THE U.S. NAVY'S FIRST EMERGENCY ESCAPE BREATHING DEVICE

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Abstract

The U.S. Navy's new emergency escape breathing device, the Survival Support Device (SSD), is now in the Fleet. Developed to help personnel escape through a smoke-filled or toxic gas atmosphere from anywhere inside a ship, the device was delivered to the first ship, USS MIDWAY (CVA 41), in May 1973. Subsequent deliveries are being made to other ships as fast as production will allow.

This paper presents a total picture of the SSD Program and includes discussion of the following salient points:

Definition of need - Why the SSD was developed at this time

Description of the Device

Donning and use techniques

Allowance and stowage philosophy

How the SSD is recharged and refurbished aboard ship

The author also describes the limitations of the present device and describes the Navy's intent to pursue development of a more optimum follow-on family of devices that will provide a range of use times and possibly be used for other shipboard breathing device functions.

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1. Introduction

Under the broad category of personnel shipboard lifesaving systems, all equipment can be considered as part of one of three subsystems. Specifically, items are used for the protection, escape or survival of personnel.

Protection equipments aboard ship are those used to protect the seaman against injury or death in his daily watch or work routine. These are, by far, the greatest variety of items in the lifesaving family. Most of all the items onboard ship used for respiratory protection, head, eye and face protection or protective clothing are similar or identical to those found in any industry.

Escape equipment, as the term implies, are those items that will protect the seaman and aid him to escape, both from inside the ship to weather and, if necessary, escape from the ship in a safe manner to the water or a waiting life raft.

Survival equipments are those items that are provided to aid and protect a man who has escaped or accidentally fallen from the ship and must now survive to await rescue.

When considering the equipment available and now used aboard ship in each of the above subsystems, and the complications that are manifested in the very size and complexity of ships today, it appears that the main problem is to increase our escape capability, to ensure that the crew of a ship can make their way to the weatherdeck, and further, escape to the water if need be. The habitat of the crew is mostly inside the ship structure and is spread over as many holes and corners as hold the population of a small city. In past disasters, a large portion of the ship's complement didn't even succeed in reaching the main deck. Yearly shipboard deaths generally occur when men are trapped in berthing or work areas by smoke during the many fires that take place, and die from asphyxiation or toxic gases, not from the fire itself.

2. Background

The time of the first consideration for an emergency escape breathing device is lost in history. It is known that low key investigations and discussions, however nebulous, were conducted throughout the late 1950's and early 1960's. A combination of lack of high level interest and technology prevented development. Unfortunately, the impetus was suddenly provided by two serious fires in 1966 and 1967 on the carriers USS FORRESTAL and USS ORISKANY. In these two disasters, 178 men died and 100 were injured, many as the result of smoke inhalation. Because of this, the Chief of Naval Operations (CNO) tasked Admiral Russell, retired, but an expert on carrier problems, and a panel to investigate the disasters and recommend ways to improve our fire fighting capability and survivability of both ships and personnel.

In 1967, after months of intense investigation, one resultant Russell Panel recommendation requested that the Navy develop a new breathing device - "To provide the Fleet with a device that will permit escape through a smoke filled or irrespirable atmosphere from any place in a ship." In 1968 this recommendation was interpreted by CNO into actual design criteria - the Navy should develop a device that would provide:

- 8-10 minutes of usage (minimum)
- Usage under heavy labor conditions
- Eye protection
- Carrying convenience
- Ease of donning and operation
- Long shelf life
- Low weight
- Fire resistant carrying case

The Naval Ship Engineering Center, acting as technical agent for the program to obtain a suitable Emergency Escape Breathing Device, canvassed industry sources. Three candidate devices were submitted for consideration.

During the subsequent 1969-1971 period, a series of shipboard operational evaluations, physiological tests and other laboratory tests were conducted. Throughout the tests, testing led to better definition of requirements, which led to device modifications, which led to more testing. Both the Navy and the industry offerors continued to learn during this period. Although each of the candidate devices was similar in meeting the criteria goals related to size, duration, weight, eye protection, carrying convenience and shelf life, the results of operational testing indicated a clear preference on the part of the participants for the more rapidly donned and simpler operating device, which had been designated the Survival Support Device (SSD) by the offeror, Lear Siegler, Inc./Electronic Instrumentation Division of California.

It was now 1972, and the SSD had surfaced as the preferred device although it still was considered deficient in several aspects, including reliability, CO_2 buildup and flammability. (The compressed mixture was 50% oxygen and 50% air.)

It was now that the Chief of Naval Material (CNM) announced that the competition was over and the SSD would be procured. As CNM stated, "Although the device selected for use in the Fleet is not the ultimate in perfection, it will do the job and we must get it into our ships as soon as possible." Two key decisions were then made:

1. The SSD was designated as an interim emergency escape breathing device, to be procured in limited quantities, after further rigorous testing and final performance characteristics were promulgated.

2. In parallel with this interim action, a long range development program was to be initiated to produce, through R&D competition, a device or devices that would fully meet all Navy requirements for escape on all ships.

Final design modifications were incorporated and final Navy testing was conducted during the latter half of 1972. Subsequently, in March 1973, a production contract was awarded to Lear Siegler. The SSD was delivered to the first ship, USS MIDWAY (CVA 41) in May 1973, and as of September 1974, a partial allowance has been delivered to every active carrier. Over 75,000 emergency escape devices are now stowed and ready for use in the Fleet.

3. Description

General - The Survival Support Device is a self-contained, semi-closed loop device that provides eight minutes of dry compressed air and protection to the user from smoke and toxic gas irritants. The six pound device may be donned in less than 15 seconds with a minimum of indoctrination, and is recharged and reusable after shipboard refurbishment. Cool air is released from the pressurized reservoir into a clear plastic hood which completely protects the wearer's head, and is activated by pulling a spring loaded start valve. (Figure 1)

The device consists of the following components:

1. Reservoir (Figure 2) -- Consists of two concentric coils of stainless steel tubing. Both coils have one welded end and are connected together at the other end through a tee connector. From the tee connector, a straight tube leads the air into the air module. The operating pressure is 6500 psi. Every unit is pressurized during production assembly to a proof pressure of 9750 psi, and the design burst pressure is 14,000 psi.

2. Air Module (Figure 3) -- The valve and regulator assembly is located in the cavity formed by reservoir tubing coils and has the following parts:

(a) Pull Pin Start Valve -- A spring loaded plunger, when released, punctures a metal burst disc which allows the compressed air to flow through the adapter tube to the pressure and flow regulators.

(b) Pressure and Flow Regulators -- These are assembled into a single aluminum housing. The pressure regulator provides constant air pressure to the flow regulator during the eight minutes of operation while the reservoir pressure is dropping from 6500 psi to 250 psi. The flow regulator provides a nearly constant flow of air to the face mask. The flow rate is nominally 0.75 SCFM.

(c) Pressure Gauge -- Reservoir air pressure is indicated by a white needle on a gauge face which is divided into a red and green sector. A fully pressurized condition is indicated when the needle is one needle width into the green sector. The gauge also serves as a plug-valve in the reservoir fill port portion of the air module.

3. Fask Mask (Figure 4) -- The face mask is a clear plastic hood made of polyvinylchloride (PVC). It has good physical properties

from +20°F to +120°F. The elastic neck band forms a seal around neck sizes from 13-1/2 to 20. The opening can be stretched to 28 inches in order to slip over the head of any user, including one wearing eye glasses. Air enters the back of the face mask from the flexible plastic hose on the air module. A duct in the mask directs air over the top of the user's head and releases it above the forehead. Entering air is approximately 40°F, helping to prevent fogging, reduce heat in the mask and prevent panic. The hood will resist penetration for six seconds of direct flame contact, and will self-extinguish when flames are removed. Pressure in the mask is slightly higher than the air outside so that no fumes or smoke can seep inside.

4. Safety Relief Valve -- If pressure in the reservoir should exceed 9300 psi, the burst disc will rupture, causing the SSD to activate and result in a safe drop of air pressure.

5. End Plate (Figure 5) -- The aluminum end plate provides structural integrity for the entire assembly and provides a base for the end plate nut that attaches to the air module.

6. Pull Ring. When a 15 pound pull is exerted on this ring, the spring loaded plunger is released to puncture the burst disc.

