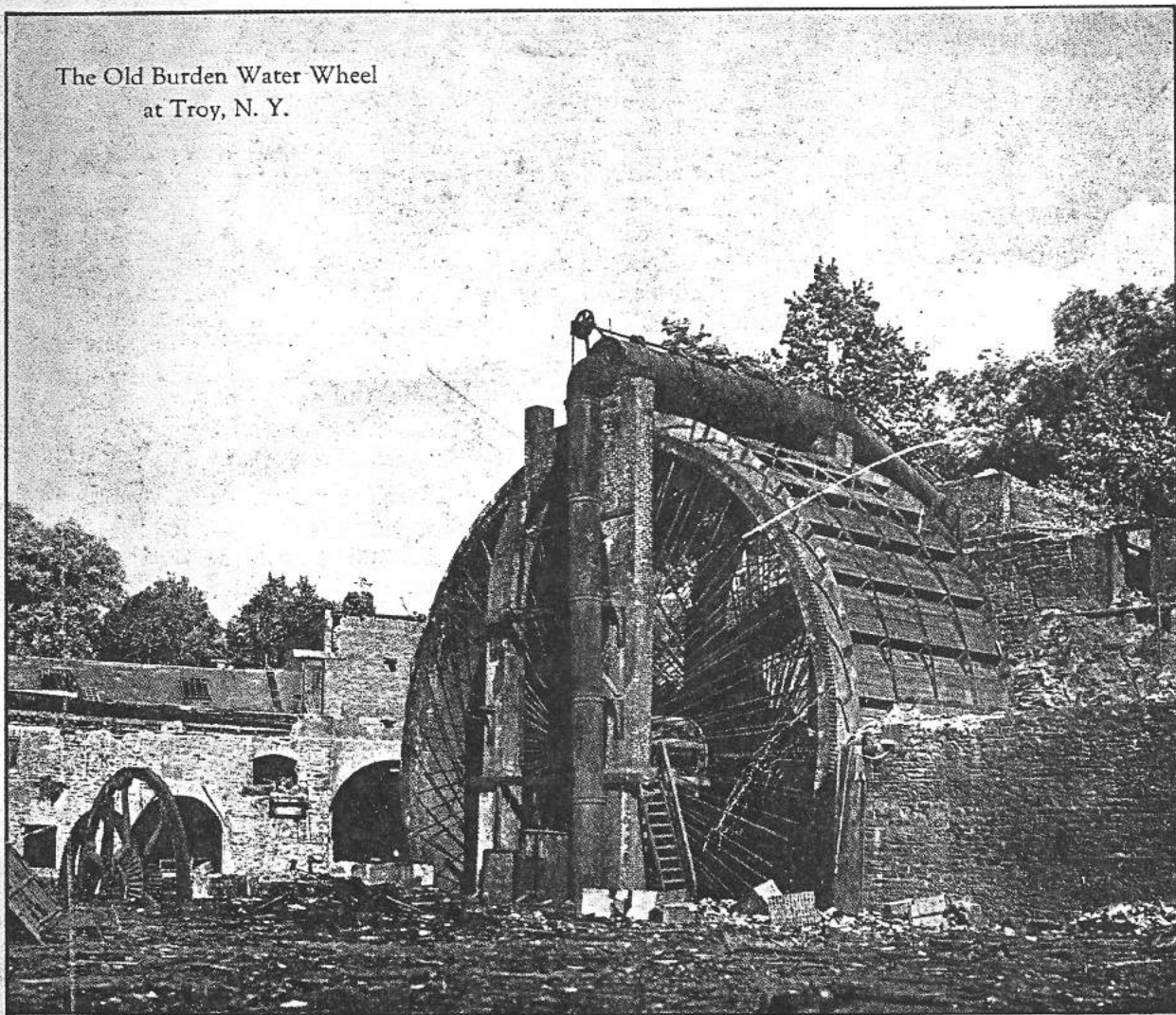


# MECHANICAL ENGINEERING

The Old Burden Water Wheel  
at Troy, N. Y.



*February* 1928

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# Mechanical Engineering

The Monthly Journal Published by  
The American Society of Mechanical Engineers

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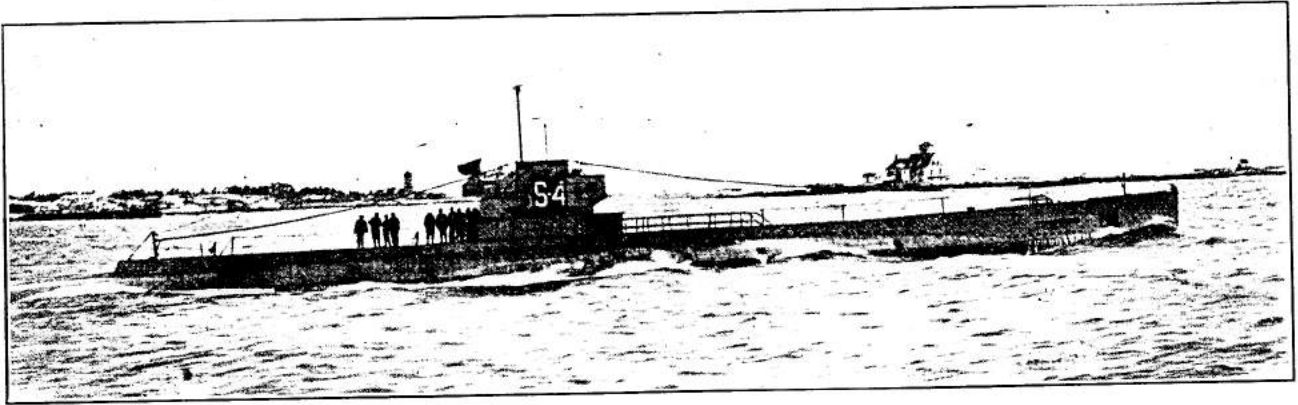
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THE ILL-FATED S-4 UNDER WAY

## Submarine Safety and Salvage Devices

Safety Weights—Detachable Chambers—Diving Suits—The Extensible Tube—Signaling Buoys—Watertight Compartments—Means of Attaching Lifting Chains or Pontoons to a Submarine—Submarine Salvage Vessels—Conclusions

