

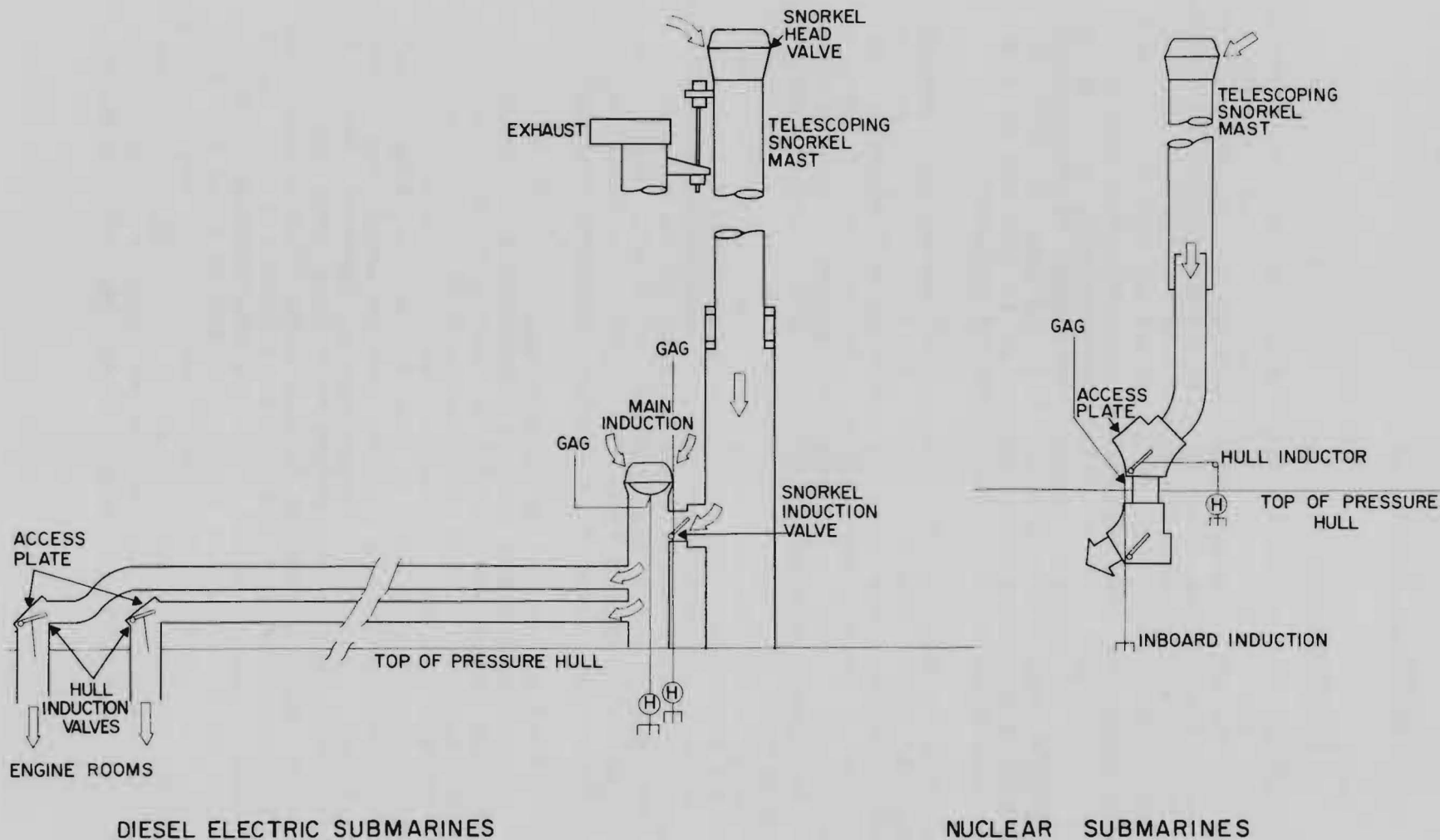
6. Submarine Self-Lift

6.1. Introduction

Since submarines are built to withstand hydrostatic pressures, they are most easily adapted to generation of self-lift. In almost all cases of submarine salvage, one or more of the internal watertight compartments will be subjected to flooding. If this flooding was the result of failure by the crew to seal the compartments during a normal evolution, divers can usually seal the opening(s) and produce some self-lift utilizing the buoyancy of interior compartments and ballast tanks. WARNING: if several compartments have been flooded, it is probable that the submarine will become unstable at some stage of the operation, especially if one end of the submarine is subjected to a large ground reaction.