7. Carrying Case (Figure 6) -- The case is molded polyethylene with fire retardant additives. A clip on one side is tripped to open the top. A nylon carrying strap is provided for carrying the unit. A clear view port is molded into the top of the case to allow gauge inspection without opening the case. Use instructions are printed on the side of case.

4. Donning and Use

The SSD can be donned, even with a minimum of training, in less than 15 seconds, and even in zero visibility conditions. Generally, it is recommended that when the alarm is sounded, the SSD is taken from its stowage location but not immediately donned. The device should be carried and donned only at the last practical moment, in order to gain the maximum amount of escape time.

When ready to use, six simple steps are followed (Figure 7):

Step 1. Open Case -- A toggle clip is tripped with a finger to open the top of the case.

Step 2. Pull Unit Out -- The unit projects about two inches out of the case and is easily grasped and removed. Once out, the case is discarded.

Step 3. Unfold Mask -- The PVC hood is wrapped around the reservoir and must be unwrapped and unfolded before donning.

Step 4. Pull Ring -- The SSD is activated by grasping the pull ring and pulling with about 15 pounds of force. The ring remains in the unit. Air immediately starts to flow into the hood and can easily be heard.

Step 5. Pull Mask Over Head -- The user inserts his thumbs inside the elastic neck band, swings the unit around to the back of the neck and brings the opened band down over the head. The reservoir coil will fit comfortably at the nape of the neck.

Step 6. Breathe Normally -- In about 10 seconds, the hood will be completely filled with incoming reservoir air and will be purged of smoke. Eyeglasses can be adjusted through the mask and normal communications carried out.

When the sound of flowing air has noticeably diminished or when the mask starts to collapse around the face, the hood should be removed by opening the elastic band and slipping it back off.

It is possible, if absolutely necessary, to continue to wear the mask briefly after the air has been exhausted after eight minutes. This additional several seconds of wear may provide the extra margin needed to complete an escape providing eye protection and reducing smoke inhalation. With the air exhausted, however, carbon dioxide buildup is rapid.

The SSD may be activated and placed over the head of an unconscious man during an evacuation. It must be monitored, however, when placed over the heads of those who cannot help themselves.

The SSD is intended for use strickly as an emergency device, to permit the user to survive until he reaches fresh air. It is not designed for firefighting, damage control or tank and bilge inspections, since its air supply is limited to eight minutes.

5. Stowage and Allowance

Almost all of the stowage and allowance studies to date have been related to aircraft carriers, the first priority ships. In determining actual numbers of devices per ship and actual locations, several overall criteria were developed and used as a base:

1. Stowage and allowance should always be in consonance with the Russell Panel recommendation - a device to allow escape from any place in a ship.

2. Since the SSD is a relatively high cost and high weight new item, an attempt should be made to minimize requirements without undue increase in risk.

3. SSDs will not be carried on the person while onboard ship and therefore will have to be readily available in any space when needed.

4. With the large numbers of devices to be stowed on carriers, accountability and availability can be best handled by having a fixed stowage location for each device.

5. Stowage of SSDs must protect against random damage and pilferage but must not restrict instant availability when needed.

Allowance - Armed with the above overall criteria, NAVSEC conducted allowance studies in early 1973 to determine outfitting requirements for the carriers. The first lesson learned was that numbers or locations could not be done "on paper" using arrangement drawings and manning documents. 5,000-7,000 men per carrier and 1,600-2,800 different compartments, depending on the particular ship, together with constant changes in configuration and manning, made the task quite formidable. Visits to ships, type commanders, and headquarters soon resulted in specific carrier allowance criteria that had general agreement by all hands.

1. All berthing compartments and staterooms would be provided with an SSD for each occupant. No berthing area was safe (easy escape).

2. Flight deck and hangar bay areas would not need devices.

3. A compartment that has multiple egress routes and ready access to the hangar bay or weather deck would not need SSDs. Ready access meaning that to arrive, one only passes through one small compartment or utilizes one ladder.

4. Passageways would not need devices. A man in a passageway is alert and can react swiftly and, in addition, is going from a compartment that is safe or has SSDs to a similar space. Risk is low.

5. A compartment may get SSDs even if it has ready access, if it is normally manned and the single exit door is usually closed, such as a small office or workshop.

6. Any compartment which requires SSDs will have an allowance for the greatest number of persons assigned to the space at any time (usually GQ condition).

With this allowance guidance, individual visits to several carriers were conducted and discussions held with representatives from all divisions. Each of the ships' crew then surveyed their ship and submitted locations and numbers of SSDs required, compartment by compartment. Based on surveys received, the total number of SSDs needed for each carrier averages to about 150% of complement - 100% for berthing and 50% for other critical spaces.

Stowage - As stated before, with the large numbers of devices, accountability and availability can best be handled by having fixed stowages. Stowage must protect against accidental damage, dirt or pilferage. Therefore, metal stowage racks were designed, with specific variations for use in crew berthing, officer staterooms, and other bulkhead and overhead racks for use in all other ship compartments. The racks are basically aluminum boxes featuring enclosed metal protection, break away doors for access, plastic seals on the doors to discourage and display tampering, and viewports to permit inspection of the SSD pressure gauge without removal of the device.

The permanently mounted racks make accountability of 7,000-9,000 SSDs per ship more easily handled. One SSD per slot in a stowage rack and vice versa.

The largest numbers of racks are provided for three men crew berths, where the greatest number of SSDs are used on carriers. Each rack holds three SSDs and is pop riveted to the bottom pan of the top berth, at the foot and inboard position, with the rack front facing into the berth front aisle (Figure 8). In this position, access to under berth stowage is not affected and does not interfere with the man climbing in or out. Yet, each man knows exactly which device is his and can quickly acquire it if needed while in the berthing space.

One device, clip-type racks are provided for officer staterooms to be mounted in any convenient location in the room readily accessible.

Other stowage racks are specifically designed for bulkhead or overhead mounting and hold one to six SSDs (Figures 9 and 10). These are intended for use in all other work or watch stations such as workshops, pump rooms, engineering spaces, offices, etc.

6. Refurbishment and Recharge

When an SSD is activated and used, the pull pin releases a spring loaded plunger that punctures the burst disc and allows the compressed air to flow into the face mask. Therefore, to ready the SSD for service again, it is a matter of recocking the plunger, replacing the burst disc and seals, and pumping a new supply of pure breathing air back into the coil reservoir.

The SSD is designed to be easily refurbished and recharged onboard ship, at a support tender, or ashore. The device can be used over and over again, and put back in service with relatively little complexity, time or cost. To this end, a Shipboard Recharge Station (SRS) and spare parts kits are provided.

The 30" x 18" x 30" station is designed to be mounted on a stand or bulkhead mounting. An adjacent work bench, in conjunction with specially provided tools, is used to refurbish the units prior to charging at the station (Figure 11). Each unit can be refurbished in approximately five minutes after a minimum of training, with parts costing slightly more than $1.00 (Figure 12). The refurbished units are connected by means of quick disconnect fill tools to fill lines inside the SRS and the door is closed (Figure 13). This provides an armored compartment for the units during the recharge operation. The station will charge one, two or three SSDs with air in 20 minutes to the operating pressure of 6500 psig. Charging valves are opened, an air drive valve is opened, and the station automatically pressurizes the units and stops at the regulated pressure of 6500 psi.

The major components of the Shipboard Recharge Station are as follows (Figure 14):

1. Pumps -- The two booster pumps are air-driven, pilot valve operated, non-lubricated, reciprocating-piston type gas compressors. The first is a two stage pump that boosts the breathing air to 470 psig. The second pump is a single-acting, single-stage gas compressor that boosts the air to 6500 psig in the reservoir.

2. Filters -- Six filters are used. One filters the ship's service air before it reaches the pump's drive motors. The remaining five filters are used in the purification of breathing air which is used to recharge the reservoir. 98% of all particles larger than five microns, 100% of particles larger than 15 microns and water is removed from the ambient air at the SRS before it enters the reservoir.

3. Relief valves -- Two safety relief valves are employed in the system.

4. Fill lines -- Three fill lines interface the SRS and SSD reservoir through the quick release couplings.

5. Pressure gauge -- The 0-10,000 psi pressure gauge indicates pressure on the breathing air manifold.

6. Cabinet -- All components are enclosed inside the sheet metal cabinet.

7. Drive air inlet -- Ship's service air between 80-125 psi will satisfactorily run the pumps. No other connection is needed.