**A** FACTOR of safety in military engineering means a vastly different thing from what it does in civilian engineering. In the latter it means a leeway in the ability of materials to resist stresses imposed by the operation of the machine itself. In military engineering another important element is introduced, and that is that the machine, be it an airplane, battleship, submarine, or tank, has to resist not only the dangers incident to its own operation but the destructive forces loosed against it by the enemy. Under these conditions it is a question of skilful adjustment of the very highest grade in the matter of factors of operation of a device. This may be best illustrated by the consideration of a pursuit plane. In commercial work such as passenger or mail air transportation, the highest degree of stability of plane is sought for. If a plane could be made so foolproof that it could not help flying on an even keel no matter how ignorantly controlled, such a machine would be unhesitatingly adopted by commercial fliers, but not for pursuit purposes. In a pursuit plane it is of the highest importance for the flier to be able to side-slip, nose-dive, fly upside down, roll, and do all such hair-raising stunts. In fact, his very life may depend on his ability to do them, and a plane that would persist in flying on an even keel no matter what was done to it, would be deadly to the combat flier. Here we have an instance of what would be supreme safety in a peaceful-purpose machine turning out to be a deadly danger in a military device.

This distinction between what might be called the engineering factor of safety and the military factor of safety must be thoroughly realized when considering the various devices either suggested at times or applied to submarines. Accidents to submarines may happen in several different ways. Under certain conditions the operation of the storage battery may lead to an evolution of hydrogen which forms an explosive mixture with the air, and this if ignited, as it is fairly bound to be ultimately, is apt to produce quite disastrous results. Such an accident happened in the Brooklyn Navy Yard on one of the submarines in the early part of the World War. Should it happen in the open sea, particularly when a submarine was submerged, the destruction would probably be so great as to make the escape of any one extremely problematic. These kinds of accidents are, however, rare and can be prevented by

proper selection of the type of storage batteries and their careful operation.

Generally, emphasis should be laid on the matter of care. The working of a submarine is inherently a very dangerous job. It ranks in this respect in the same category as the handling of high explosives and the most poisonous chemicals. The slightest lack of care in any way is practically certain to lead to disaster. It is surprising, nevertheless, how many accidents on submarines are really due to carelessness of the operators and are therefore entirely preventable. And not only Americans, who are proverbially considered to be reckless, may be guilty of this lack of care but even the supposedly methodical Germans. This is well illustrated by the disaster to the U-3 which sank in the Kiel Harbor because it had submerged with one of the valves open to the water.

Explosions of fuel gases or rather mixtures thereof with air were formerly a possible source of danger when submarines were operated on the surface by gasoline motors. Today with Diesel engines as the practically universal method of drive, this hazard has been practically eliminated.

There is of course always present the possibility of failure of machinery, particularly the electrically driven pumps and air compressors operating the submergence tanks, and also of the failure of controls. In such a case a submarine would have to lie at a certain depth, and it becomes a matter of luck where the accident happens. If the depth is not great and the plight of the submarine is quickly discovered it can be raised, otherwise it is lost.

One of the serious dangers to a submarine lies in the possibility of collision either with another submarine or with a surface vessel. This was the cause of the loss of the S-4 which startled the country recently. Here again it is a matter of luck how it happens. If the collision is of such a character that the men or some of them can escape into one of the watertight compartments and rescue conditions are favorable, there is a chance of their being saved; otherwise there is none, as, for example, in the case of the S-51 sunk by collision with the *City of Rome*.

According to an official statement of the Navy Department the F-4, S-5, S-48, and S-51 are the only relatively modern sub-

marines in our Navy which have gone to the bottom and have been unable to bring themselves to the surface. In the case of the F-4, as the vessel undoubtedly went to the bottom very quickly, no type of rescue apparatus would have been of any value. In the case of the S-5, the bow of the vessel rested on the bottom and the stern projected above the surface. If the S-5 had been fitted with the stern torpedo tubes which are being installed in the latest classes of submarines, the escape of the crew through these tubes would have been a comparatively simple matter. The case of the S-48 parallels that of the S-5, except that the personnel of S-48 succeeded in raising the bow to the surface and effecting their escape through the bow torpedo tubes. The sinking of the S-51 by collision and consequent flooding of the interior of the inner hull resulted in conditions similar to those of the F-4. In the salvage operations on the S-51 the method used in raising the F-4 and the former German submarine U-111, i.e., the "pontoon" system, was employed, with the same signal success.

There have been very many devices proposed for the salvage of submarines. Some of these are too impractical to call for serious consideration—for example, the use of huge magnets to lift the submarine from the bottom. Other devices, however, are in one way or another worthy of notice.

There are certain technical limitations with which the submarine designer has to contend, and those must be most carefully taken into consideration when it comes to the installation of any device whatsoever on a submarine. In the first place, submarines are now built so as to be capable of submersion to increasingly great depths. Where formerly 100 ft. or 150 ft. was considered good, the modern submarine should be capable of freely submerging to a depth of 300 ft., which means roughly a water pressure of 145 lb. to the square inch. This requires a very great increase in the strength of the hull, with a consequent increase in weight. Any addition of weight to the outside of the hull of a submarine requires an increase in size to provide the increased displacement necessary to carry this weight. The result is that when one ton is added to the weight of a submarine in the form of some fixture or attachment, such an increase in size is made necessary as will increase the total weight to the extent of 2.7 tons.

The next great limitation is that of space. A submarine has to carry about three times as much equipment for the power developed as does a surface ship. The propelling plant of the latter is what might be called a single-acting unit, say, steam or Diesel. A submarine carries a Diesel engine which drives it on the surface and also charges the storage batteries. To do this it has to have a powerful generator. The drive under surface is by electric motor from the storage battery. A three-step arrangement therefore becomes necessary, in addition to which the submarine has to carry water tanks, a supply of air, and for its size an inordinate amount of military equipment. It is therefore about as full of machinery as an ordinary watch case, and every square inch of space is utilized to the utmost degree. None of this can be given up to any additional gadget without taking it away from something else.

#### SAFETY WEIGHTS OR DROP KEELS

One of the earliest methods of submarine salvage was the use of the so-called "safety weights," which consisted of huge blocks of iron or lead so attached to the bottom of the submarine that they could be released from the inside. The purpose of this was to decrease very rapidly the specific weight of the submarine and permit it to rise to the surface. Such weights were fairly regularly employed up to about the time of the World War, but the recent trend of opinion is against their use. In the first place, it has been found that the working of this de-

vice is neither rapid nor reliable enough for practical purposes. In the next place, the additional load reduces the speed of the submarine and its cruising radius to such an extent as to affect very materially the military value of the device. Finally, with the great increase in the size of submarines the weights that could have been used would have had to be inordinately large and, moreover, would have complicated the important problem of balancing when submerged. On the whole, therefore, the present tendency in design is to dispense with their use.

