CONTENTS

(Section 4)

List of Tables

4. CONTAINMENT

4.1. Introduction

The containment comprises a combination of compartments and equipment having the purpose of minimizing release of radioactivity outside the ship following an accident. This system is the NS Savannah's principal engineered safeguard. Its performance and reliability are vital to safety at the ship and in the surrounding environment.

The arrangement of the major parts of the containment is shown in Figure 4-1. For convenience of description, the containment is divided into two parts: the pressure containment and the reactor compartment.

Numerous improvements have been made in the containment since initial construction, and a considerable amount of operating experience has been accumulated. A description of the upgraded system and accumulated operating experience is presented in this section.

4.2. Pressure Containment

4.2.1. Function and General Design Criteria

The function of the pressure containment is to minimize the release of fission products after a serious accident. The MCA considered in the design of the Savannah is that accident which would result in the greatest potential hazard to the general public. As can be seen from Figure 4-2, the entire primary system and all primary components are located inside the pressure containment. A major failure of the primary system in the MCA is followed by rapid flashing of the primary coolant water as it is released to the containment. A major portion of the coolant escapes and causes the containment pressure to rise. As decay heat is added to the core, lack of adequate cooling results in an increased core temperature. Ultimately, failure of the cladding releases fission products to the primary system and containment. Although the containment must necessarily have access openings and service penetrations where some finite amount of leakage is possible, the pressure containment is designed to hold the largest possible quantity of these fission products.

The following are criteria established for the pressure containment:

1. The containment is sealed at all times during plant operation, and no entrance is permitted until the plant has been shut down and the radiation has been reduced to a safe level.

2. Design pressure of the containment vessel is determined by expansion of the primary fluid from the entire primary system and of the secondary fluid from one main steam generator. The blowdown occurs through a postulated pipe rupture.

3. No high-temperature piping containing primary water is permitted to penetrate the containment vessel.

4. Electrical containment penetrations are designed to withstand the containment design pressure and temperature.

5. Fluid penetrations and piping outside the containment up to and including the first shutoff valve are designed to withstand the containment design pressure and temperature.

6. Any equipment inside the containment vessel that might fail or give trouble during plant operation is installed either in duplicate or in such a manner that the faulty equipment may be isolated from the rest of the plant without hindering the plant operation.

7. The shell and all its penetrations are designed in accordance with USCG[5] and ASME[6] requirements.

4.2.2. Containment Vessel

4.2.2.1. Description

The containment vessel (see Figure 4-3 and Drawing 529-200-6) is a horizontal cylinder with hemispherical ends having an outside diameter of 35 feet 4-3/4 inches and a length of 50 feet 8-1/2 inches. It has a centrally mounted vertical cylinder 13 feet 6 inches in diameter extending 16 feet 6 inches above the horizontal cylinder. The gross volume of the containment is approximately 40,000 cubic feet, and the net free volume is approximately 31,200 cubic feet. The containment vessel wall thicknesses vary from a minimum of 1-1/4 inches at the hemispherical ends to 3-3/4 inches in the cylindrical portion of the vessel.

The vessel lies fore and aft on the ship's center line, 18 inches above the inner bottom. It rests in a saddle-shaped support, which is integral with the ship's structure, and is secured only at the bottom at the after end of the cylindrical section. This connection provides resistance to rotational forces and fore-and-aft motion. The support can thus accommodate thermal expansion. Lateral support is provided at mid length by the collision mats, thereby preventing movement due to the roll of the ship. Structural chocks at C-deck level provide lateral support and ensure that the containment remains in place at critical angles, including those in the capsized condition.

The containment has 99 major penetrations and openings through the shell. Some of these are subdivided into several minor penetrations for electrical or pneumatic service. All of the normal access and maintenance openings are located on the upper half of the vessel. Nearly all of the electrical and fluid penetrations pass through the lower half of the vessel.

4.2.2.2. Structural Design

Design of the pressure containment is based on the MCA conditions. Very early in the design phase of the project, the MCA was defined as the instantaneous release of the fluid energy in the primary system while the reactor was at full power. The preliminary calculation for this condition resulted in a peak pressure of 186 psig. The containment shell and all penetrations were designed for this pressure. Later, the accident was specifically defined as a primary system rupture having a flow area equal to the cross-sectional area of the largest primary pipe. Also included in the energy release was the fluid energy of one main steam generator. Since the rupture area had been defined, the postaccident analysis was made time-dependent, and the resultant peak pressure was determined to be 173 psig. The containment vessel hydrostatic test was conducted at this pressure. Later analysis included the effects of a subsequently authorized higher maximum reactor power. It also included the effects of experimental data for postaccident condensing film heat transfer coefficients. The net effect of these two factors on the peak pressure was a reduction to 160 psig. Hence, the shell thickness is approximately 15% greater than that which is required by section VIII of the ASME Boiler and Pressure Vessel Code.[6] The design stress of the code is one-fourth of the ultimate tensile stress. The pressure containment detailed design calculations were reviewed and approved by the USCG and the ABS.

