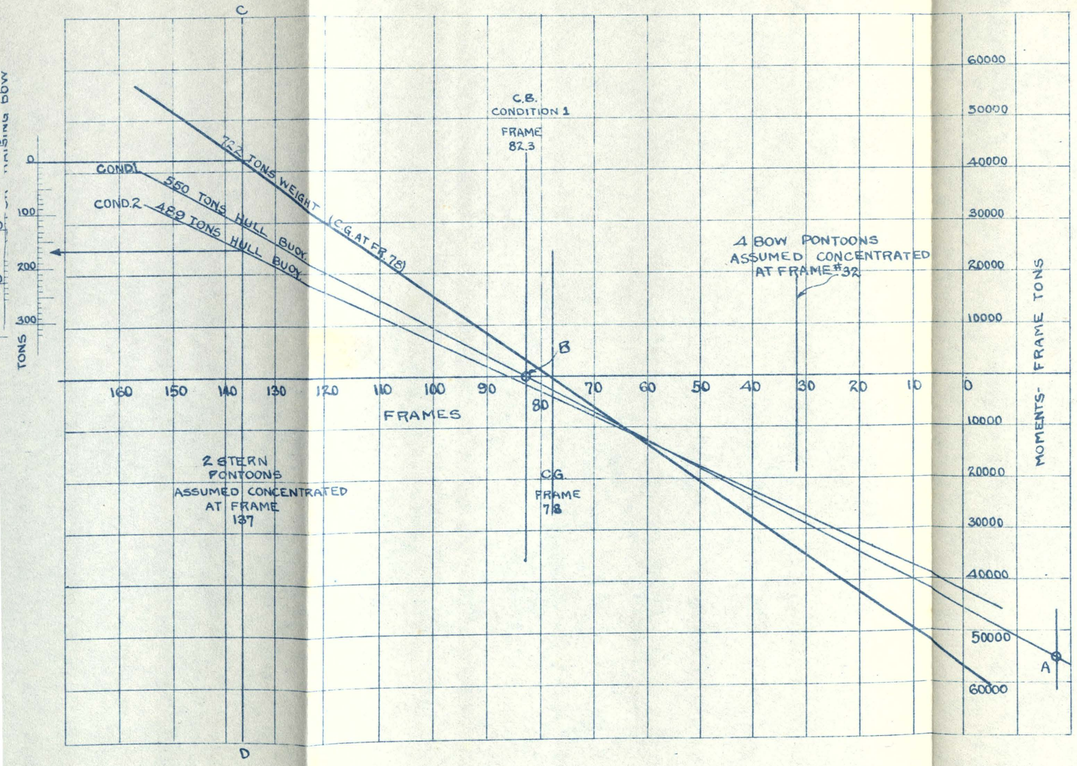


NOTE:- SLOPE AND POSITION OF EACH LINE FIXED BY POINTS A AND B.
POINT A IS FRAME LOCATION OF CENTER OF BUOYANCY OR GRAVITY.
POINT B IS 100 FRAMES FORWARD OR AFT OF "A" WITH ORDINATE EQUAL TO TONS BUOYANCY (OR WEIGHT) TIMES 100