The SRS is provided to carriers that have thousands of SSDs distributed throughout the ship. Smaller ships that have only several hundred or less devices use shore based or ship tender located stations for necessary support.

7. Future Development

As previously stated, the SSD has been designated as an interim emergency escape breathing device, to be procured in limited quantities. Meanwhile, in parallel with this interim action, a long range development program has been initiated to develop a device that will fully meet all Navy requirements for escape on all ships.

The SSD, as provided, is doing a remarkable job as an interim device. The device was purchased "off the shelf" during a time of urgent need and little modification was pursued before production in order to attempt to satisfy all Navy specifications. The present SSD shortcomings, in conjunction with present Navy requirements are as follows:

1. Eight minute limit -- The Navy desires a minimum 15 minute duration use time to cover most escape situations more satisfactorily, especially on the larger ships. It is also desirable to have longer use times, up to 60 minutes with little model changes.

2. Weight and bulkiness -- The six pound SSD is considered overweight under the goal of seeking a three-four pound limit for a 15 minute device. The SSD weight and size becomes prohibitive at 15 minute or more use times, using the compressed gas reservoir concept, unless a sophisticated rebreather and CO_2 scrubber is added with its additional parts and move away from "simplicity".

3. CO_2 buildup -- Using a moderate work rate and O_2 consumption of 1.3 liters/minute, CO_2 buildup is marginally satisfactory in the SSD. The Navy desires a heavy work rate using 1.7 liters/minute and CO_2 buildup not to exceed 4% in the mask or hood.

4. Cost -- The SSD contains a number of highly expensive and hard to obtain materials and components, including stainless steel tubing, polyvinylchloride and aluminum, making it more expensive than desired. This initial cost is offset somewhat since the SSD is reusable if maintained properly.

5. Availability and Reliability -- Needless to say, reliability is of prime importance to the mission of an air escape device that may lie untouched for years and yet need to be immediately available for use during an emergency to function properly. The use of a very high pressure charge, several seals, and many components and connections makes the SSD more vulnerable to failure if not carefully assembled, not only during manufacture, but also during shipboard recharging when conditions are less than ideal.

The Navy, therefore, in 1973 developed a specification of desired performance requirements and solicited industry to respond; to bid on an R&D effort leading towards an "ultimate" device to satisfy all U.S. Navy Fleet needs and possibly to replace the interim device. Over 50 firms considered the Navy's request for proposals and eight responded. Of these eight, four different design concepts were presented for consideration; a dual purpose chemical oxygen source, a chlorate candle oxygen source, a compressed oxygen source, and a compressed air source, similar to the Lear Siegler Survival Support Device.

To fully develop the more promising concepts prior to large production involved with Fleet application, development of more than one concept in order to best push the state-of-the-art in this pioneering area through competition is desirable. Final award considerations are being considered at this time with the goal of the development effort and thorough Navy testing and evaluation completed by the end of calendar year 1975. After that time, production should be feasible and the optimum device could be phased in by 1977-78.

8. Summary

Until 1973, the use of shipboard personal emergency escape breathing devices was still an idea, not a reality. Even as late as May 1973, production of the first device to fulfill this new lifesaving improvement was just commencing. Today, less than 20 months later, over 75,000 SSDs are distributed and ready for use onboard all of the U.S. Navy's active carriers, supported by spare parts, stowage racks, recharge stations and training films.

True, the SSD is an interim device, has had introduction growing pains and is of course less than perfect. In its limited role on only 15 ships to date, the fact is that it is out there, ready for use, doing a job. This was most dramatically demonstrated by the USS KITTY HAWK (CVA 63) fire that occurred in December 1973 while on station in the Pacific. Based on interviews of survivors from the machinery room and adjacent spaces' fire area, it was concluded that the SSD was used extensively, performed very well and prevented the deaths of six men and possibly six others. Several of the men were nearly overcome by smoke, had SSDs put on them by others, allowing them to clear the area safely. There is no better testimonial to the wisdom of the program to date than that of a hospitalized survivor who states that he would never have made it without the use of an SSD.

The Navy is not resting on these accomplishments to date, but is pushing the above mentioned R&D development with the goal of providing devices to satisfy all requirements on all type ships at least cost and risk. Meanwhile, the present producer continues to improve the SSD and search for even further advances to meet the Navy's challenges.

All of these efforts are aimed at the ultimate goal of eliminating the loss of even one seaman in the future from shipboard smoke and toxic gas casualty.