Each submarine is made up of a number of watertight compartments, some of which are surrounded by tanks. Some of the tanks (main ballast) are used to submerge and surface the submarine during normal operations. The volume of tanks is determined by the type, size and configuration of the submarine. The older, diesel-electric (fleet-type) submarines have a large main ballast tank capacity because they operate much of the time on the surface, and, therefore, require more reserve buoyancy. In addition, they have a large fuel supply. Nuclear submarines, which are submerged much of the time, have relatively small main ballast tanks outside the pressure hull, and a small amount of fuel. Thus, more self-lift can be obtained from the tanks of a diesel-electric submarine than from those of a nuclear-powered submarine.

The conventional method of obtaining self-lift is by introducing compressed air into a compartment or tank. To do this, the space that is to be dewatered must be sufficiently sealed to hold air pressure of a few pounds over that of ambient sea pressure. Main ballast tanks that are intact can be blown down if the vents are closed and there is an opening at the bottom through which the water may be expelled. Internal compartments, however, have large openings and piping systems which make them more difficult to seal. The hatches, valves in air induction piping, and exhaust lines penetrating the pressure hull all seat with sea pressure. Even if these fittings are undamaged and closed, they must be gagged shut in order to hold an air pressure in the compartment (see Figure 6-1). The gagging gear provided for induction valves is often difficult for divers to operate since access plates must be removed in order to reach the gag nut which holds the valve shut.



SUBMARINE AIR INDUCTION SYSTEM.

FIGURE 6-1

6.2. Compartments

Internal compartment watertight integrity with respect to adjacent internal compartments is achieved by watertight doors, stop valves in piping, and flapper valves in ventilation lines. These internal closures may not be accessible for the purpose of gagging. The internal compartment may possibly be dewatered in this case by pumping. This can be accomplished by connecting the salvage pump to the compartment low salvage fitting. The internal compartment air pressure may then be raised to ambient sea pressure using the high salvage fitting. The small size of the salvage air lines makes this a slow process, and, therefore, it should be started well in advance of the planned lift operation. Figure 6-2 is a typical diagram of a submarine compartment salvage air system.

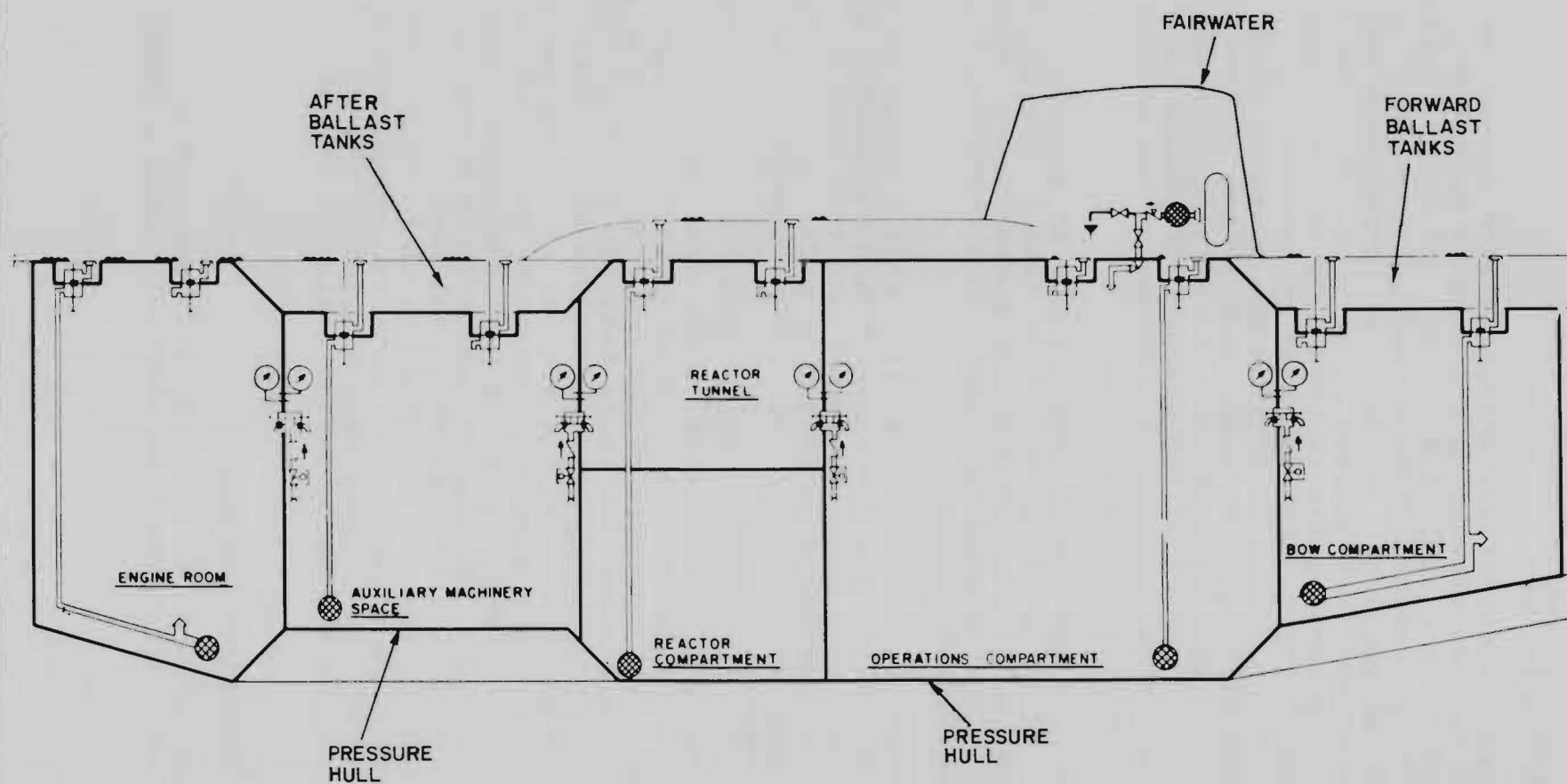
If a compartment is open to the sea through an unknown source, it may be possible to locate the leak by blowing the water level down until escaping bubbles pinpoint it. Whether or not self-lift can be obtained from such a compartment will depend upon the circumstances.