In one instance during the World War the drop keel was accidentally knocked off an English submarine by contact with the sea bottom. The vessel was unable to submerge after the accident and ran the danger of being sunk by the enemy, getting back to England by mere fortune. A step in the direction of abandoning this scheme was the adoption of safety tanks. These tanks were filled with water, thus providing an extra weight, and when necessary could be very quickly emptied by introducing very high-pressure air carried for this purpose in special cylinders.

#### DETACHABLE CHAMBERS

The next device from which great things were expected was the detachable chamber. The idea was to provide in the hull of the submarine small compartments with double doors working something like the Servidor device used in hotels. Double doors were to be provided so that a person could pass into this detachable chamber, close the doors after him, have the chamber detached from the submarine, and float up to the surface. One of the suggestions was to make the entire conning tower act as such a chamber, so that in case of necessity the whole crew of the submarine might save themselves in this way. The problem of designing such a device so that it will withstand when detached the considerable pressures met at substantial depths is not an easy one. Moreover, with the present large submarines carrying a crew of some 85 people, the device would have to be of a very considerable size. The question of placing these detachable chambers is also not an easy one. If they were located inside the hull they would occupy most valuable space, and space is what the designer of a submarine can least spare. If the chambers were located outside the hull, somewhat like warts on a frog's back, they would materially reduce the submerged speed of the vessel.

#### DIVING SUITS

It has been suggested many times—but not by submarine designers—that diving suits be provided for the crew, the idea being that in case of accident the crew could don these suits, open doors, and serenely walk out on to the ocean floor. The trouble with this scheme is, first, that in case of an accident, particularly where the hull is ripped open, there is seldom time for the rather elaborate operation of donning a diving suit. Next, not many men employed on a submarine are physically suited for work at substantial depths in an ordinary diving suit. On the other hand, however, in several European navies the so-called "oxylite" masks are carried. These masks have a chemical which is capable of absorbing moisture from the human breath and evolving oxygen in proportion thereto, so that a man can live in an oxylite mask for as long as three-quarters of an hour without breathing any outside air.

The main value of these masks is in case sea water should accidentally penetrate into the storage batteries. Because of the reaction between the sodium and magnesium chloride in sea water and the sulphuric acid in the batteries, such an accident would result in the evolution of chlorine. Should this happen when the submarine was submerged, time would be

needed to bring the vessel to the surface and either ventilate it thoroughly or permit the crew to get outside. For such a purpose masks of the oxylyte type are quite valuable, and being comparatively light and small they are not in the way.

#### THE EXTENSIBLE TUBE

This device has been suggested on numerous occasions, the idea being to provide a tube of a diameter sufficient for a man of ordinary girth to pass through. This tube is supposed to be collapsed under ordinary conditions, somewhat like a traveler's aluminum drinking cup. In case of necessity it is to be extended so as to reach the surface and thus provide a means of egress for men trapped in a submarine. The device has never been adopted in practice by any navy, and the reasons for this are fairly obvious. Such a tube would have to be at least 25 in. in diameter. For a hollow tube to withstand water pressure at a depth of, say, 300 ft. it would have to be made very strong, particularly at the joints, which means that it would have to be quite heavy. It would occupy a lot of room, require quite an elaborate arrangement for extending it, and then would provide egress only to men trapped in the one compartment with which the tube communicated.

#### SAFETY TANKS

All submarines of the United States Navy are fitted with an automatic device which may be set to operate at a predetermined depth. Several different types of valves have been used, all of which operate on the same principle, i. e., the unbalancing of forces previously in equilibrium by sea pressure due to the depth of submergence. The tripping of such a valve opens the 100-lb. air line to one or more of the main ballast tanks, usually forward of amidships, and allows air to be blown into the tank, forcing the water out through the Kingston valve and thereby bringing the boat to the surface. These valves are not of an automatic repeating type but require to be reset by hand after each operation. Valves of this type have generally proved satisfactory, being capable of arresting the descent of the vessel to within 5 ft. of the intended depth, and criticism mainly has been directed to the capacity of the reducing valve which supplies air from the 100-lb. line. No standard valve has been adopted. Two varieties have been installed on contract-built submarines, both of which are covered by United States patents. A special type of automatic valve has been designed by the Portsmouth Yard and installed on the "S" vessels built by that yard, but has not been thoroughly tested as yet. Automatic control of the diving planes has been suggested and has been considered in a tentative way at various times, but no definite action along these lines has been taken, as it is believed that the complications involved would not be warranted by the advantage gained. The practicability of providing automatic arrangements for controlling the regulating or adjusting pump has been investigated, but in view of the complications involved it is not believed that the arrangement is practicable or would serve any useful purpose.

#### SIGNALING BUOYS

Many of the European submarines are equipped with signaling buoys which in case of accident can be released by the submarine and will indicate its position. In the German navy, for example, these buoys are equipped with telephones, and at times attempts have been made to equip them at night with flares and in the daytime with smoke or sounding devices. These buoys were formerly quite extensively used in the American Navy, but of late have been discarded. The reason for this appears to be the possibility that in war time the concussion produced by depth bombs might release the buoy and thus

indicate the position of the submarine to the enemy. It would seem to be quite feasible to use these buoys in peace time, and either batten them down or cut them off completely in war time.

If properly used and equipped these buoys constitute a valuable auxiliary, in particular, by indicating immediately the location of the submarine and possibly giving information as to the condition of the vessel, the condition of the crew, and the degree of necessity for prompt action. The design of these buoys is, however, as yet in a very crude state, and no facilities are provided for the men in all of the watertight compartments to communicate with the outside world by the telephone apparatus enclosed in the buoy. It may be stated in this connection that the whole subject of submarine safety devices is in an inchoate state, and that even where such devices are used their design is usually quite crude and lacking in that careful working out which characterizes safety devices in civilian engineering.

This matter has been discussed with some of the officers of the Navy Department, who state that signaling buoys are not really necessary any longer. With the present listening devices the submarine can make its presence known quite easily in various ways and can be located without any trouble, provided some one is alive inside who can send out the information. If every one were killed in an accident, the marking buoys would not operate anyway.