Maximum stresses in the containment vessel under full shielding and dynamic stress of a 30-degree roll are experienced in the main cylinder rings located 7 feet 6 inches forward and aft of the containment vessel center line and in the inner cylinder rings located 2 feet 6 inches forward and aft of the center line. These stresses were determined by loading each element of the ring sections with vertical and horizontal loads at a 30-degree roll combined with the dynamic effect of this roll. Each ring was analyzed by use of strain-energy equations. The rings were considered stable and statically determinate structures with unit loads applied to each redundant reaction and moment. Unit deflection equations were then obtained, which when equated to zero, resulted in simultaneous equations, whose solutions yielded the reactions and moments. The final moments in each element of the rings were found, and since the section properties of the elements were known, the resulting bending stresses were obtained.

Maximum stresses in the main cylinder ring are 16,000 psi in the inner flange and 8400 psi in the outer shell of the ring section. These stresses occur when support is horizontal (90 degrees to the vertical). Maximum stresses in the cylinder partial ring sections are 20,500 psi in the inner flange of the ring and 6200 psi in the outer shell of the ring section. These stresses also occur when support is horizontal (90 degrees to the vertical).

The torque developed by a dynamic 30-degree roll is considered to be carried in the shell of the containment vessel as a shear in the shell. The shearing force resulting from this condition is resisted by the bolts located at the aft external support.

Maximum stresses in the hemisphere rings are not appreciably affected by a 4-degree pitch condition since the longitudinal center of pitch is located near the center line of the containment vessel. The stress in these rings is 20,000 psi for a static condition at a point 90 degrees from the vertical.

The external structural supports at 90 degrees to the vertical, port and starboard, are stressed to 6000 psi by the reactions from the cylinder rings. These stresses occur in the D-deck transverse members during a 30-degree roll condition.

The external foundations of the containment vessel were designed to resist the reactions from the hydrostatic test. These reactions exceeded those experienced during a 30-degree roll. Thus, the containment vessel foundations are suitable for all loading conditions, since maximum reactions due to the hydrostatic test are the most critical reactions experienced by the external foundations.

All internal equipment foundations are designed to stresses less than 12,500 psi for the combined roll-and-pitch condition.

4.2.2.3. Fabrication and Strength Testing

The cylindrical section, the two hemispherical heads, and the cupola were fabricated as four separate units. All welds in each section were preheated, and the roots and fillets were inspected by Magnaflux methods. After completion of welding, all welds were radiographed, and the four sections were stress-relieved. The sections were then lowered into the reactor compartment and welded together manually by the same procedures used for the individual pieces. Since the final assembly welding of the sections was on sections of plate whose thickness was less than 1-1/2 inches, no final stress relieving was required. Before installation of components in the containment, the completed vessel was hydrostatically tested at 173 psig with the penetrations capped or plugged closed.

The fabrication and welding procedures were reviewed by the USCG and the ABS. Site inspectors were present during fabrication and testing of the vessel to ensure compliance with the approved procedures.

4.2.3. Containment Vessel Penetrations

The containment penetrations, the containment isolation valves, and their location and method of operation are listed in Appendix A.

There are six openings which can be used for access or equipment removal. All but one (the double-door air lock) of these openings are bolted closures. The double-door air lock permits entering the containment without breaking containment integrity. A full-diameter hatch at the top of the cupola is provided for major maintenance and refueling operations. A 5-1/2-foot-diameter hatch is located in the top of the cupola for control rod drive removal. In addition to the air lock, a 42-inch-diameter bolted hatch is located forward of the cupola. This hatch can also be used for access and servicing of small equipment when the plant is shutdown. Two combination manways and flooding hatches are located on the starboard side in the lower quarter of each hemispherical head.

There are 99 service penetrations carrying air, water, steam, hydraulic fluid, and electrical power through the containment vessel shell. Piping penetrations less than 2 inches in diameter utilize a simple nozzle, while larger pipes use a nozzle with a reinforcing doubler. The penetrations for the 8-inch-diameter main steam line from the top drum of each main steam generator are sealed off with a special 14-inch-diameter expansion joint, which is welded to the pipe at the top and to the containment at the bottom.

There are only two other service penetrations which are larger than the main steam lines: the 10-inch air-purging penetrations. However, no special provision for attachment is made except for the reinforcing doubler, since these pipes are essentially always at the same temperature as the containment.