The use of salvage hatch covers requires that a diver be sent inside the submarine. This operation should be undertaken only if the low salvage line becomes blocked and then only if self-lift from such compartments is needed in order to raise the ship. This method of obtaining self-lift frequently involves a great deal of work by divers.

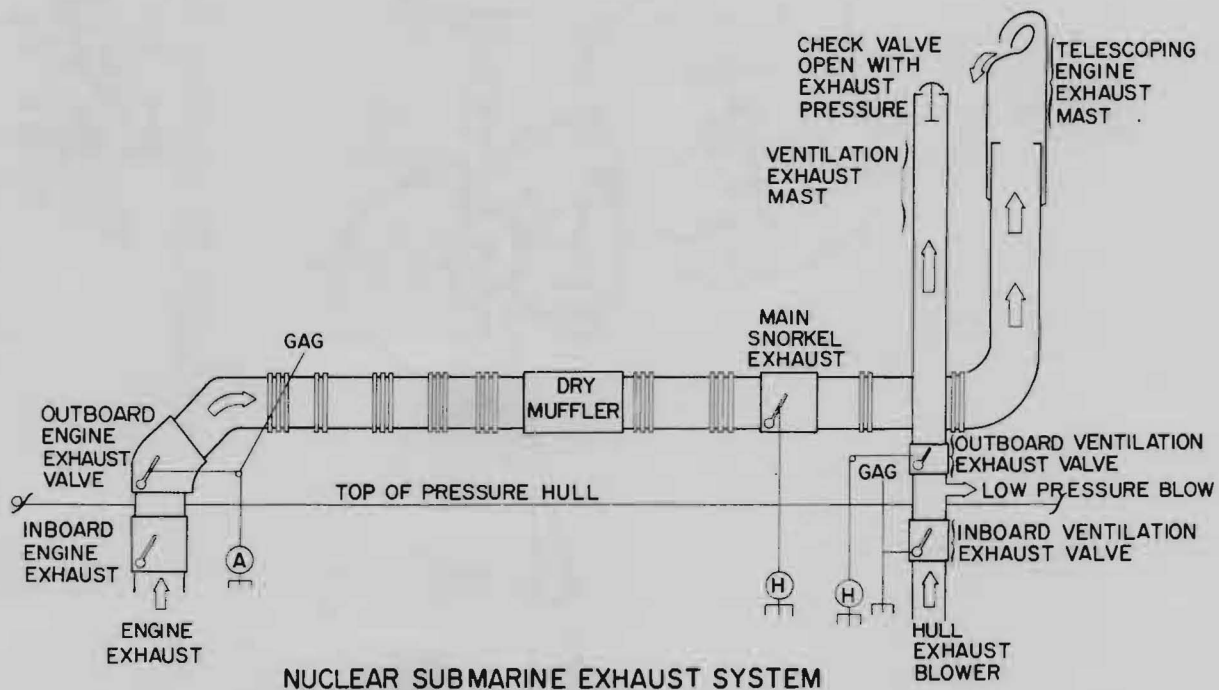
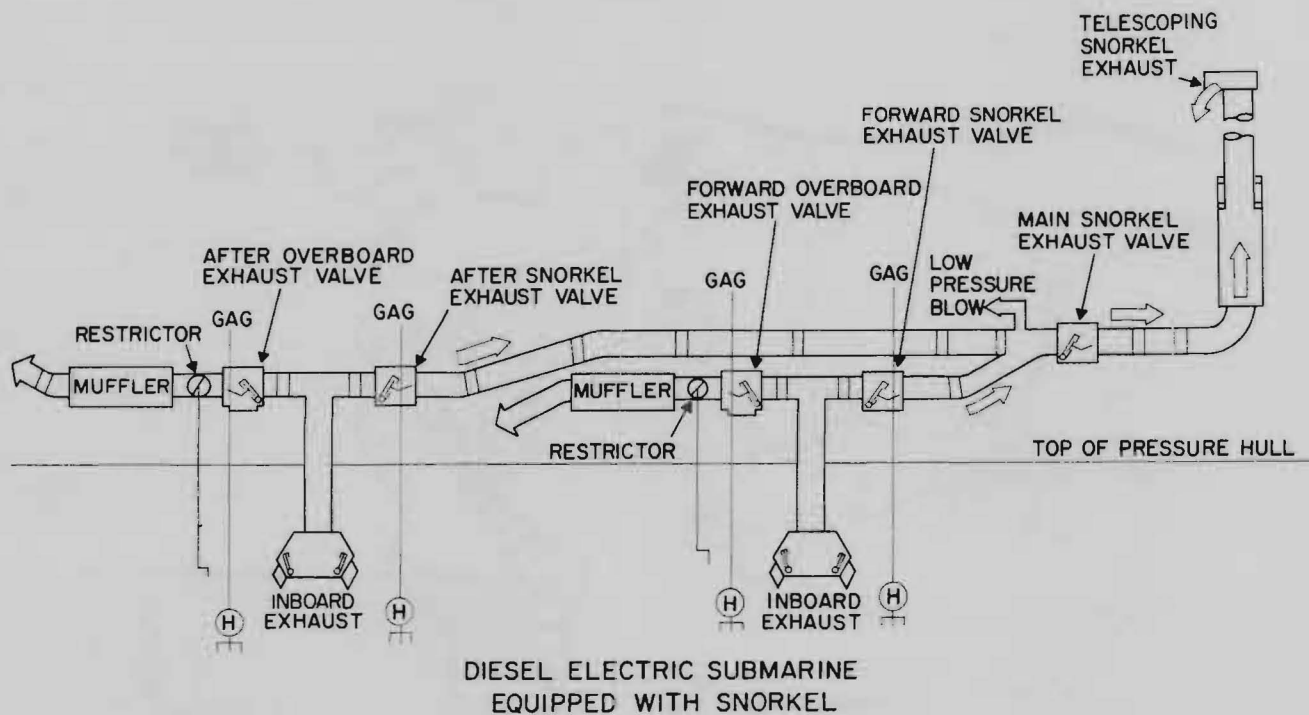
A vulnerable part of the submarine is the ventilation induction system. A typical ventilation system is illustrated in Figure 6-1. Details of the induction valves on a modern submarine are shown in Figure 6-3. In the past, it has been possible to seal ventilation valves with cement when gagging proved unsuccessful. Removal of the access plate exposes the valve disc and permits cement to be placed in the area above the disc. A bin or cofferdam constructed around the valve will allow a quantity of cement to be placed in and around the valve. The weight of this seal aids in holding the disc on its seat and permits air pressure to be maintained in the compartment. The diesel engine exhaust system, shown in Figures 6-4 and 6-5, is in many ways similar to the ventilation induction system and may be closed or sealed in the same manner.