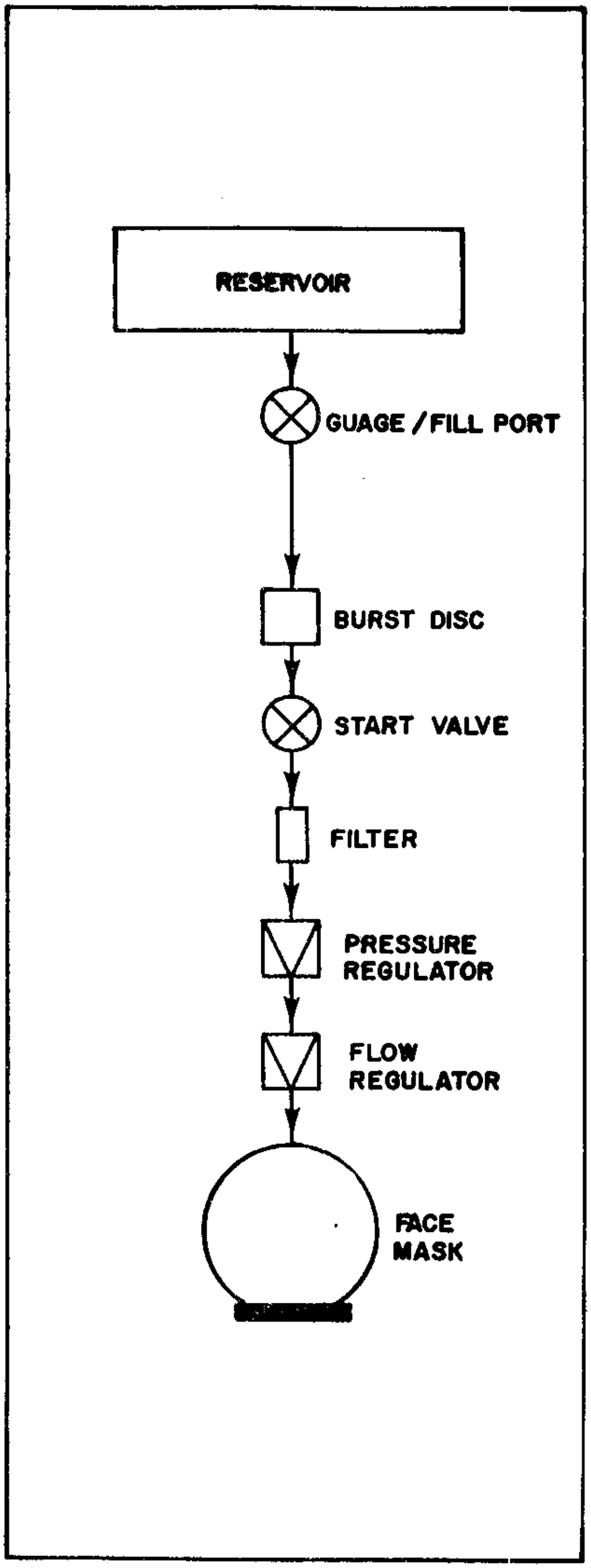

FIGURE 1. DIAGRAM OF AIR FLOW THROUGH SSD

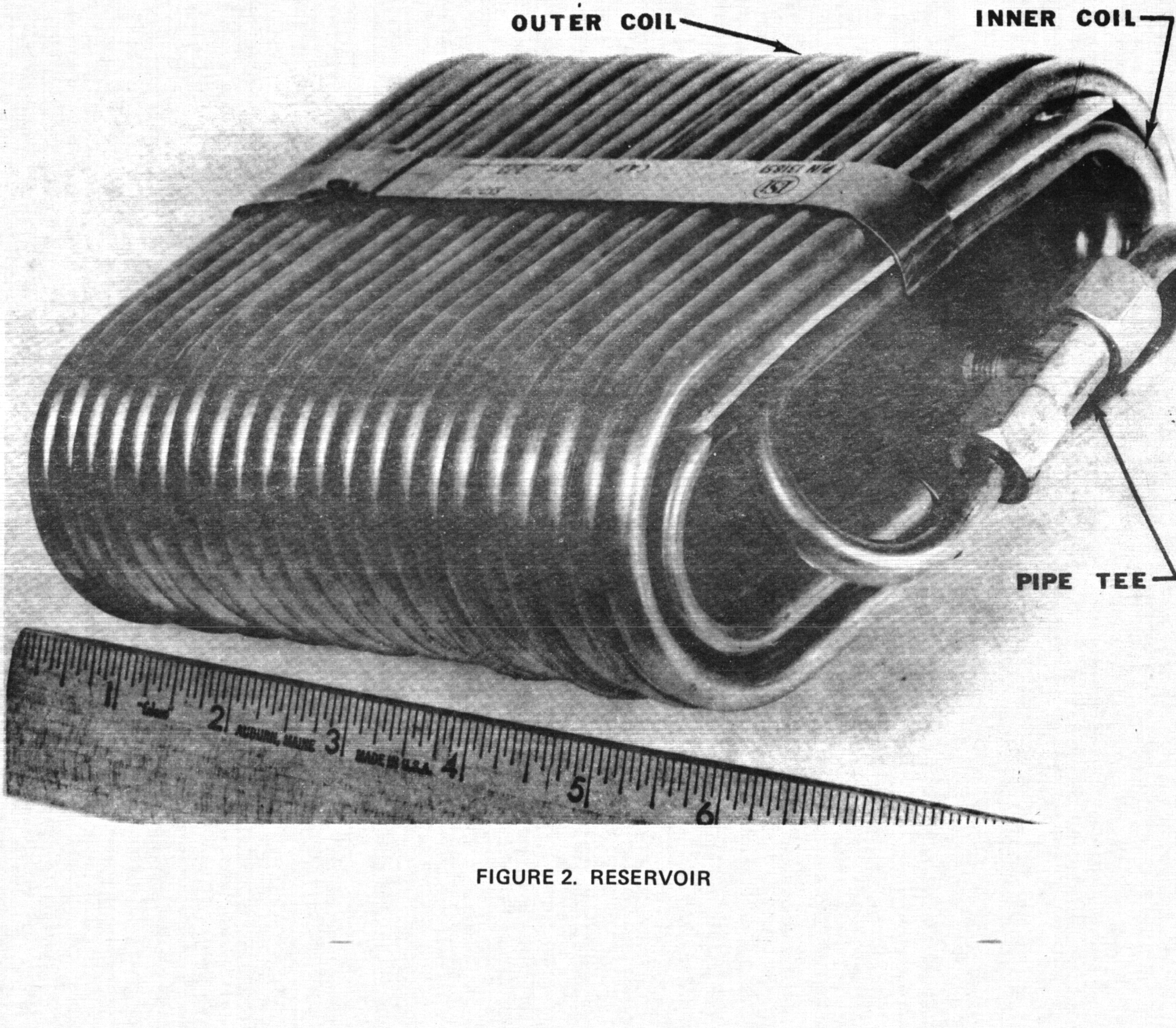

FIGURE 2. RESERVOIR

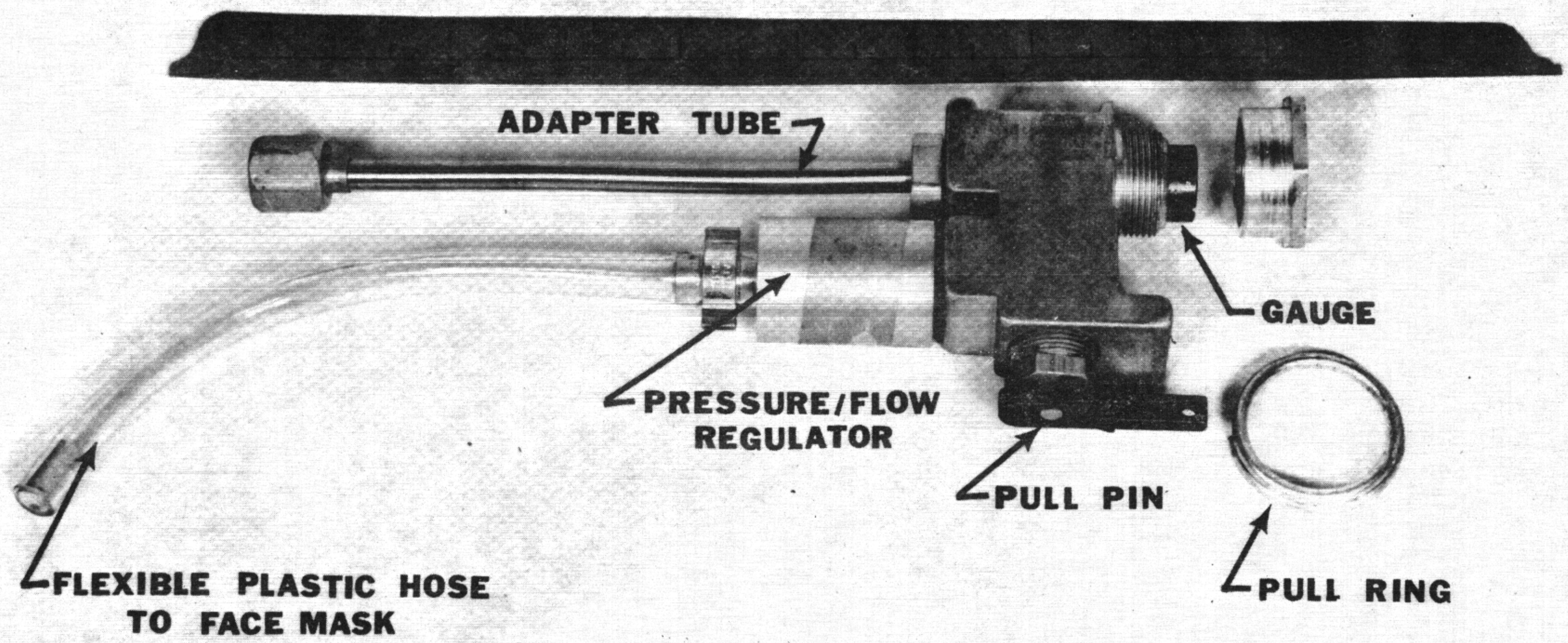

FIGURE 3. AIR MODULE