Electrical penetrations are grouped together in boxes at the point where the cables penetrate the containment. The number of subpenetrations in each major penetration varies from 8 to 25 depending on service, conductor size, and location of equipment being served. Leakage occurred through the original penetrations. In January 1964, a program was begun for replacing the original electrical penetrations with fused glass-to-steel fittings (see Drawing SK13-G-885). The replacement program is now complete. The electrical penetrations are individually tested at 286 psig with helium.

4.2.4. Containment Auxiliary Features

In addition to the pressure vessel itself, many auxiliary features are required to fulfill both normal and emergency functions. During normal operation the atmospheric conditions both inside and outside the pressure containment are maintained in a suitable range for the installed equipment. This is accomplished inside by the cc system, which is an arrangement of air-distribution ducts, duplicate two-speed circulating fans, and cooling coils. The circulating fans are operated and supplied with power from either the main console in the engine room or the emergency cooling panel on the navigation bridge deck. Associated with the cc system is the necessary instrumentation to measure pressure, temperature, and humidity. By maintaining a slight positive pressure in the containment, any large change in containment integrity is brought quickly to the operator's attention. This system maintains an average internal containment air temperature of about 130 F. As a backup to this system, should the normal cooling water supply be unavailable, a third cooling coil is available as a part of the DK system. This coil is supplied directly with sea water.

The atmospheric conditions in the reactor compartment are maintained by the RSV system. Air that has leaked into the reactor compartment is discharged through filters and up the 90-foot mast just forward of hold 4.

Following a major pipe rupture inside the containment, it is desirable to reduce the postaccident pressure. The following design features permit this pressure reduction:

1. Either the normal or emergency cooling coils in the cc system can be used, and heat will be removed by forced air circulation if the fans are operable or by natural air circulation if they are not. The possibility of forced circulation is enhanced because the fans at half speed are capable of operating in a steam-air atmosphere below 100 psi. Either forced or natural circulation will be increased after the accident by the automatic opening of two large side plates in the cooling ductwork located just below the fans.

2. Pressure reduction is accomplished by spraying water from the fire main into the containment through the CO_2 injection system.

3. Heat removal and pressure reduction can be accomplished by partially flooding the lower void so that heat flows through the containment shell into the flooding water.

Following the MCA, the possibility exists that radioactivity could escape through some of the fluid penetrations. In the case of most penetrations, this escape can occur only if the MCA breaks a pneumatic, hydraulic, or water pipe inside the containment to permit radioactive fluid to leave the containment through the pipe. However, this escape is prevented because each fluid line that is in service during normal operation contains either a check valve or a quick closing shutoff valve. This is schematically illustrated in Drawing SK13-G-884. With only two exceptions, these quick closing valves are tripped closed if containment pressure reaches 5 psig. The two exceptions are the two heavy-walled, 8-inch main steam lines, which are secured by pushbutton from the main console because of the possible desire to continue operating the turbine generators for a brief period after the accident.

Because the containment is inaccessible during operation, several other parameters in addition to temperature, pressure, and humidity can be monitored. Two channels of the RM system include detectors located in the containment: one for monitoring neutron level outside the neutron shield tank and the other for monitoring gamma level near the containment air lock. By piping connections, other RM system channels may be valved into the containment atmosphere to monitor radiogas and particulate activity. Because of the possibility of hydrogen leakage from primary components in the containment, provision is made for monitoring the hydrogen content of the containment atmosphere. The use of hydraulic oil in the containment means that there is a possibility of fire if a combustion-supporting atmosphere is present. To eliminate this possibility, an inert nitrogen atmosphere with less than 10% oxygen is kept in the pressure containment during normal operation. A complete spare charge of nitrogen is kept aboard the ship to recharge the containment if an outside supply is unavailable. As a safety precaution, a continuous oxygen analyzer is available to monitor the oxygen level in the containment. Figure 4-11 shows the equipment used to inert the containment.

Another feature of the containment design provides assurance that the containment would not collapse should the ship be involved in an accident which results in sinking. On the lower half of the vessel are two spring-return, bolted, flooding hatches which open and permit sea water to enter the containment if the ship sinks to a depth of 100 feet or more. When the containment is flooded and the pressures are equalized, the hatches reclose, thereby preventing escape of water from the containment through the flooding hatches.

For a sinking accident in shallow water, the containment has four salvage connections on the cupola head. Shutoff valves are located immediately adjacent to the vessel on each of these connections, and blank flanges are installed on the open end of each valve.

4.2.5 Containment Performance Requirements

Current operating procedures stipulate that the following containment performance is required:

1. Leak rate tests on the pressure containment must be conducted annually at approximately 60 psig. The daily leak rate is required to be less than 1.2% of the contained air mass at test pressure.