6.3. Main Ballast Tanks

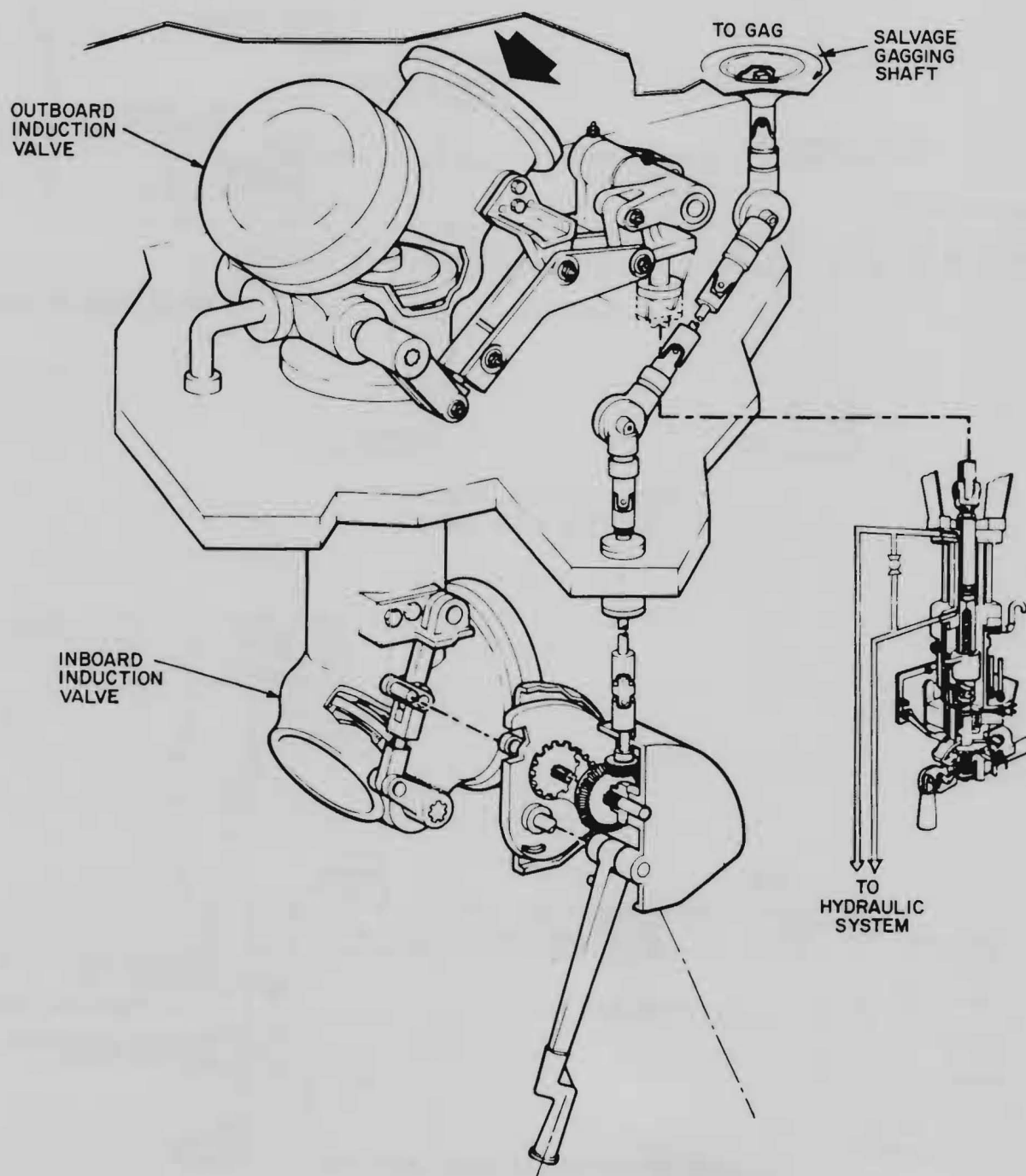
Salvage air connections for main ballast tanks are available on most U.S. NAVY submarines with hull numbers lower than 571.