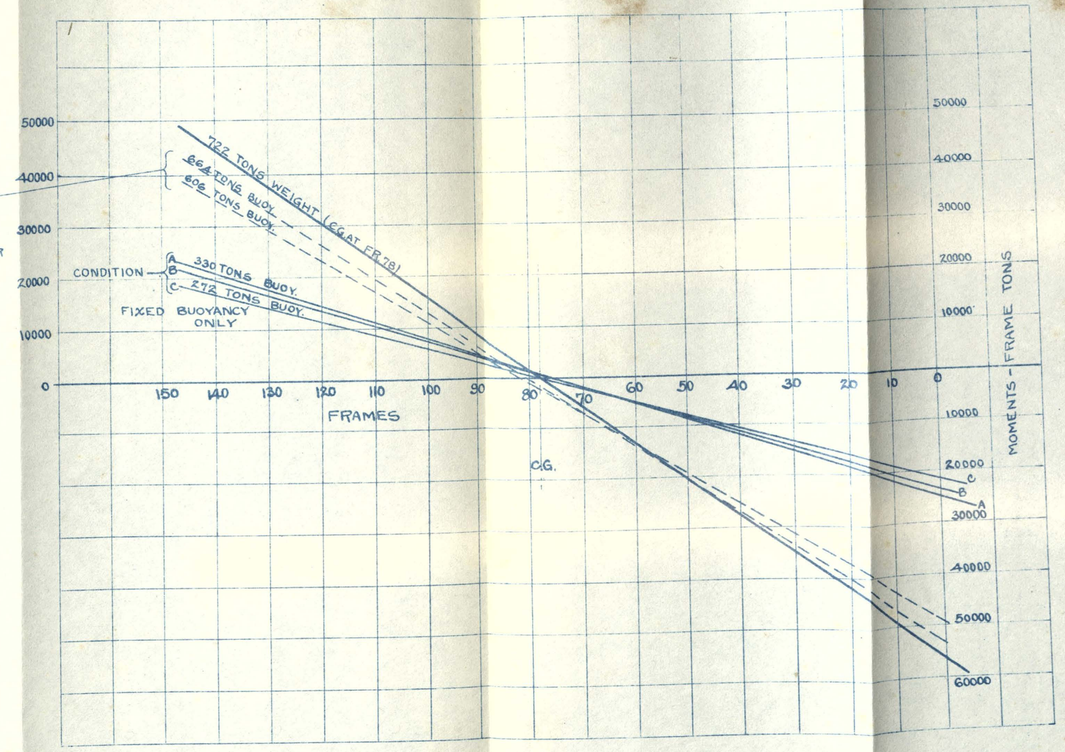
	BUOYANCY TONS	C.B. AT FRAME	MOMENTS ABOUT FRAME 56 (+)	(-)
TORPEDO ROOM	77.0	30		1,995
BATTERY ROOM BUBBLE	10.6	62	70	
CONTROL ROOM	73.5	83	1,995	
ENGINE ROOM	105.7	104	5075	
MOTOR ROOM	87.2	125	6,020	
ST. GEAR ROOM	4.0	143	335	
FUEL OIL	40.6	53		110
CONNING TOWER	4.5	78	100	
SAFETY	14.0	81.5	355	
MIDDLE MAIN BALLAST	63.0	82	1640	
AFTER MAIN BALLAST	56.0	101	2525	
			18,115	2,105
			2,105	
TOTAL	536.1 TONS BUOYANCY		(+) 16,010 FRAME TONS MOMENT	