2. Normal containment integrity (closed air lock) is required at any time that more than one control rod is withdrawn.

3. The air lock, purge valves, and containment drain valves must be locally retested and demonstrated tight after each use.

4. An inert atmosphere (10% oxygen) is required in the containment before operating temperature is achieved or when more than one control rod is withdrawn.

5. A slight overpressure is required in the containment at all times during normal operation, and at least a daily log entry of this pressure must be recorded.

6. Automatic tripping of the containment integrity valves must be check during each leakage rate test.

7. Half-speed operation of both containment cooling fans must be checked at test pressure.

8. The integrity of the containment cooling coils must be checked monthly.

9. The emergency cooling system and emergency power supply must be checked weekly for proper operation.

4.2.6. Operating Experience

Evaluation of the ship's environmental safety is affected significantly by the confidence placed in the containment integrity. Since August 1963, confidence in the leak rate used in the environmental analysis has increased primarily due to high-pressure leak rate test results. The initial containment leak test was conducted at 30 psig, and the measured leak rate was extrapolated to 60 psig using the viscous flow relationship. This was done because environmental calculations were based on a leak rate that was consistent with the pressure for the first 24 hours after the accident. Hence, one of the first steps taken to increase the confidence in the environmental analysis was to conduct containment tests at 60 psig. The validity of the leak rate data was further demonstrated by implementing in 1963 a program of quarterly high-pressure tests. Physical improvements since August 1963 have resulted in significant reductions in the containment leak rate.

Until January 1965, tests were conducted using both the absolute and reference methods of leak rate determination. The basic test arrangement and the equipment required for both methods are shown in Figure 4-4. All tests showed reasonable agreement, and consequently it was no longer considered necessary to measure leak rate by both methods. Since the absolute method is simpler and difficulty had been experienced in repeatedly demonstrating reference system tightness, the absolute method was selected for future tests. Results typical of these tests are shown in Table 4-1.

As shown in Table 4-1, there were significant reductions in the leak rate. Primarily, these are the result of the electrical penetration replacement program although other physical improvements were made at the same time. The first group of electrical penetrations was replaced before the January 1964 tests, the second group before the April 1964 tests, the third group before the May 1965 tests, and all penetrations were replaced before the July 1965 tests.

Table 4-1. Containment Vessel Leak Rate at 60 psig Test Pressure

Date	Leak rate, % of contained air mass per day — Reference method	Absolute method
August 1963	1.3	1.3
January 1964	0.9	0.9
April 1964	0.7	0.6
July 1964	0.8	0.7
October 1964	0.7	0.7
January 1965	*	0.7
May 1965		0.6
July 1965		0.3
October 1965		0.5
January 1966		0.5
June 1966		0.6
September 1966		0.7
February 1967		0.7
April 1967		0.7
April 1968		0.7

* Reference Method Discontinued

In addition to the 60 psig tests, an extensive test was conducted in August 1963 at various pressures. This test was run to determine the relationship between pressure and leak rate. The measured relationship is shown in Figure 4-5. Tests results from the July 1965 leak rate test, extrapolated from the 60 psig test pressure by use of the viscous flow relationship, are also shown in Figure 4-5.

In addition to periodic whole-vessel tests, containment integrity has been qualitatively enhanced by improved operating procedures. Between whole-vessel tests, current operating procedures require immediate local retesting of certain penetrations or openings after they are used. Examples of these penetrations are the air lock, purge valves, and containment drain valves. The air lock, for instance, is tested by pressurizing the space between the two doors, and the containment drain valves are tested by pressurizing the space between the two valves using the arrangement shown in Figure 4-6. Current procedures also require operation with a slight positive pressure in the containment so that sudden changes are quickly brought to the operator's attention.

Since the program of high-pressure tests and containment improvement began, numerous modifications which affect containment integrity have been made. Some of these changes have had direct effects on containment integrity and have resulted in reductions in measured leak rate. Other changes have improved the ability to measure containment integrity or to maintain its continuity. The principal modification, which has had a direct effect on containment integrity and has resulted in reductions in leak rate, has been the electrical penetration replacement program.

A second change was the modification of the containment drain line, the containment drain tank drain line, and the containment drain tank vent line. Two changes were made at each of these three points. A second valve has been added in series with each of the original valves in these lines, and Teflon seats have been added to all valves. The two valves in series decrease the possibility of containment leakage, and the Teflon seats reduce the possibility that a small dirt particle on the seat of any valve will render it ineffective.