#### WATERTIGHT COMPARTMENTS

In case of partial failure of the hull through collision or otherwise, watertight doors dividing the submarine into several independent compartments may prove to be the means of saving the lives of at least part of the crew. It is in this way, for example, that the lives of the men of the German submarine U-3 were saved, and those on the American S-4 prolonged.

The installation of watertight partitions and doors is a well-known naval device, and its reliability of design has been fully established in the past.

In the American Navy the bulkheads making watertight compartments are considered to be one of the most important provisions for safety on submarines. It is because of their presence that the lives of men on the O-5, S-48, and S-5 were saved. The engineering features involved in the design of the watertight bulkheads are very interesting and are being given the most serious consideration by the Navy. It should be realized in this connection that the big modern submarines are built to operate at depths in excess of 300 ft., which is equivalent to a pressure of about 145 lb. to the square inch. The bulkhead has to be built actually much stronger than even the hull, because while the pressure on the hull is determined by the  $2\pi R$  relation, that on the bulkhead, should the water come in, is determined by the  $\pi R^2$  relation. The modern bulkhead is therefore not a diaphragm structure with a door cut through it as one would imagine offhand, but a system consisting of very strong ribs with inverted dished partitions between them, and altogether represents an extremely strong structure.

#### EXTERNAL MEANS OF SALVAGE

All the foregoing devices may be classed as internal means of salvage by which the men in a submarine in case of accident can take care of themselves. Assuming, however, that this proves to be impossible, or that the question is not so much the saving of life as the recovery of the sunken vessel, we come to external means. These may be classified into two groups—first, those for the saving of life, and second, those for the salvage of equipment. In war time, under certain conditions, the order of importance is reversed, the equipment being considered more valuable than the few lives which it may contain.

#### AIR SUPPLY TO THE SUBMARINE

Only recently has this problem been thoroughly studied. There are two views as to how it should be done. One way is to supply air to the general air system, which includes the submergence tanks. The piping is so arranged that under ordinary conditions air pumped from outside will be delivered to all compartments. This may not happen, however, if the submarine has been seriously damaged, as, for example, was the case with the S-4. The other way is to provide proper valve connections so that air can be admitted to individual compartments even when the general air system is injured. The former system has been adopted on American submarines. As a makeshift, air can be supplied to some compartments, as, for example, through the listening tubes, provided the proper valves are opened from the inside, and provided proper connections are either available or have been made for attaching the air hose. It does not appear clear why both systems should be used simultaneously, and it would appear perfectly feasible to change somewhat the piping arrangements, possibly by providing two-way valves, so that the system could be used either as a single system or for supplying individual compartments.

#### LIFTING MEANS

In the event that the injury to the submarine is of such a character that there is no way for it to rise to the surface of itself, even with the main tanks emptied of water, the thing to do is to raise it by outside means. There are only two ways available: one is to attach to the submarine additional tanks, force the water out of them, and thus float the vessel; the other is to attach chains or wire ropes directly to the submarine and hoist it by brute force. In either event the operation falls into two stages: (1) attaching lifting pontoons or hoisting chains to the submarine; and (2) putting through the hoisting operation itself. When plenty of time is available the operation is comparatively simple, provided of course that the submarine lies at a depth at which diving operations can be carried out without extreme difficulty. Where sufficient time is not available, those who are going to carry out the raising operation will sincerely appreciate any provision for doing the work as quickly as possible. It may be mentioned in this connection that time may not be available for two reasons. In the first place, men yet alive may be caught in the sunken vessel and the highest possible speed of operation may be needed to preserve their lives. In the second place, weather conditions may be such as to afford only a limited time in which to do the job. A combination of these two conditions was present, for example, in the initial salvage operation of the S-4.

#### MEANS OF ATTACHING CHAINS OR PONTOONS TO A SUBMARINE

Any engineer who has had experience with crane operation or derrick work in construction knows the great difference between raising a heavy piece so designed that it can be conveniently held by the crane hooks or chains, and doing the same job with perhaps a much lighter piece of such a shape that one has to use special ingenuity to hold it and is then perhaps not quite certain of being able to do so. While every designer of submarines knows that because of its very character of operation it is apt to get into trouble, out of which it will have to be pulled by raising, still the provisions for carrying out this operation are anything but ample. The most obvious way to assist in the raising operation is to do with the submarine what is, for example, done with a ladle or ingot mold in a steel mill, i.e., provide it with either bosses or eyes to which hooks or chain loops can be engaged. In fact, the Navy has been blamed by some congressmen for not having done so in the case of the S-4. However, this question of hooks or bosses is more in-

olved than appears on the surface. The early submarines were quite frequently provided with eyes riveted on the hull. Those vessels however, were comparatively small and the load on each eye was therefore quite light. With large modern submarines a rather different situation presents itself.

It should be remembered in this connection that the stress is not applied evenly to the eyes in lifting a submarine. A crane operator lifting a foundry ladle can more or less control the stress on the crane hook by pulling it up slower or faster. He is, however, operating from a perfectly fixed base, the crane bridge. The salvage vessels, on the other hand, when raising a sunken ship have no such fixed base, but on the contrary are supported by that most restless element, the ocean, with the result that the stress is either half eased off or suddenly applied with a powerful jerk. The strength of the hook or eye on a submarine is no greater than the strength of the rivets or the weld that holds it to the hull, or the strength of the hull itself. A brief calculation will show that if it were attempted to raise a submarine of the size of the S-4 by a few hooks or eyes welded or riveted on to it, the chances are that the hull would be ripped apart or the hooks torn away.

Of course, the reply to this will be, why have a few hooks and not a multiplicity of them? Here again the trouble lies with the lack of a fixed base. If we were to hoist a load from a crane bridge, it would be a comparatively easy proposition to provide, if necessary (and it is seldom necessary), a multiplicity of chains and arrange them in such a manner that the load would be easily distributed among all the chains. If, however, the same thing were attempted in marine salvage operations without some very special equipment, the chances are that the load would alternately vary and be carried at all times by some two or four sets of eyes, at least to the extent of 75 per cent, so that the multiplicity of these eyes would not materially help in relieving the stresses on the hull.

The French submarine designer Laubeuf proposed, however, a modification of this device which appears to be of sufficient importance to deserve serious consideration. What Laubeuf suggested is to attach wide bands of metal to the submarine by riveting or welding and to have the hooks or eyes for the accommodation of the lifting chains made a part of these bands. In this way the hoisting stress would be distributed over a comparatively wide area of the hull, and with proper design and distribution of these bands it would appear possible to give these hooks or eyes such proportions and such a distribution as would assist materially in accelerating the raising operations.