ASSUMED EXTREME CONDITION OF MAXIMUM WEIGHT - MINIMUM BUOYANCY
SHIP 2½° BY BOW
27. FEB., '28

SUBMARINE S-4 SALVAGE
MOMENT DIAGRAM
SHEET-1
PLATE No 10

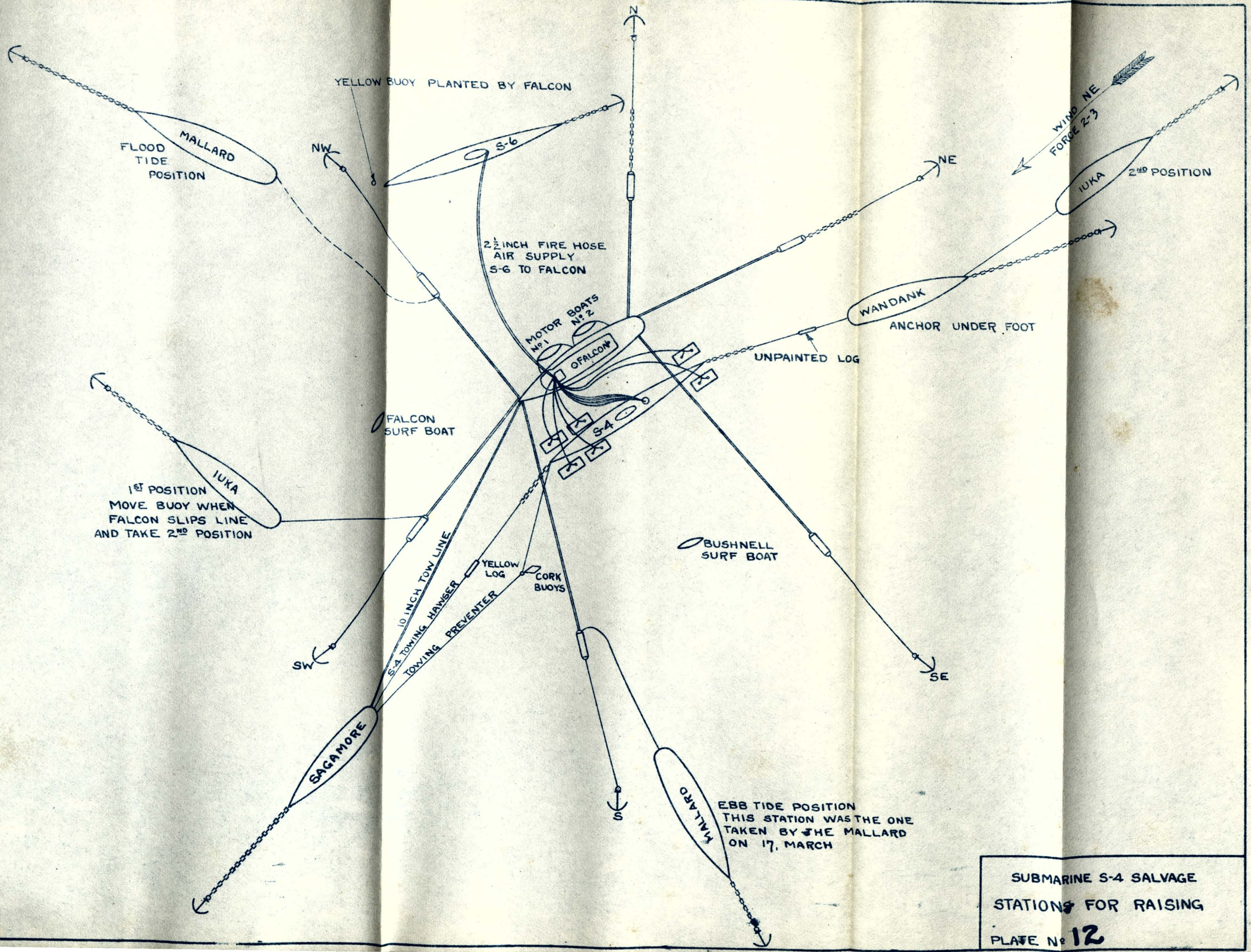


FIXED BUOYANCY PLUS ALL VARIABLE BUOYANCY INCLUDING 16 TONS BUOYANCY IN EACH PAIR OF PONTOONS (FUEL OIL TANKS #2-#6 FULL OF WATER