A third change involved modifications to both of the 10-inch containment air purging valves, which had on occasion been difficult to make tight. These valves are of the split-wedge gate design, which essentially contains double seats, one on each side of the gate. In this design, a void volume exists between the two seats (see Drawing SK13-G-884). In the original design, all mating surfaces were metal-to-metal. To improve seating characteristics, two new seat rings containing Teflon inserts have been installed in each valve, thereby making the mating surfaces on each side of the gate more resilient.

The fourth change was the addition of a leakage-monitoring arrangement for containment connections. This arrangement was added at the containment drain line, the containment drain tank vent and drain lines, and the two purge valves. A pressure-monitoring connection was made between each pair of valves, as shown schematically in Figure 4-6. A pressure-monitoring connection was also made to the volume between the two seats of the purge valves. Experience had shown that these points are the ones most likely to change status between whole-vessel leak tests. Since the pressurizing and monitoring manifold is located in the accessible upper reactor compartment, the tightness of these valves can be checked after each use.

The original single-speed containment cooling fans were replaced with two-speed fans. Since the new fans can operate in a high-pressure atmosphere at low speed, this change not only provides increased postaccident pressure suppression capability, but also provides a means of maintaining more stable containment temperatures during a high-pressure leak rate test.

4.3. Reactor Compartment

4.3.1. General Description

As shown in Figure 4-1, the reactor compartment surrounds the containment vessel and thus forms a secondary containment around the pressure containment. The principal auxiliary system associated with this compartment is the RSV system. The present RSV system was installed during the spring 1963 outage. The system consists of two physically independent sections. One section is for heat removal from the upper part of the reactor compartment; the other section is for exhausting air from the reactor compartment (see Drawing RS101-F-325).

4.3.2. Cooling Section

The cooling (or upper void recirculation) part of the RSV system is located entirely in the reactor compartment. Drawing RS101-F-120, sheet 1, shows the arrangement of the components of this section. Two air intakes are provided. The recirculating air intake is on the port side at the A-deck level. The fresh air intake is supplied by fan 1-105-1 via regulating valve RS-40V. The recirculation fans (one is a spare) take suction on the intake manifold and discharge past the salt-water-cooled air cooling coils into a common header. This header distributes the air throughout the upper part of the reactor compartment.

Each cooling unit is designed to provide a flow of 3600 cfm at the normal fan differential pressure of 3-1/2 inches wg. The cooling coils are designed to reduce the air temperature from 116 F to 98.3 F when using sea water at 95 F (maximum). The heat load is 57,800 Btu/hr for air under these conditions. Both cooling and dehumidification amount to 90,000 Btu/hr.

The pushbutton controls for the fans are located in the forward control area. Normally, only one fan is in operation. Backflow through the standby fan is prevented by an electrically operated damper interlocked to open only when the fan is running. If both fans are off, an alarm sounds on the main control console. High temperature in the reactor space is also annunciated in the main control room.

The water supply for the cooling coils is from the sea water pumps of the CW system. A booster pump RS-P5 provides additional head for the cooling water when required. This pump is designed for 30 gpm flow at a 30-foot head and is used when additional cooling is required. The air temperature from the cooling coils is regulated by automatic control valves, which restrict cooling water flow.

4.3.3. Exhaust Section

4.3.3.1. Function

Drawing RS101-F-120, sheet 2, shows the arrangement of the components of the exhaust system. This section of the RSV system is part of the engineered safeguards for the ship. Its primary purpose is to retain any particulate and halogen fission products which may leak from the containment vessel. The effectiveness of this filter system is tested periodically to demonstrate desired efficiency for iodine and particulate removal.

The exhaust section of the RSV system maintains the reactor compartment at a pressure of approximately 1 inch wg below the B-deck corridor pressure. The reactor compartment pressure is, therefore, below that of the surrounding shipboard areas and the containment vessel. This arrangement ensures that any containment vessel leakage will be exhausted via the filter-adsorber banks in the RSV system and not to the surrounding shipboard areas. The reactor compartment also acts as a surge tank in providing additional holdup (decay) time for fission products escaping from the containment vessel. This is significant in reducing the activity of isotopes with short half-lives.[7]

The pressure in the reactor compartment is regulated by adjusting valve RS-40V. The control for this valve is located in the B-deck hydraulic equipment room, and a pressure gage measuring the differential pressure between the reactor compartment and the B-deck corridor is located nearby. Additional gages to indicate this differential pressure are located in the emergency diesel room and in the main control room. If the reactor compartment pressure rises to within 0.3 inch wg of the pressure in the B-deck corridor, an alarm sounds on the main control console.

4.3.3.2. Containment Vessel Purging

The containment vessel is purged via the exhaust section of the RSV system. Purging is done by opening the containment vessel purge valves (WL-12V and WL-13V) and closing a damper in the suction of the exhaust section of the RSV system. Air is thus drawn from the reactor compartment into the containment vessel and then to the exhaust section of the RSV system.