SALVAGE AIR SYSTEM.
FIGURE 6-2

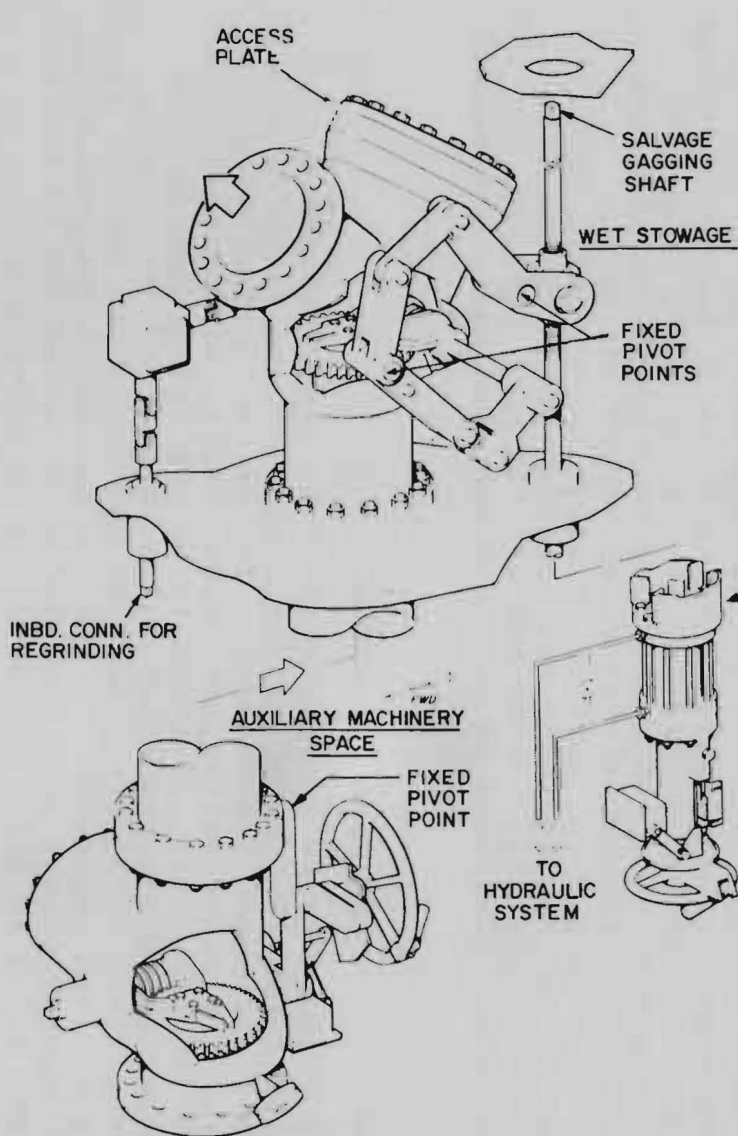


**TYPICAL SUBMARINE
EXHAUST SYSTEM.
FIGURE 6-4**



INBOARD AND OUTBOARD
INDUCTION VALVES.

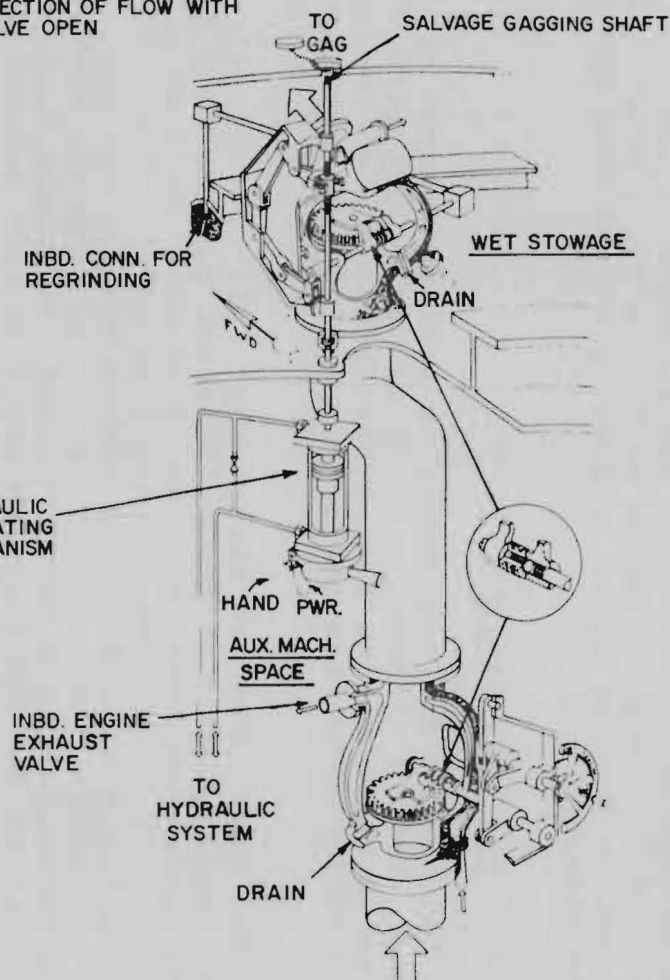
FIGURE 6-3



(A.) INBD. & OUTBD. ENGINE EXHAUST VALVES, SSBN599 CLASS

NOTE:

LARGE ARROW INDICATES
DIRECTION OF FLOW WITH
VALVE OPEN



TYPICAL SNORKEL AND ENGINE
EXHAUST VALVES.