- SUBMARINE S-4 SALVAGE
MOMENT DIAGRAM
SHEET-2

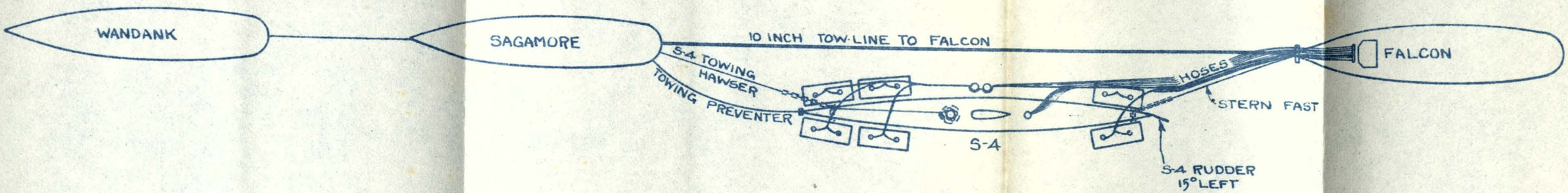
PLATE Nº 11



SUBMARINE S-4 SALVAGE

STATIONS FOR RAISING

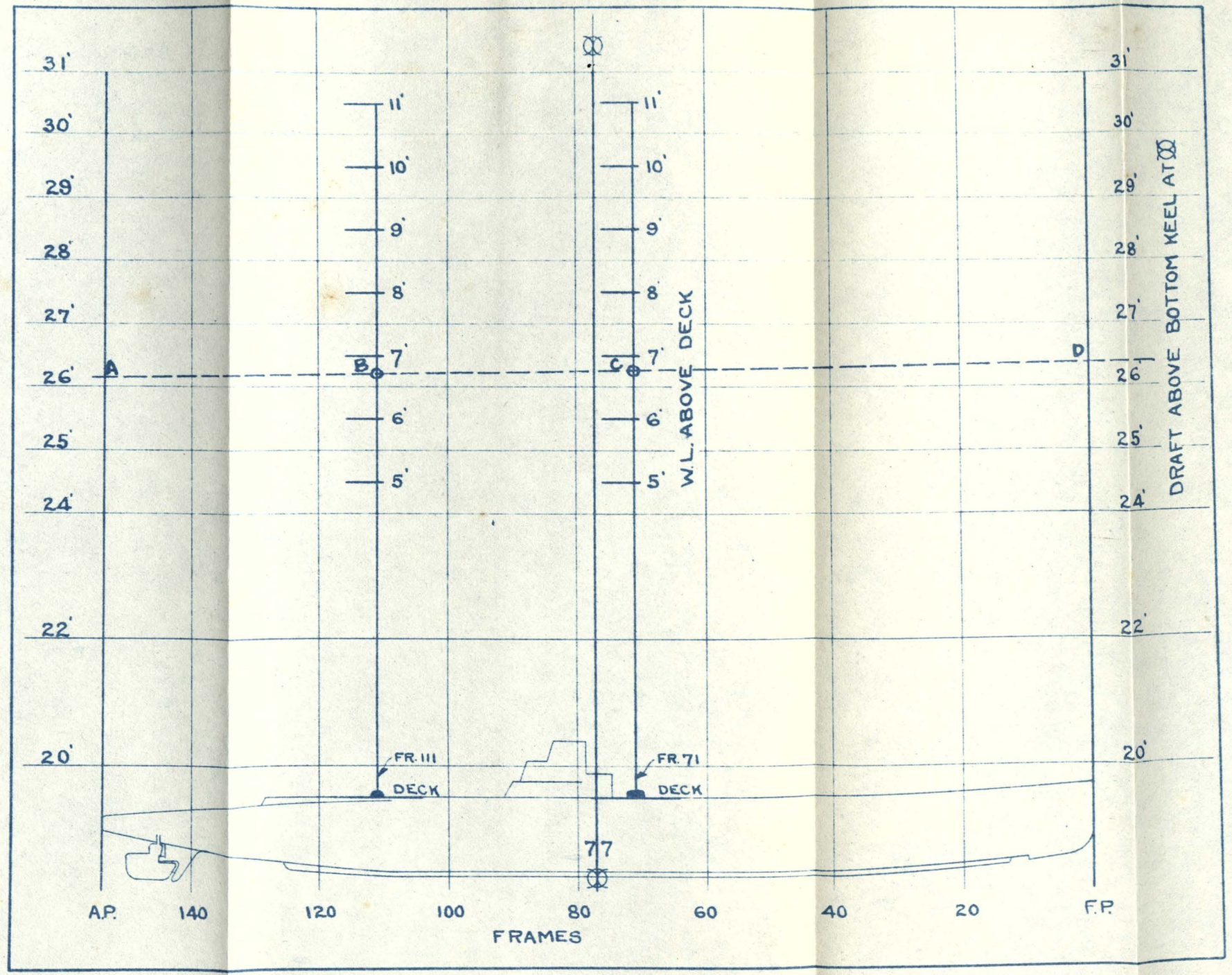
PLATE Nº 12