4.3.3.3. Suction Ductwork and Lower Plenum

The exhaust section of the RSV system takes suction in the lower part of the reactor compartment via a single duct to the lower plenum. Separate connections on the lower plenum lead to the two filter-adsorber banks. Motor-operated valves (RS-3V and RS-4V) adjacent to the lower plenum are provided for flow control. Controls for these valves are located nearby. Normal operation is with one of the filter-adsorber banks in service and the other on standby.

4.3.3.4. Filter Units

The filter units consist of demisters, roughing filters, absolute filters, and iodine adsorber assemblies. The filters and adsorbers are each designed for a specific purpose. Each filter and adsorber is described below.

The demister is the first process unit downstream of the inlet valves and is provided for the removal of any entrained water in the exhaust gases. The demister consists of a mat of Teflon yarn on a stainless steel core. This type of construction has been extensively tested at the Savannah River Laboratories (SRL).[8] The demister is designed to remove water droplets at the rate of 1 lb/min from the ventilation stream. It is rated at 1600 scfm air with 0.95 inch wg pressure drop.

The roughing filter follows the demister. Its purpose is to remove particulate matter from the exhaust stream. The filtering medium consists of a glass wool mat arranged in a pleated pattern for greater surface area. Details of the roughing filter are shown in Figure 4-7.

The combined pressure drop through the demister and roughing filter is 1.0 to 1.1 inches wg at the normal RSV system exhaust flow rate of 1050 cfm. This pressure drop is monitored and is used to determine when the filters have become clogged and should be replaced.

The absolute filter is located downstream of the roughing filter. Its purpose is to remove very fine particulate matter which passes through the demister and roughing filter. The filtering medium is a glass sheath that is arranged in the form of deep pleats for additional surface area. Details of the absolute filter are shown in Figure 4-8.

Extensive tests[8] have established that the flow rate capacity of the particulate filters in use is in excess of 4000 scfm. These filters remove about 99.97% of particulate matter 0.3 micron or larger. These characteristics exceed the required 99.9% particulate matter removal at 1000 to 1600 cfm flow rate of the RSV system exhaust section.

The absolute filters are tested quarterly and prior to each port entry for particulate matter removal efficiency. This test is performed using an aerosol produced by bubbling air through the liquid DOP. The aerosol is carried along in the RSV system by the exhaust air stream, and the DOP concentration is determined on both sides of the filter-adsorber bank. The concentration is determined by a forward scattering photometer developed by the Naval Research Laboratories. This type of photometer is used as standard equipment by ORNL, SRL, and other AEC laboratories concerned with removal of particulates from reactor ventilation systems. Each absolute filter has been tested many times, and the efficiency has consistently been indicated to be more than 100 times higher than the required 99.9%.

The iodine adsorber assembly follows the absolute filter. This unit consists of three parts mounted in a common housing. The unit is shown in Figure 4-9. The first and last parts of the assembly are identical and consist of mats of silver-plated copper ribbon. This material, made of 4% silver and 96% copper, is compressed to a density of 27 lb/ft^3 and is 4 inches thick. The function of this adsorber is to remove halogens from the exhaust stream by chemical combination with the silver. Details of the silver-copper ribbon mat are shown in Figure 4-10.

The middle part is a charcoal adsorber. Granular activated charcoal is contained in 10 horizontal beds, each of which is 2 feet wide, 4 feet long, and 1 inch thick. The charcoal is held in place by perforated plates. Baffles at the ends of the trays ensure parallel flow through all 10 beds. Details of the trays are shown in Figures 4-9 and 4-10.

Activated charcoal is uniquely efficient in removing halogens from gaseous streams. Charcoal adsorbers have demonstrated iodine removal efficiencies of 99.9% under conditions expected to exist if an MCA occurs.[9] The iodine removal efficiency of the adsorber assembly is demonstrated by periodic tests. The tests involve injection of radioiodine (I-131) into the ventilation stream ahead of the filters. Samples are taken ahead and downstream of the charcoal adsorber and are analyzed for I-131 content using a gamma spectrometer. These tests have indicated the radioiodine removal efficiency to be greater than 99.9%.

The differential pressure across the filter-adsorber bank is monitored. In the event of high differential pressure, an alarm sounds on the control console.

The ventilation stream from both filter-adsorber banks goes to the upper plenum. Air from the upper plenum goes to the fans.