FIGURE 6-5

(B.) INBD. & OUTBD. ENGINE SNORKEL EXHAUST VALVES, SSN588 CLASS

A considerable amount of buoyancy can be gained from those tanks that are intact and whose main vents are closed or are capable of being closed. Blowing the main ballast tanks may also assist in breaking the bottom suction if the flood holes are below the mud line. Main ballast tanks that do not have salvage air connections can be blown by use of temporary air fittings installed with a velocity power tool, as discussed in Chapter 2, or by placing an air hose through the flood opening.

6.4. Fuel Oil Tanks

The fuel oil system differs widely on various classes of submarines. Before attempting to obtain self-lift with fuel tanks, a study of the fuel system plans and an inspection of a sister ship from the same building yard should be made.

The external fuel tanks are always kept full of fuel oil or sea water, as this part of the hull cannot support full sea pressure. Such tanks are kept equalized with sea pressure through the salt water compensation line and the fuel filling and transfer line. This system has inboard vent valves for ensuring that all air is vented from the tanks; these are normally locked shut. Submarines constructed before USS NAUTILUS (SSN 571) are provided with salvage air connections at the top of all fuel oil tanks.

To avoid contamination of the salvage area, oil in the fuel tanks should be transferred to the tanks of one of the ships in the salvage force through the salvage hose. When the hose has been attached and the salvage valve has been opened, the oil will run out of the upper end of the hose. The height above the surface to which the oil will flow depends upon the depth of the submarine and the specific gravity of the oil. After the oil has been removed, the water which displaced it can be blown down using compressed air.

6.5. Fuel Ballast Tanks

Fuel ballast tanks are designed to be used for either fuel oil storage or as main ballast tanks. These tanks have main vent risers, and are connected to the fuel oil compensating line. The flood valves are large flapper valves that seat with sea pressure. If these tanks are being used as main ballast tanks and the flood valves are open, the tank may be dewatered by blowing, as with any undamaged ballast tank. If the flood valves are closed and buried in the bottom mud, the salvage divers will have to cut holes as low as possible in the tanks to allow the water to be expelled.

If the tanks are full of fuel, they can be emptied by installing a hose fitting with a velocity power tool, cutting flood holes, and allowing the oil to be forced out as discussed in Paragraph 6.4.

6.6. Variable Ballast Tanks

It is much more difficult to obtain any buoyancy from the variable ballast tanks as they are located within the pressure hull and are connected to the trim line as well as the bilge drain line. It would be difficult for the Salvage Officer to know the condition of these systems before the submarine sank. It may be possible that by blowing water from one tank, it would be transferred to another, the variable ballast tanks, which include the auxiliary tanks and the forward and after trim tanks, are much smaller than the main ballast tanks. The amount of work required of divers to prepare the variable tanks for dewatering generally is comparable to that required for blowing down a main compartment, but the lift gained is considerably smaller. These tanks should be the last spaces considered for obtaining self-lift.

6.7. Salvage Foam

A recent development has been the application of generated-in-place foams to displace water from within salvable objects. This technique of generating self-lift can significantly reduce the external lift requirement.

The present state-of-the-art limits the practical usage of foam systems to depths of less than 100 feet, although specially compounded foams have been used with varying success down to 200 feet and present studies are attempting to lower the use depth to the 400-foot range.

The most successful system used to date is based on a two-component urethane foam supplied in self-contained pressurized containers. In application, each component is forced under pressure from the surface through separate hoses to the submerged salvage site. There, the components are mixed and released into the submergence atmosphere where initial foaming takes place. The initial foaming produces a cream-like mass and is initiated by the expansion of an extremely low boiling liquid contained within one of the components. In this state, the foam, although not fully expanded to its final low density, has excellent insulation properties. As a large mass is formed within a compartment, the generation of exothermic heat takes place due to the nature of the chemical curing reaction.

This heat further expands the foam to its final density by vaporizing a second low boiling liquid component. This expansion is created with enough pressure to displace the water from within the sunken object.

After the gas generation cycle is completed, a cure period is required to allow the foam to reach its maximum strength. The length of this cure period depends upon the nature of the chemical reaction and the ambient temperature conditions. The ultimate aim of the foam system is to replace water from within an object with a foam of minimum density and which has sufficient strength to prevent cell rupture and the subsequent loss of entrapped gas as the hydrostatic pressure decreases during ascent. At the shallower depth, low density foams are capable of sufficient cell strength; but as the depth increases, a corresponding increase in the foam density must also be maintained.