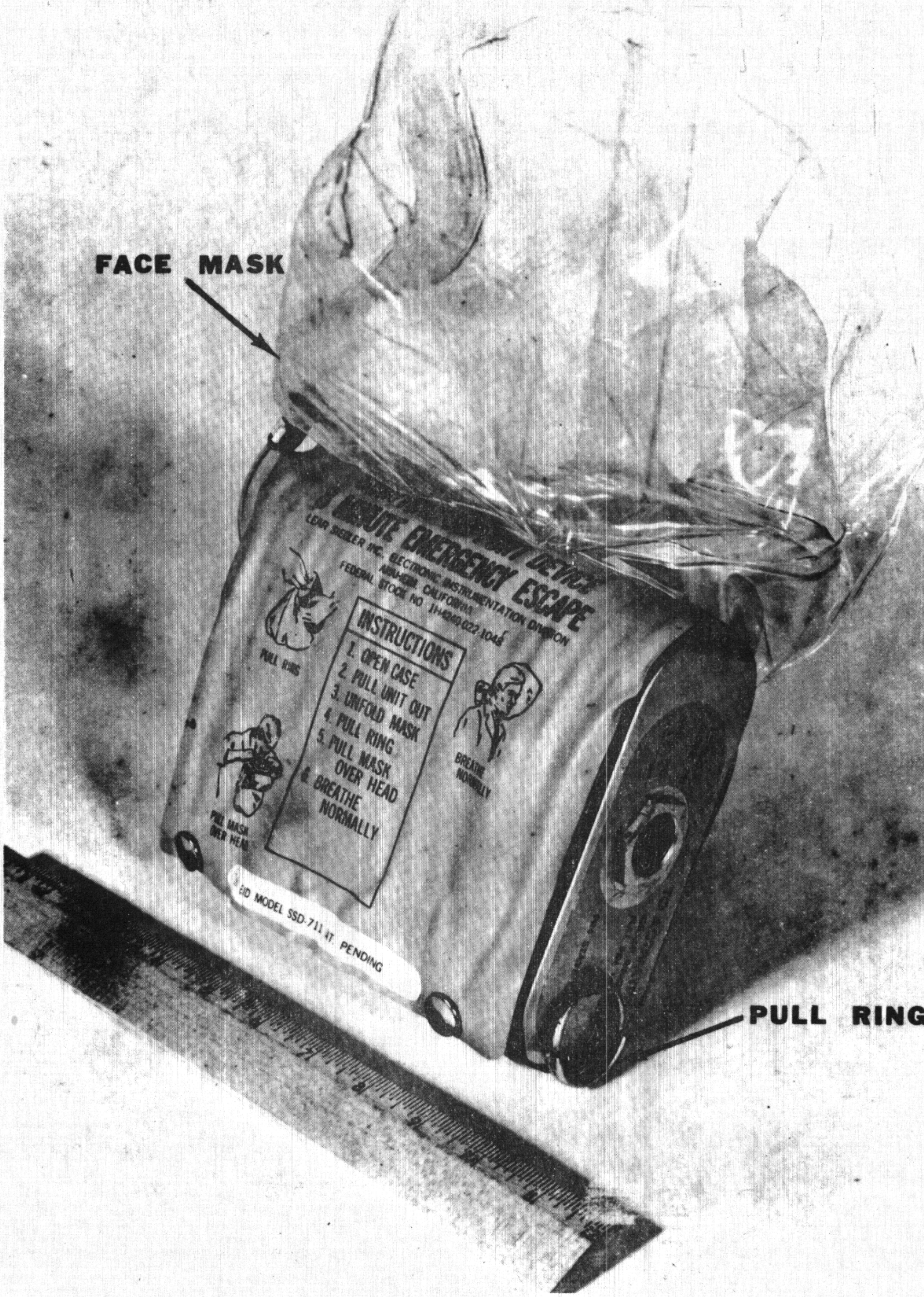

FIGURE 4. FACE MASK

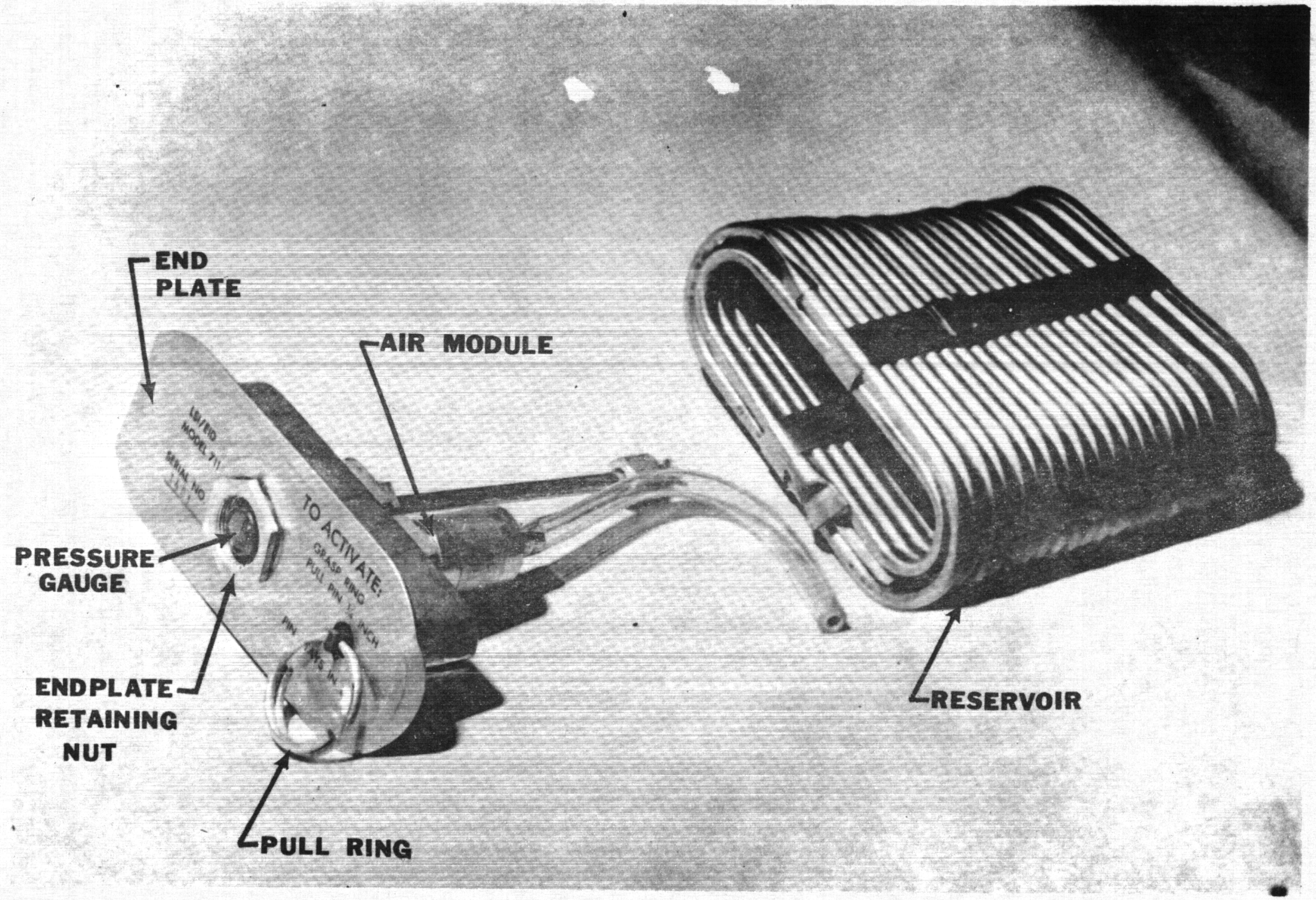

FIGURE 5. COMPONENTS ARRANGEMENTS INCLUDING END PLATE

FIGURE 6. CARRYING CASE

FIGURE 7. DONNING SEQUENCE