The upper plenum is fitted with two vacuum switches. One switch alarms on the main control console if the pressure in the upper plenum rises to within 5-1/2 inches wg of the B-deck fan room pressure. A continued pressure rise to within 5 inches wg of the room pressure automatically starts the standby fan. The second vacuum switch alarms on the main control console if the differential pressure between the upper plenum and the B-deck fan room increases to more than 8-1/2 inches wg. This arrangement of alarms and controls brackets the normal operating range of the upper plenum. Thus, any malfunction resulting in abnormal operation of the RSV system exhaust section is annunciated on the main control console.

The exhaust fans take suction from the upper plenum. These are steep-characteristic (22 inches wg static pressure at shutoff) fans, which deliver about 1000 cfm air over the range of pressures normally encountered. During normal operation, one is running, and the other is on standby. In the event of a rise in upper plenum pressure, the second fan is automatically started. One fan is normally powered from the emergency bus, and the other fan is powered from the main bus. A bus transfer switch is provided to operate the second fan from the emergency bus, if desired. Backflow through the inoperative fan is prevented by a normally closed motor-operated valve, which opens automatically when the fan is started. Both fans discharge into a single duct leading to the foremast (90-foot elevation). Drains are provided to handle any condensate formed in the fan or the discharge line. These drains terminate in the forward sump in the reactor compartment.