SUBMARINE S-4 SALVAGE

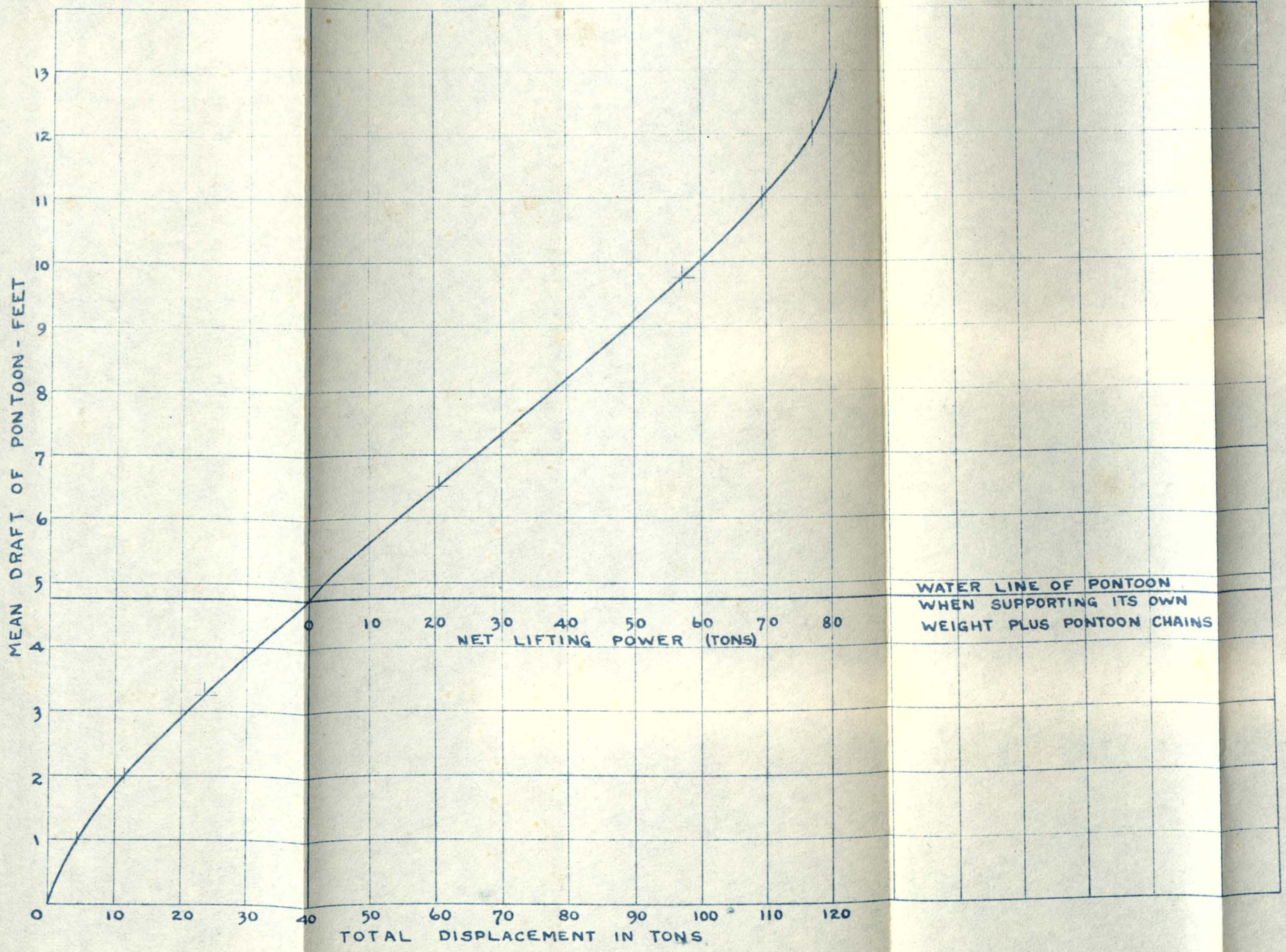
STATIONS FOR TOWING

PLATE Nº 13



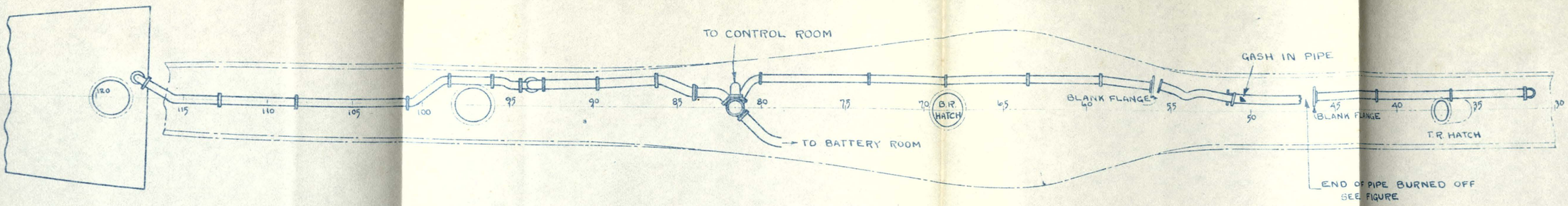
SUBMARINE S-4 SALVAGE
DRAFT DIAGRAM

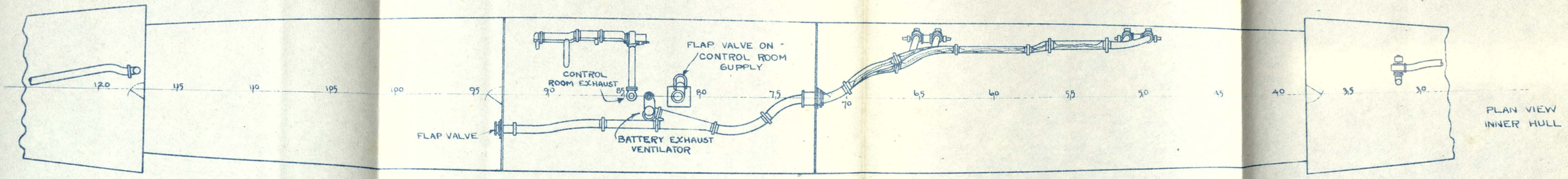