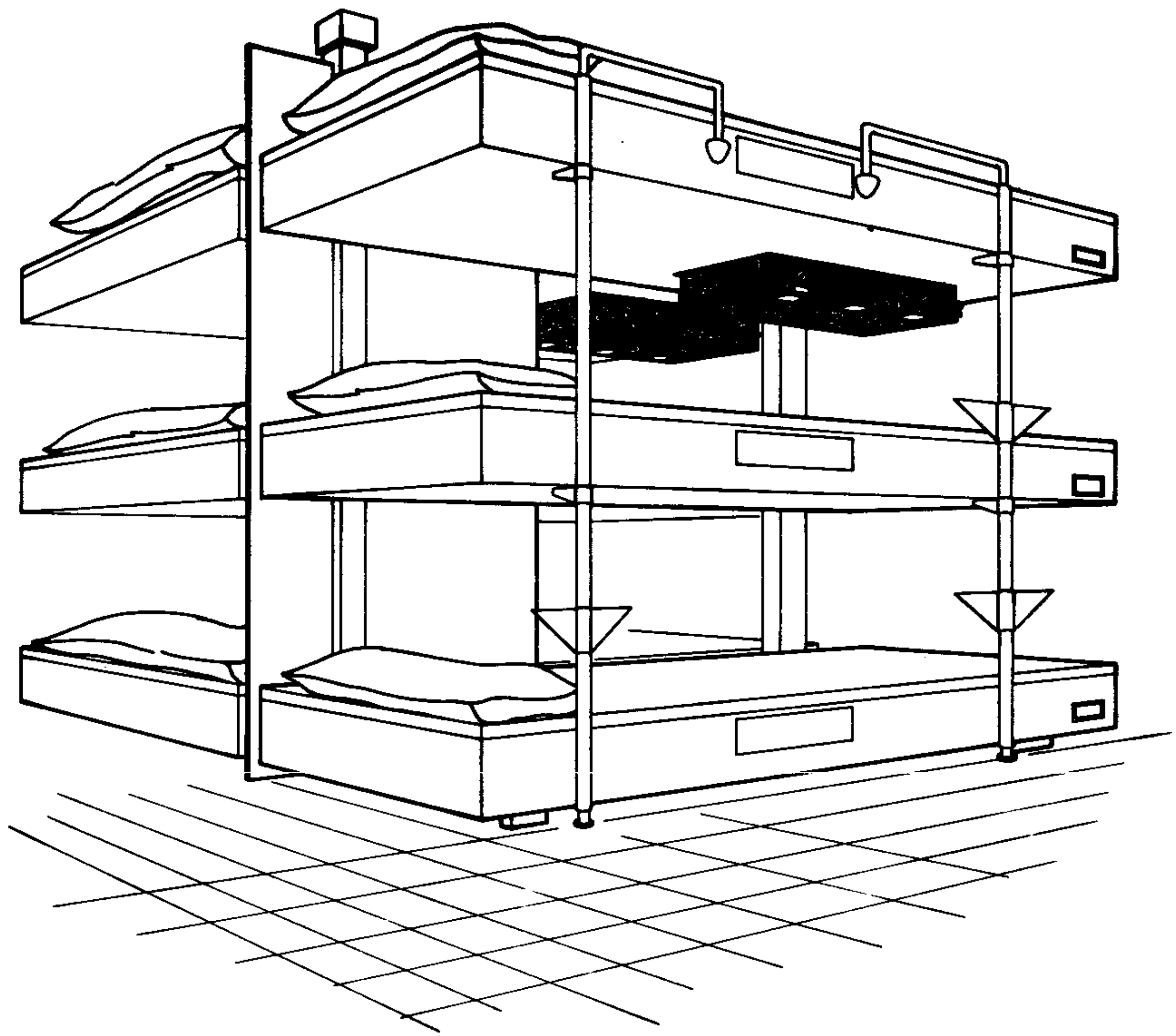

FIGURE 8. CREW BERTH STOWAGE OF SSD

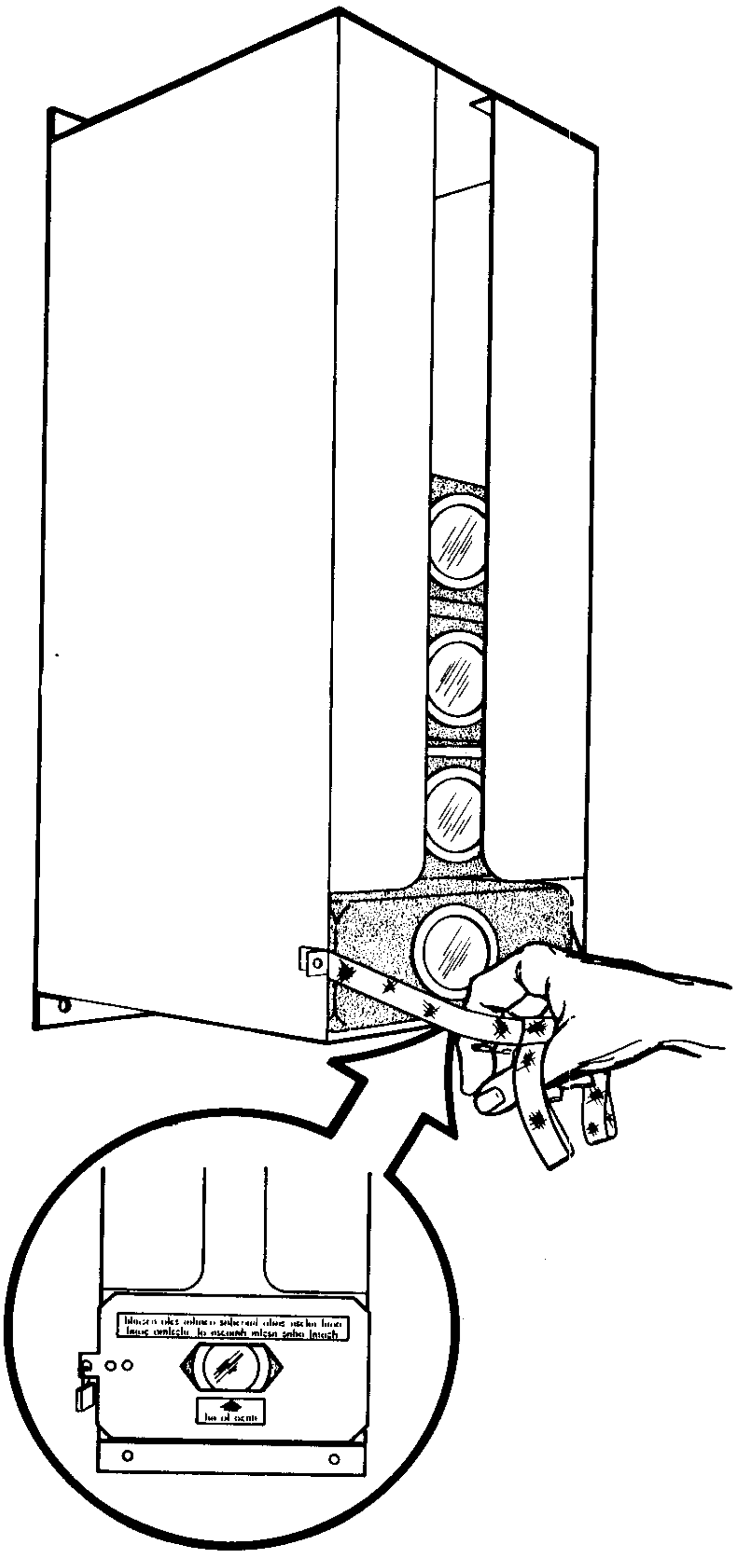

FIGURE 9. TYPICAL BULKHEAD STOWAGE RACK

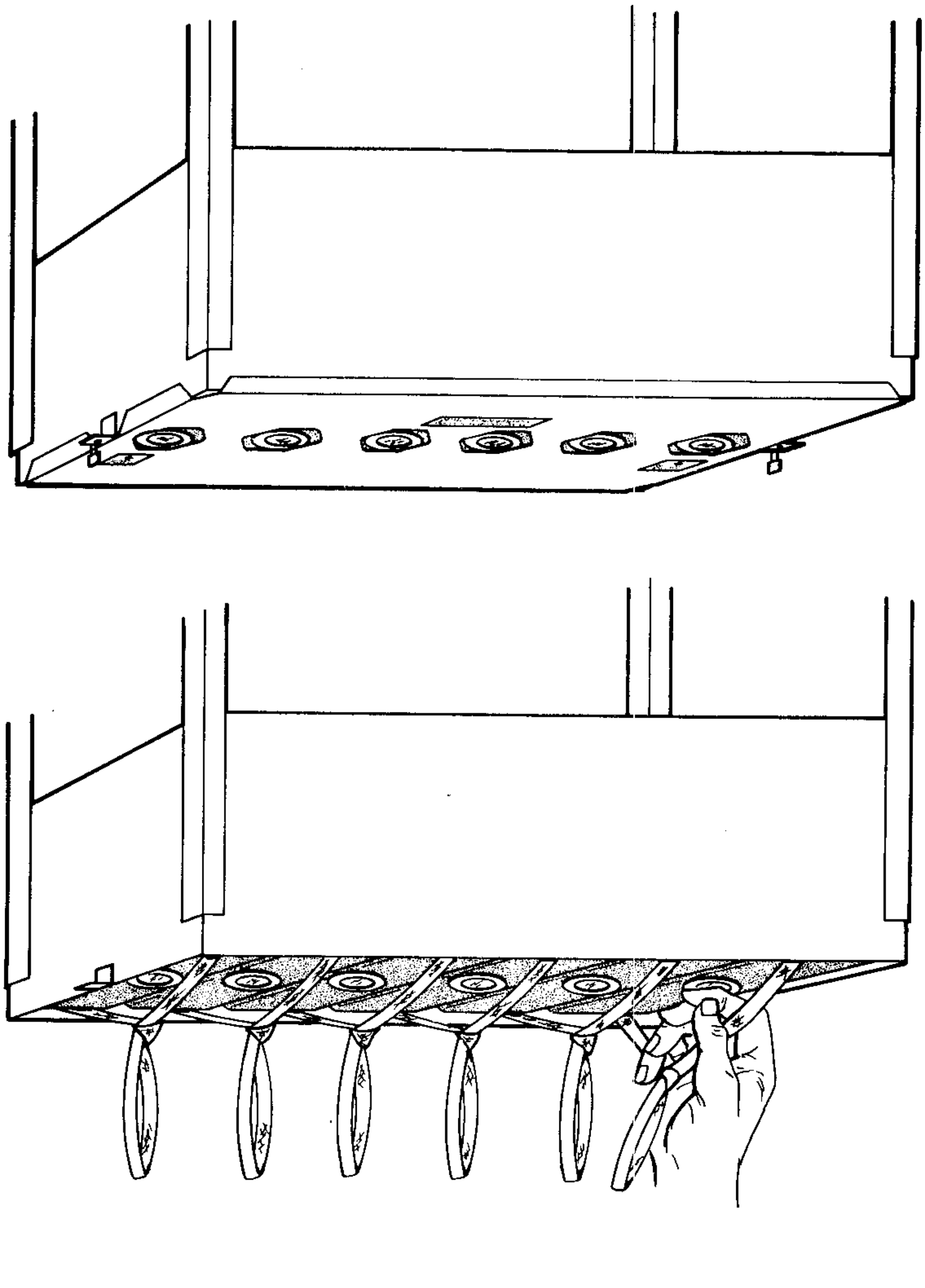