Since Laubeuf's time a new development has taken place which may help in this connection. All that Laubeuf had at his disposal were carbon-steel bands with a tensile strength of some 100,000 lb. Today it would be possible to make these bands in the form of chrome-nickel steel forgings with a tensile strength considerably in excess of 200,000 lb. and a permissible emergency loading of some 175,000 lb. per sq. in. Under these conditions such bands with the concomitant hooks or eyes would appear to be well deserving of serious consideration.

It should be borne in mind that the provision of bands will require in the first place possible changes in the design of the longitudinal frame members of the submarine, with the idea of giving them additional stiffness. This is a more difficult problem than a layman or engineer who has not had anything to do with submarine design realizes. The other point to which very serious consideration must be given is such streamlining of these bands as will not materially reduce the submarine speed, particularly its surface speed, the underwater speed being too low to be materially affected by the presence of the bands.

ATTACHING CHAINS TO SUBMARINES

Obviously, before a submarine can be lifted, chains have to be passed properly around it. It may be somewhat surprising to an engineer to learn that no provision for doing this quickly and conveniently is made on any of the submarines of any country. The submarine may be lying in the most inconvenient position, on a rocky bottom or—which is equally bad if not worse—partly sunken in mud as is the case with the S-4. When this happens tunnels have to be laboriously blown under the submarine hull to pass the chains or hoisting ropes. This means increasingly hard and dangerous work on the part of the divers, possible interruptions by weather, with destruction of what has been already done on the bottom, and furthermore no certainty that the chains will be placed where they should be. To an engineer it would appear that a very simple provision could be made to take care of this situation. This could take the form of welding on to the submarine hull a few thin channel-shaped pieces so

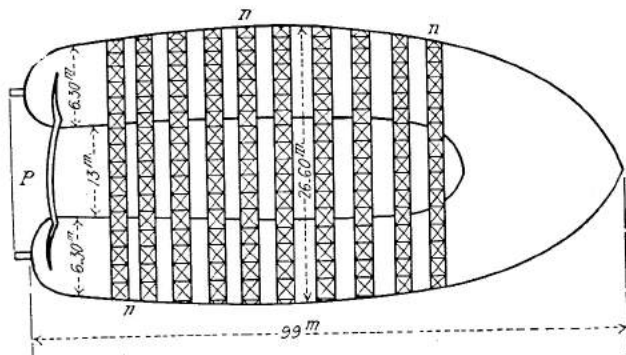


FIG. 1 FRENCH SUBMARINE SALVAGE VESSEL

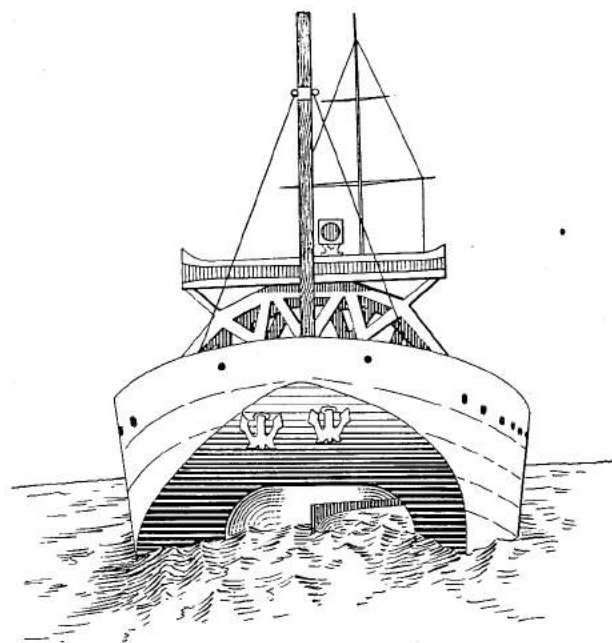
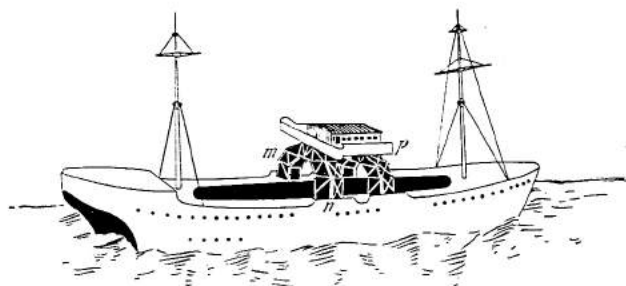
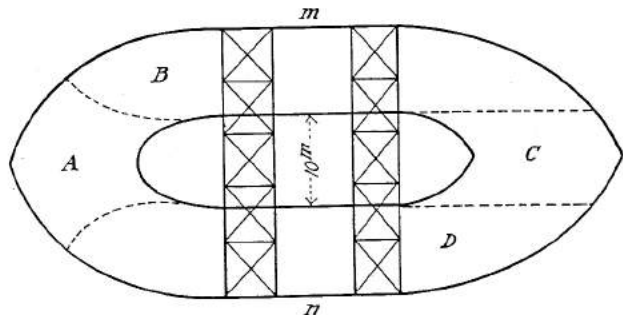
arranged that they could be opened in places and serve as guides for the hoisting chains. It would be a simple matter to locate in these channels a slender wire rope with proper provision for attaching the chain at one end and passing it around the submarine by pulling on the rope from the other side. The operation in principle would not differ from the way in which heavy cables are passed underground by the telephone companies. Proper thought should be given to making these channels of such a shape as not to reduce the surface speed of the submarine, but otherwise the device is extremely simple. There is one objection to it, however, and that is that these guide channels being made of fairly thin metal, would be apt to get bent or twisted. Should this happen the submarine would be no worse off than it would be without them, and there is really no reason why they could not be made strong enough to withstand ordinary bumping.