PLATE Nº 14

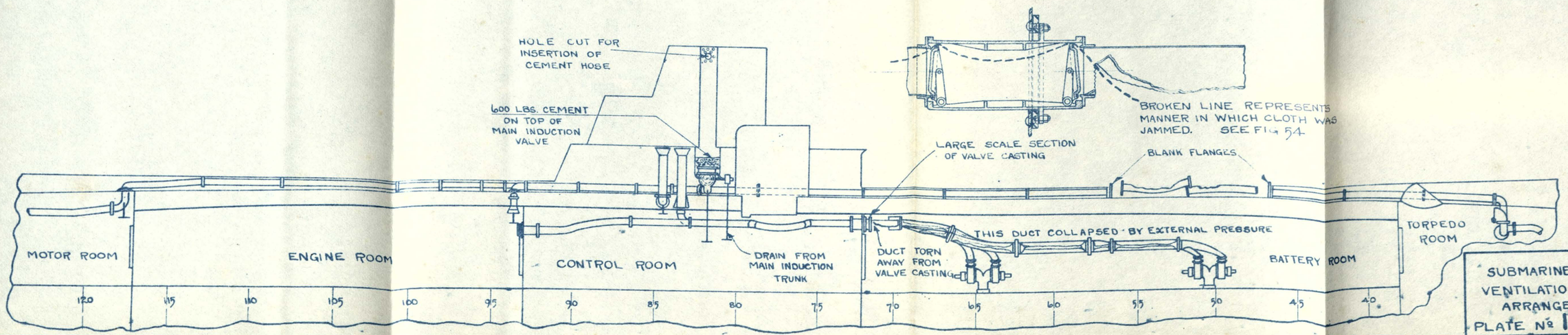


SUBMARINE S-4 SALVAGE
DISPLACEMENT CURVE
80 TON PONTOON

PLATE Nº 15

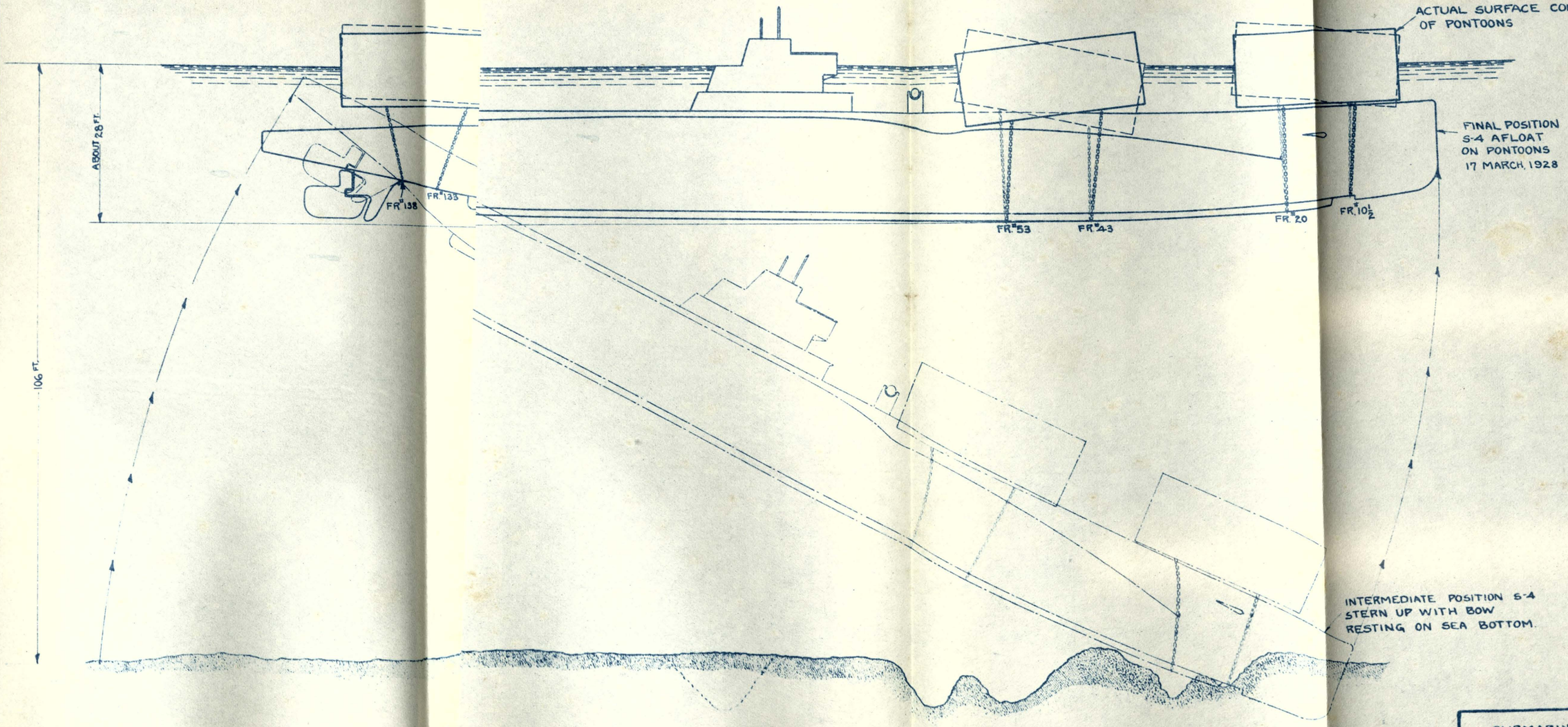






SUBMARINE S-4 SALVAGE
VENTILATION SYSTEM
ARRANGEMENT
PLATE Nº 16

PORT PONTOONS- BROKEN LINES
STARBOARD PONTOONS- FULL LINES



SUBMARINE S-4 SALVAGE
PONTOON ARRANGEMENT AND
SALVAGE POSITIONS
DURING RAISING

PLATE Nº 17