FIGURE 10. TYPICAL OVERHEAD STOWAGE RACK

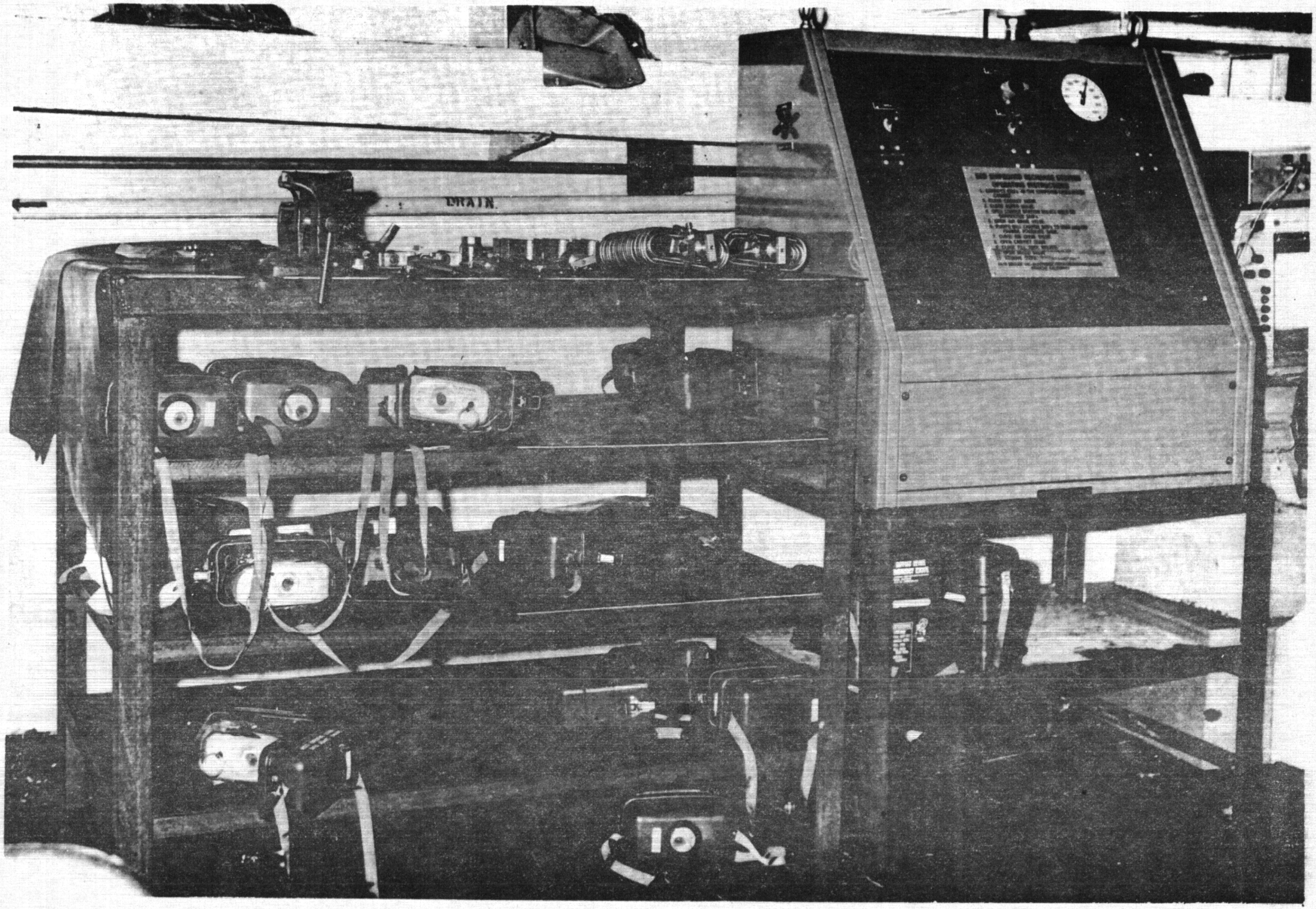

FIGURE 11. SHIPBOARD RECHARGE STATION INSTALLATION

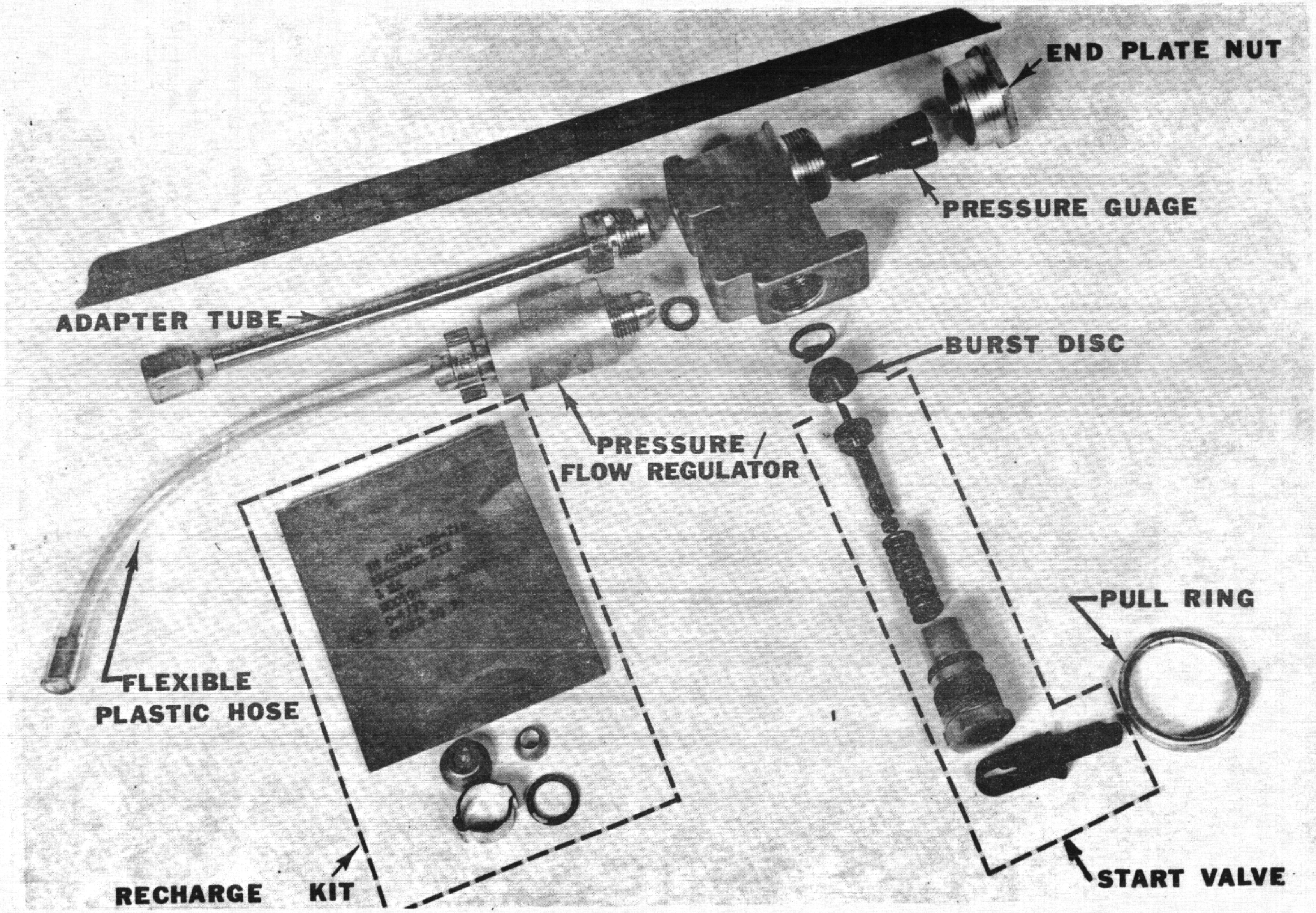

FIGURE 12. RECHARGE KIT AND START VALVE ASSEMBLY