SUBMARINE SALVAGE VESSELS

The next great question is that of the apparatus for hoisting the foundered submarine. The mass to be raised in this case may amount to as much as 75 to 80 per cent of the surface displacement of the submarine. Taking the latter at 1200 tons, which is fairly close to present practice, the weight to be raised would have to be estimated at about 960 tons. The first question, therefore, is to provide a sufficient number of chains in order not to twist the submarine all out of shape in raising it, or perhaps break it in two. On the small prewar type of German submarine three fixed points were provided, distributed longitudinally. On French submarines lifting eyes were provided in pairs, one eye on each side, from six to seven pairs being used. However, this multiplication of points of suspension makes it necessary to employ special devices to equalize the loads imposed on the different chains. Load-limiting brakes have to be used

in order to limit the rupture of chains by overloads and also to prevent some of the chains from carrying the whole weight and others none of it.

The speed used in hoisting in the European navies is on an average from 0.4 to 0.8 in. per sec. Notwithstanding such low velocities the total power at the drum is quite considerable because the efficiency of the transmission is probably under 40



FIGS. 2-4 THE GERMAN SUBMARINE SALVAGE VESSEL "VULKAN"

per cent. Taking a speed of 0.4 in. per sec., the effective work in hoisting a submarine of, say, 1000 tons, is 66,666 ft-lb. per sec. or close to 120 hp. Assuming an efficiency of 40 per cent, it would appear that the power of the hoisting engine must be at least 300 hp., and it is usually a good deal more than that in catamaran-type hoists provided with propeller screws on both sides. This arrangement is used on the German *Vulkan* and the Brazilian *Ceara* submarine salvage vessels.

There are two types of arrangements employed on submarine salvage vessels. In one type the hoisting chains are passed through vertical holes in the body of the ship itself; in the other type, they are passed over sheaves usually located in the stern of the vessel. The German salvage vessels *Nordsee* and *Ostsee* embodied the former type of construction, while the *Oberelbe* and *Untereibe* had sheaves located on the stern and carried between the arms of a cantilever support.

Coming now to the types of vessels, the French have developed what is known as a "kangaroo" ship. In this, part of the bow opens up, permitting a submarine to enter. The doors are then closed and the water expelled, leaving the submarine high and dry. The original purpose of the design was to transport submarines built in France overseas to places where they would be put into service.

Further details concerning an older type of the French submarine vessel are given in Fig. 1. It must be realized, of course, in this connection that everything concerning the submarine services of the various navies is in the "hush-hush" class. Publication of data of recent developments is not encouraged. From information available, however, it does not appear that the most recent vessels are in any way radically different from the one described here. This particular vessel was built in 1911 by the Loire Shipbuilding Co. and has a displacement of 2430 tons. It is equipped with electric motors rated at 170 kw. As shown in Fig. 1 it has one bow, but the stern is divided in two, with an open space between the two sections 13 m. (42.6 ft.) wide. The two parts are powerfully braced together by the bridge structure *P*, but each part is equipped with a rudder of its own to facilitate maneuvering. The main dimensions are: length, 99 m. (324.7 ft.); width of each of the two sections, 6.30 m. (20.6 ft.); width between the sections, 13 m. (42.6 ft.). The vessel is capable of lifting up to 1000 tons.

The structure supporting the suspended load is formed of ten steel frames interconnected so as to form a single powerful bridge. The chains are 66 mm. (2.6 in.) in diameter.

A very interesting type of submarine salvage vessel is the German *Vulkan*, Figs. 2, 3, and 4. This vessel is 70 m. (229 ft.) long and 16.75 m. (55.25 ft.) beam. Its center part consists of two hulls with parallel axes and an intervening distance of 10 m. (32.8 ft.). These hulls are jointed together both at the bow and at the stern, leaving an elongated free space in which the operation of raising the submarine is performed. For this latter purpose is provided a huge bridge member *p*, Fig. 3, supported on metal frames *m* and *n*, Fig. 2. The great strength of this structure is shown by the fact that it is capable of supporting a load of 600 tons. A submarine may be actually lifted from the water and supported inside the hull of the ship. Facilities are provided for minor repairs.

#### THE LAURENTI SALVAGE VESSEL

One of the most interesting designs for submarine salvage work is shown in Fig. 5, for which credit is due to the Italian engineer Laurenti. The purpose of this vessel is really twofold, as in addition to submarine salvage work it is also designed for carrying out certain acceptance tests on submarines. The most important of these is the test of the vessel for its ability to stand pressure when submerged to a certain depth. The conventional method of carrying out this test, which consists of letting the submarine submerge to a given depth, is somewhat like the famous method of determining whether certain mushrooms are of the right kind. Eat them, and if you die you know they were toadstools. It does not help the crew of the submarine very much to find out at a depth of, say, 100 ft. that their submarine hull is not strong enough.

The Laurenti design comprises a long and extremely strongly

built steel tube capable of resisting the designed high pressures. It is supported by four U-shaped caissons *B*, located one at each end and two at even intervals between. These caissons have inside of them ballast tanks so arranged that water can be admitted into the pressure tube *A* when lowered to the desired extent, which is so low that the submarine can float into it. The water is next expelled from the ballast tanks of the caissons *B*, which makes the pontoon rise and lift the submarine with it. As the water is expelled the submarine gradually comes to rest on powerfully-shored-up wedge blocks. When this is done the hood *E* is set in place, enclosing the control turret, while watertight doors at the bottom of the pressure tube are closed. The hood *E* is equipped with rubber rings, the purpose of which is to make the joints perfectly watertight.

The next step is to pump water into the space between the pressure tube *A*, including hood *E* and the submarine *D* contained therein, it being of course assumed that the submarine has all the valves closed and is generally in proper state for submersion. A steam-driven pump of adequate power is used and water is

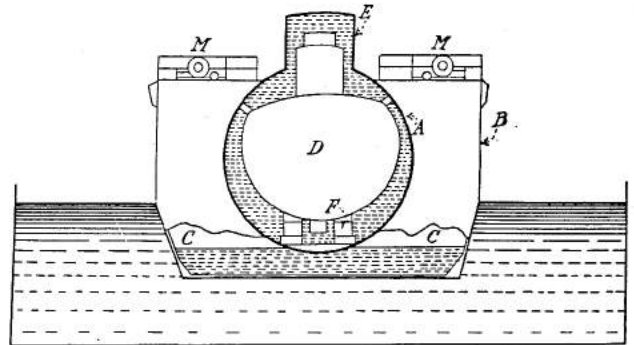


FIG. 5 LAURENTI'S SUBMARINE SALVAGE VESSEL

applied at such a pressure as may be designed for test purpose or otherwise. The advantage of this method of testing is that even should the submarine hull fail to support the required pressure, neither would the submarine be lost nor the personnel endangered. It should be remembered that in such a test the engineering personnel has to be inside of the submarine in order to make the necessary observations and also test the working of the various devices while in the state of submersion. In this case the engineers and officers are at all times in telephonic communication with the pontoon personnel and the test may be stopped and the water pressure released very rapidly, if desired.