A listing of the advantages of foam over compressed air includes the following:

1. Foam expands very little during ascent - air requires venting to prevent structural damage from increasing internal pressure.
2. Foam eliminates the free surface effect, thus tending to preserve static stability of the object during ascent; air may cause static instability.
3. Foam requires little or no elaborate sealing or shoring procedures before application. Deck loading is, at times, reduced because the foam can adhere to structures within the compartments, distributing the buoyancy forces. Foam will not spill through small, undetected leaks because of its viscous nature - whereas air is more difficult to contain.
4. Foam can be selectively distributed throughout the interior of the salvable object to optimize its effect upon trim and submerged stability.
5. Because of the compressive strength of the foam, it may be used to increase the longitudinal strength in areas where the load is compressive.

A major disadvantage of foam, compared with compressed air, is its reduced buoyancy per cubic foot. In addition, it has several inherent disadvantages which limit its application in most salvage operations; some of these are:

1. It requires sensitive pumping, proportioning, and mixing controls, and technical personnel for operation, to produce reliable foam.

2. Foam density increases with increasing hydropressure and decreasing ambient temperature.

3. The placement of the foam in a sunken object requires divers to be located at the submerged salvage site during application.

4. The average density and density distribution of the foam is difficult to measure after it has been generated in place.

5. The total buoyancy of the foam is continuously being reduced with time, at pressure, because of water absorption and reduction of its initial volume.

6. Trapped gases may result during the foam generation cycle or the ascent, and produce buoyancy changes and internal structural loads due to their expansion. This would tend to nullify the first advantage.

7. After salvage, the material is more difficult to remove than air or water and special equipment may be required for this operation.

8. Generated-in-place foams are a "one-shot" operation and, as such, are costly. At an estimated cost of 50 to 75¢ per pound for the chemical, the total cost increases rapidly with increasing foam density.

In each specific salvage operation, the necessity of employing generated-in-place foams must be evaluated against their relative disadvantages.

6.8. Hose Requirements and Handling

The hose normally used by salvage vessels to raise submarines is supplied in 50-foot lengths. The hose presently available has an inner diameter of 1-1/4 inches and an outer diameter of 2-1/16 inches. Working pressure is 100 psi, and the burst pressure is 600 psi. If it must be used at a pressure exceeding the rated working pressure, the period of such increased pressure should be limited to as short a period of time as possible.

The length of hose required for each task will depend upon the depth of the water. At least 200 feet more than is needed to run from the submarine to the surface should be used to enable the salvage vessel to move a short distance away from directly over the submarine.

On some salvage jobs it has been found advantageous to bring the salvage hoses together at a common point on the submarine and then lead them to the surface from this point.

The number of hoses required would be one for each compartment being used to provide self-lift, one for each tank to be blown, an additional one for each compartment which is to be pumped out, and two or possibly three for each pontoon.

When making up the hose, a globe valve is usually mounted on each end. A fitting (piece 34 of Table 5-1), suitable for the point of attachment on the submarine, is mounted on the lower end. When pressurized, the hose is slightly buoyant. After the hose is attached, it is then lashed to the submarine to avoid having it pull on the salvage air connection. It may then be buoyed off when not in use.

6.9. Dewatering of Tanks and Components

As the preparatory work on each tank is completed, the tank should be tested by blowing it down to ensure that the self-lift will actually be available when the submarine is to be lifted. After such tests, enough of the tanks should be reflooded to avoid any possibility that the submarine can become light enough for either end to leave the bottom prematurely while other compartment and tanks are being so tested.

It is safe to assume that, if all tanks are fully flooded, the main compartments can be dewatered as much as possible through the low salvage lines or the salvage hatch cover spill pipes without making the submarine too light to remain on the bottom. It is therefore usually unnecessary to reflood the main compartments after dewatering them.

If the salvage plan calls for the use of pontoons because of external lift requirements to improve static stability of the submarine, then enough water must be left in the main compartments to keep the submarine on the bottom until such pontoons have been completely blown down. The tanks and/or lift pontoons should then be used to provide the final increment of lift.

6.10. Past Salvage Operations

When viewing the self-lift aspects of past salvage operations, it is apparent that self-lift alone was never successful except when the submarine was near enough to the surface to be entered through hatches which were, or could be, extended via cofferdams to a point above the water. The interior could then be pumped out completely, the free surface in compartments eliminated, and the ship refloated with little danger of static instability.

Not all of the successful salvage operations on submarines in deep water have employed self-lift, but all of them have employed external lift. It is probable that for the large nuclear submarines, insufficient external lifting facilities would be available to obviate the need for self-lift. Where a choice exists between self-lift and external lift, the one which requires the least preparatory work is recommended.