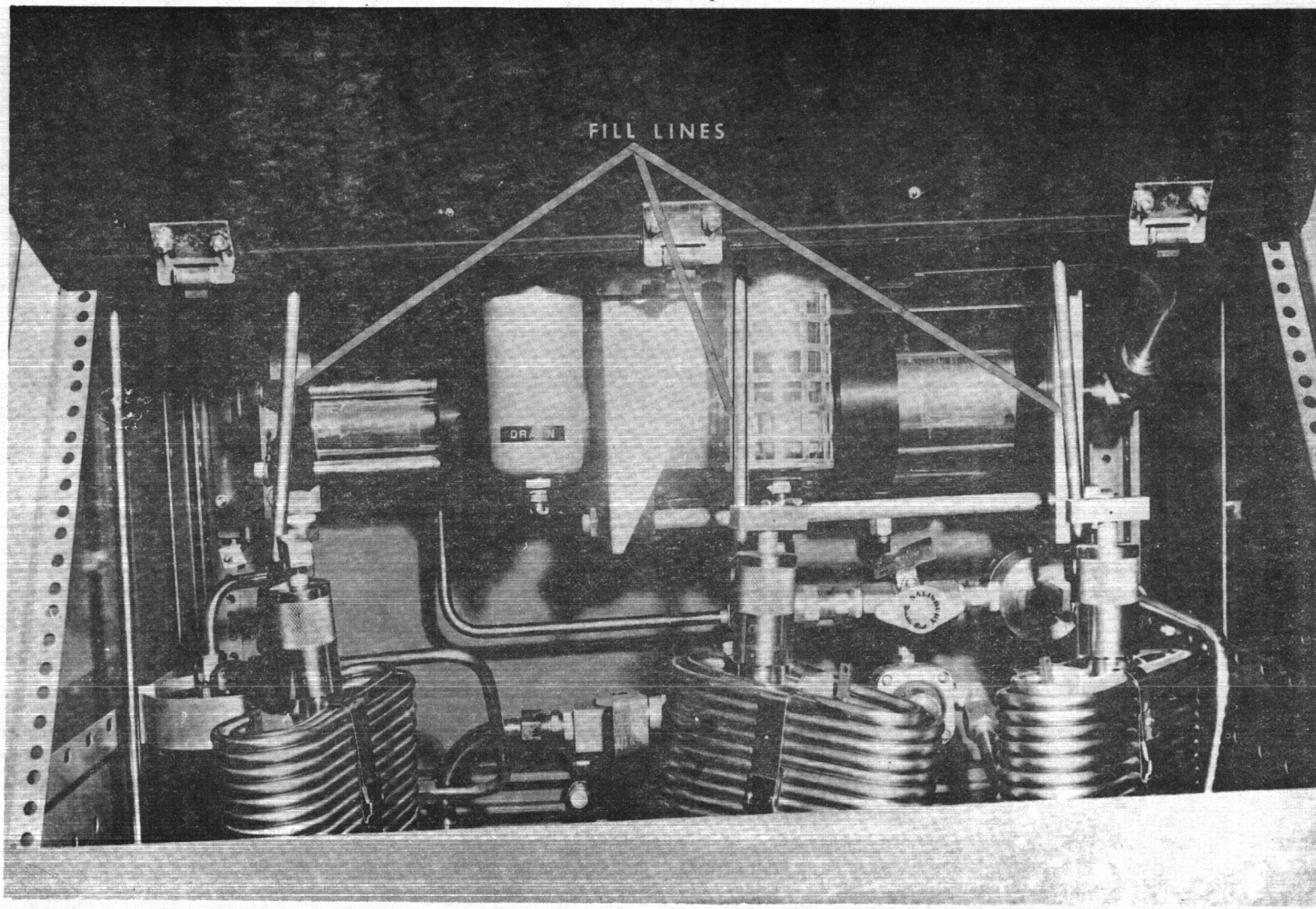

FIGURE 13. SHIPBOARD RECHARGE STATION - INTERIOR VIEW

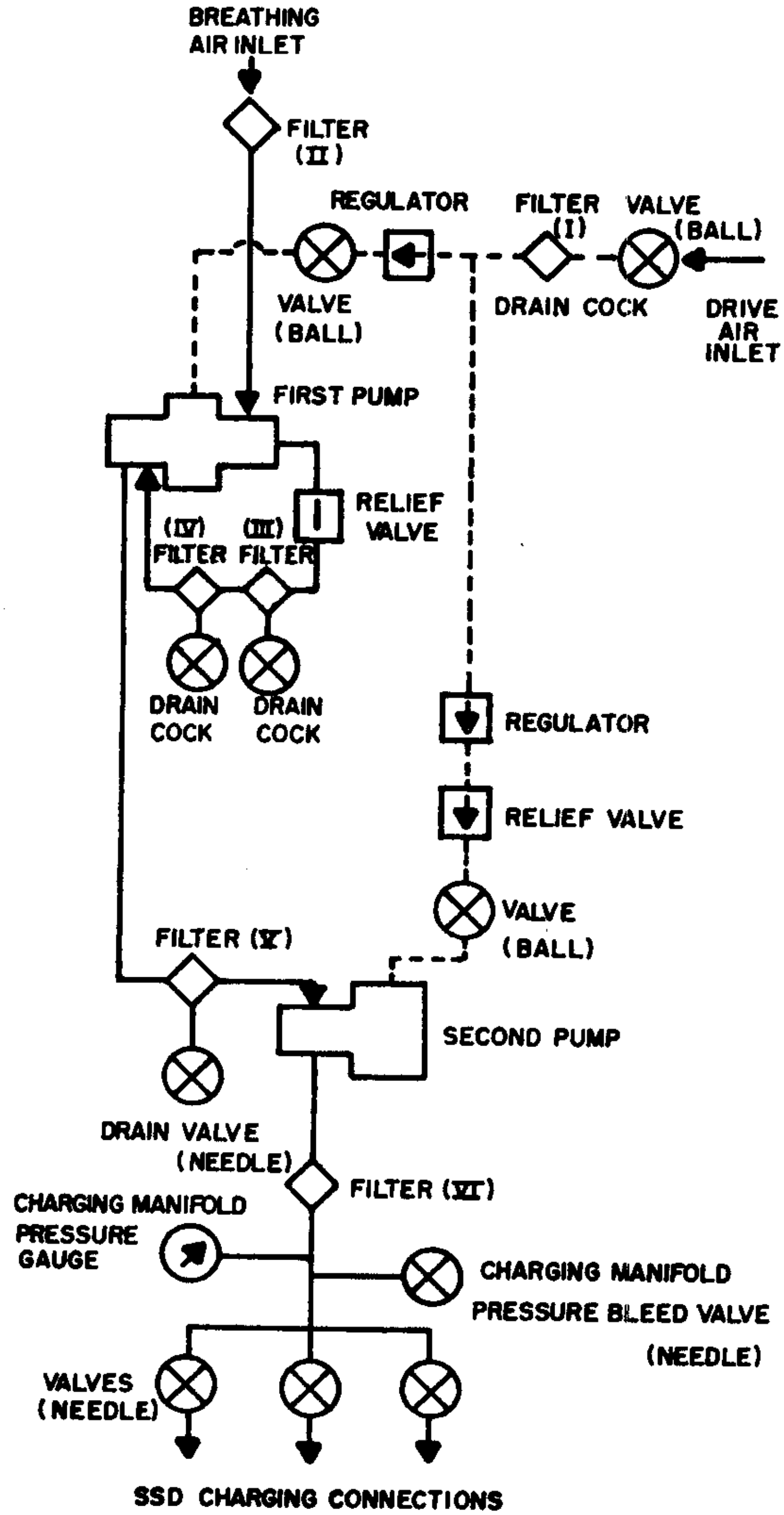

FIGURE 14. SHIPBOARD RECHARGE STATION - DIAGRAM OF COMPONENTS