The Laurenti pontoon may be also used for the salvage of submerged submarines. To do this the caissons are lowered to the desired depth with strong chains and hooks which may be attached to rings or bosses on the submarine. When such an attachment has been effected the ballast tanks on the pontoons are emptied, which produces a very powerful upward drag. The device may of course also serve as a drydock in which case the submarine is taken in the usual manner into tube *A*, which is then closed at the ends, and water completely expelled, leaving the submarine dry and accessible for all repair work.

The Brazilian Navy has had constructed at the Fiat-San Giorgio Works, from the designs of Laurenti, a mother ship for submarines. This vessel has the following dimensions:

	Meters	Feet
Length between perpendiculars.....	100	328
Maximum beam.....	15.50	50.8
Height.....	8.2	26.9
Full-load immersion.....	4.2	13.8
Displacement, tons.....	4200	

This vessel is designed to carry accommodations for the

personnel and officers of a squadron of six submarines each of a displacement of 250 tons or thereabout, or three submarines each with a displacement of from 250 to 400 tons. The vessel is to carry sufficient supplies of fuel to accommodate these submarines and is equipped with facilities for supplying them with sets of fully charged storage batteries in exchange for those on the submarines. It also has facilities for recharging the submarine reserve tanks, thus saving the submarine machinery from too frequent use. The mother vessel carries all the service and reserve torpedoes of the squadron, as well as such other military material as may be required. It also has a well-equipped shop for taking care of usual repairs. As the main motors for operating the auxiliaries are of the Diesel type and the electric and compressed-air machinery of a type similar to that used on the submarines, the mother ship can also serve as a school for submarine personnel.

In addition to the equipment for submarine salvage it has also two diver outfits. It has one tube for carrying a submarine of the type described above and of the following dimensions:

	Meters	Feet
Length of the cylinder body.....	64	210
Maximum useful length.....	55	180
Average diameter of cylinder at the entrance orifice.....	7.56	23.80
Net inside diameter of cylinder.....	7.07	23.18

For raising the submarine the vessel is equipped with a crane for handling up to 400 tons, while for its own defense against enemy destroyers it carries eight 100-mm. (4-in.) guns and four 57-mm. (2.25-in.) guns.

CONCLUSIONS

When all is said and done, one thing remains unfortunately true, and that is that a submarine is inherently a dangerous sort of vessel to operate. There are ways to make it somewhat less dangerous to its crew, but thus far no really safe submarine is in sight. With this fact fully recognized, there is no reason, however, why submarines should not be made much safer to operate than they are now. With proper arrangements certain classes of accidents can be largely though not entirely prevented, while certain other classes can be made less deadly. The proper way to go about it is to devote real and sincere attention to the problem. Many of the most hazardous operations in industry have been made safe, or comparatively so, by proper attention to the element of danger.

In the first place, it should be clearly realized that submarine operation in peace time is different from that in war time, and that certain risks which must of necessity be taken when operating on a war footing are unnecessary in peace-time operation. Safety codes should therefore be prepared for submarines as well as for all other war vessels operating in the areas where submarine exercises are being undertaken. To such extent as is necessary commercial vessels should either be kept out of such areas entirely, or else they should be properly instructed as, for example, by radio to be on the lookout for submarines when operating in exercise areas of the latter. Such a comparatively simple and perfectly feasible program would have prevented the two disasters which have occurred within the last couple of years, namely, those of the S-51 and S-4.

In peace time no submarine except as part of a military maneuver should be permitted to operate without some device to indicate its rising to the surface at least 3 min. before the actual rise occurs. It is immaterial whether the device acts by sound or visually. If the latter is the case the device ought to be so arranged as to provide a signal both in the daytime and at night. There are a number of such devices that can be used.

The Chemical Warfare Service would be ready to design a number of them combining black smoke for use in daytime and a powerful flame for use at night, the flame part being of such a character that it would not be affected by water spray. The size of such a device is very small. The signaling bomb for a 3-min. operation need not be more than, say, a cylinder 9 in. long by 4 in. in diameter, and it can be projected from the submarine by a device resembling a miniature torpedo tube. The details of such a device are so simple that any navy mechanic could build it. Several such are actually known and some have been used by the American Navy in the past.

Simple means should be provided by which a submarine which is unable to rise to the surface for any reason whatsoever could indicate unmistakably its position. These means should be so installed that they could be operated from any of the watertight compartments. They may take the form of a small buoy with or without a telephone connection. Where for some reason this is not feasible, a cork or balsa float may be substituted.

Special connections for the supply of air should be provided in every compartment of a submarine, and corresponding connections should be available on every vessel owned by the United States Government or rescue companies (more will be said about these later) that may be called upon to take part in submarine salvage work.

Above all it is vitally important that submarine salvage work should be systematized. So long as it is known that a submarine is inherently a device dangerous to its operating crew and so long as submarines have to be used for national defense, it is rather unreasonable to consider a submarine disaster as an emergency. It is nothing of the kind. It is an inherent part of the hazard of operating a submarine, and suitable provision should be made to meet its occurrence. In large mills engineers do not consider accidents to workmen as emergencies. They know that no matter how careful the operators may be, things will happen. People will be cut, will have their fingers caught in gears, will be hurt by flying pieces of metal or by falling weights. In properly conducted mills a careful program is worked out for rendering first aid and for taking care of more serious cases. First-aid cabinets are provided and foremen are carefully instructed on how to behave in case of more serious accidents which cannot be handled by facilities available in the shop. There is no reason whatsoever why the United States Navy should not have a similar plan.

There is a story, whether authentic or not is immaterial, to the effect that when the Franco-Prussian war of 1870 was declared, Moltke, then chief of the German General Staff, was awakened in the middle of the night and told of the declaration of war. "Plan No. 4," he muttered, turned over, and went back to sleep.

There is no reason why in case of a submarine disaster a similar course should not be followed. Instead of having lieutenant-commanders, commanders, admirals, and such like running around and devising ways and means on a Saturday afternoon, all that should be necessary would be to take a certain envelope marked, for example, for the Portsmouth, New Hampshire, Area, as "Plan No. 4," and send out by radio or wire these three words; then we should know exactly beforehand what would happen.

Obviously, the Navy alone cannot and should not be called upon to provide complete facilities for submarine salvage all along the thousands of miles of the American coast from Maine to Panama on the Atlantic, and Panama to British Columbia on the Pacific. All along these coasts there are many commercial companies which are more or less well equipped to do this kind of work and would be proud to take part in it at only the most reasonable compensation. It would be a comparatively simple

matter for the Navy to make agreements with all such companies by which they would specify the equipment available for salvage operations in their respective districts and keep the Navy posted as to the movement of such equipment. Some one at a desk in Washington ought to be able to tell at a glance what derricks, divers, etc. are available at 4 o'clock on a Thursday afternoon outside of San Diego Harbor, and the information should be sufficiently precise to make it absolutely certain that it is good for Thursday of this week and not two weeks ago. With such information it would be a comparatively simple matter to assemble, practically at a moment's notice, all salvage equipment required, and it would not be necessary for the Navy to try to locate the men responsible for the equipment and arrange for terms on which such equipment could be used. A steel mill knows exactly to what hospital it can send a man injured in its plant. A railroad, all along its right of way, knows the hospitalization and relief facilities. The Red Cross has a skeleton organization of that kind, and there is no reason why with a comparatively little trouble the Navy should not.

In each district and at each submarine base there should be kept special codes for work on each submarine operated in that particular district. Submarines differ considerably in types and sizes. Those which will be built from now on will probably be more amply equipped with safety devices than those of the older makes. It may be also that the new safety devices will be operated differently from the old ones. New fittings will probably be installed and their location may not be familiar to the divers, etc. There is no reason why, knowing that men only in a certain compartment are alive, air should be supplied in a way in which it cannot reach that particular compartment. A simple blueprint showing how to attach air hose so as to help men in a given compartment will easily obviate such an occurrence. In each district, therefore, complete information in a form that he who runs may read should be available. The signaling facilities of each particular submarine should be indicated, the location and size of air connection should be shown, and the corresponding connections should be specified. A supply of all connecting pieces, chains, hooks, etc. should be kept in charge of the same office that keeps the information as to the method of procedure of salvage of each submarine.

The Navy and Army Air Services and commercial aeronautical companies, including the Air Mail, should be given an opportunity to thoroughly familiarize themselves with submarine salvage programs and show ways in which they may be helpful. It may happen that some gadget vitally necessary for submarine salvage work is missing. It should not be necessary to scurry around and search for an airplane that could rush it to the proper destination. The Navy office in the particular district

in which the need occurred should be able to turn to its files and find the telephone number of the office of the Air Service or commercial aeronautical company that should at that particular hour have a machine available to carry the part required to its destination.

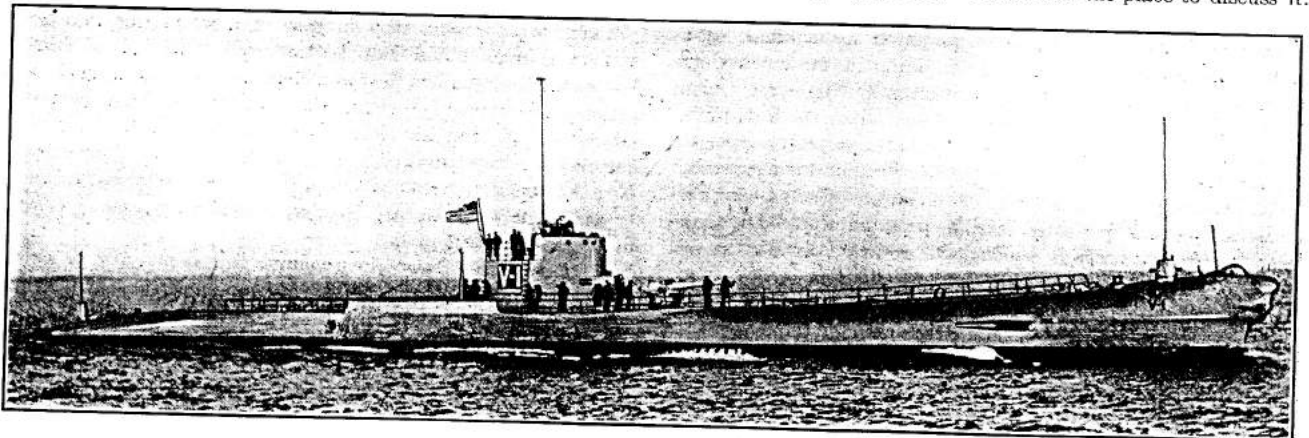
When a submarine is sent for a prolonged cruise out of its regular range of operation in peace time, all districts within the range of which it will have to pass should be notified, and be on the lookout and prepared to handle anything that may happen, not in the spirit of emergency, but as a part of their regular day's work.

There is one reaction that may be expected to the above program. What has been outlined above will require going to a considerable amount of trouble and to no little expense. Submarine accidents are comparatively few and far between, and the question may be raised whether it is worth while to go to such a lot of trouble for such an infrequent emergency.

Some officers, including the commander of a submarine, appear to feel that the problem of submarine safety should be considered from two points of view. In the first place, the utmost attention should be paid to improving the design of the submarine in the way of increasing its mechanical strength, making the operation of the submarine more reliable, and particularly in increasing its military efficiency. Their feeling is that the real question of safety will arise when the margin becomes vanishingly small, and that is under war conditions, and it is of the utmost importance for the men to see that this margin of safety under war conditions does not vanish entirely.

Because of this a whole list of improvements have been made, which, while not classified specifically as safety devices, nevertheless strongly contribute to safety.

As to outside salvage means, the feeling seems to be that while all should be done that can be reasonably done with approximately the present amount of attention and explanation, it would not be wise to undertake an elaborate and expensive program of safety and salvage provision for submarines. It appears to be felt that the number of accidents has not been very large considering the extensive use of submarines being made in peace time. A statement has been made, for example, that in one Atlantic area only, subsurface work with submarines is being done approximately one day in every two, year in and year out. According to the proponents of this view, such money as can be secured from Congress ought to be used for general Navy purposes and will in this way ultimately contribute to the increase of safety of submarines. This is a view which deserves very serious consideration as it comes from men who are most closely connected with the design and operation of this branch of Navy equipment. This is not the place to discuss it.



THE V-1, THE LARGEST SUBMARINE IN THE UNITED STATES NAVY