FIGURE 4-1

SIMPLIFIED DRAWING OF THE CONTAINMENT SYSTEM

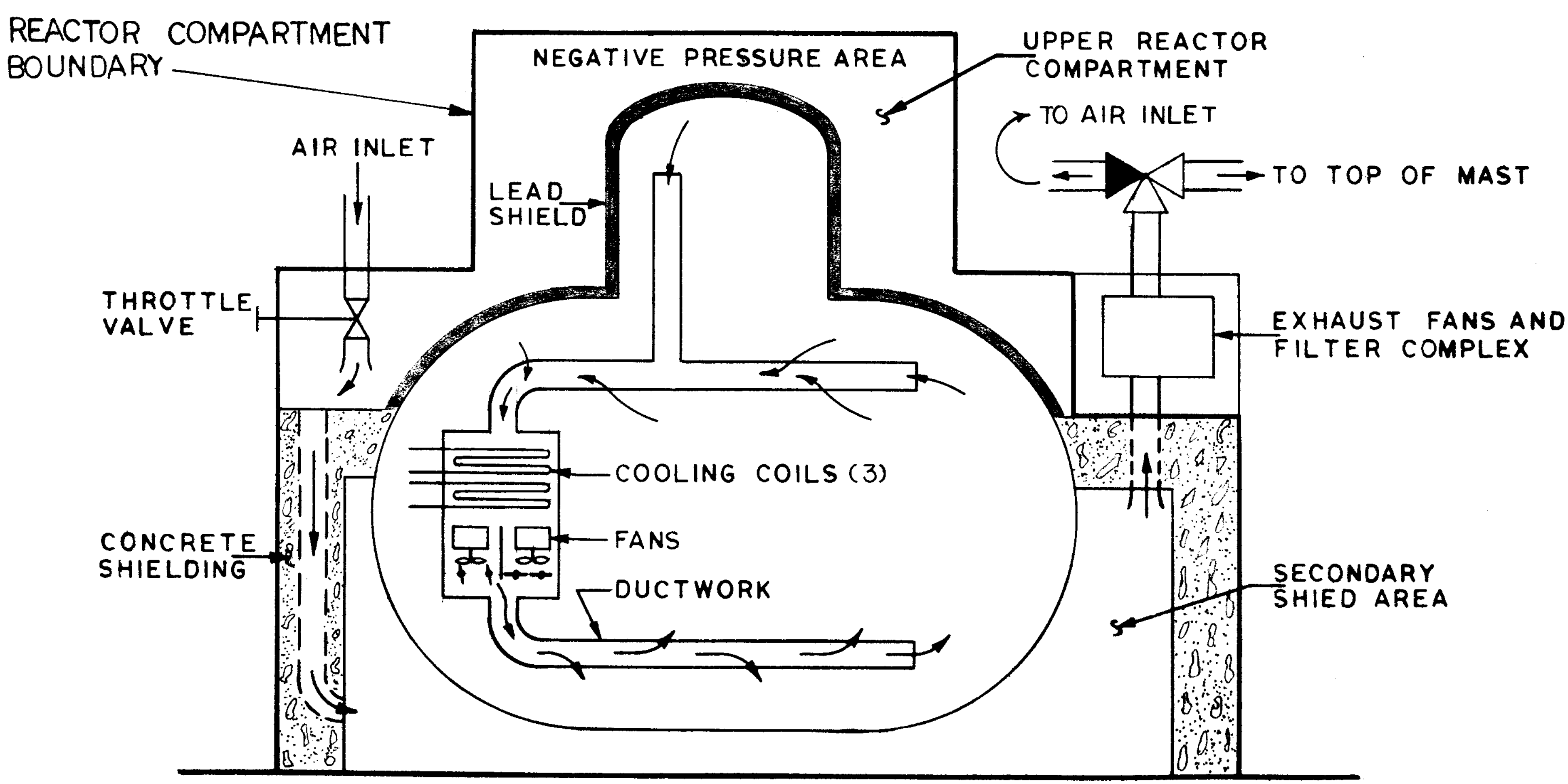
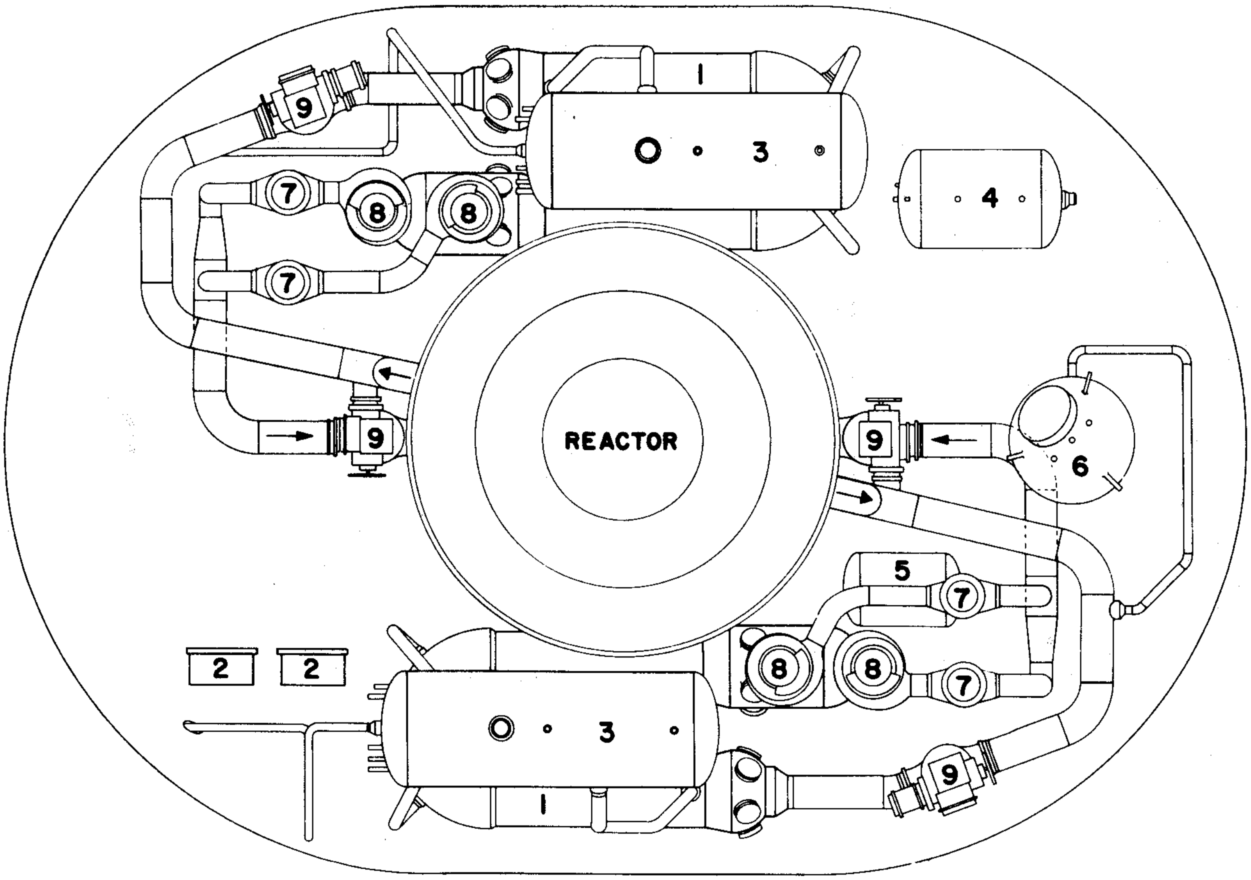


FIGURE 4-2. ARRANGEMENT OF PRINCIPLE COMPONENTS IN CONTAINMENT VESSEL



① HEAT EXCHANGER ② LET DOWN COOLERS
③ STEAM DRUM ④ CONDENSING TANK
⑤ CONT. DRAIN TANK ⑥ PRESSURIZER
⑦ CHECK VALVE ⑧ PUMP ⑨ GATE VALVE

FIGURE 4-3

ARRANGEMENT, CONTAINMENT VESSEL

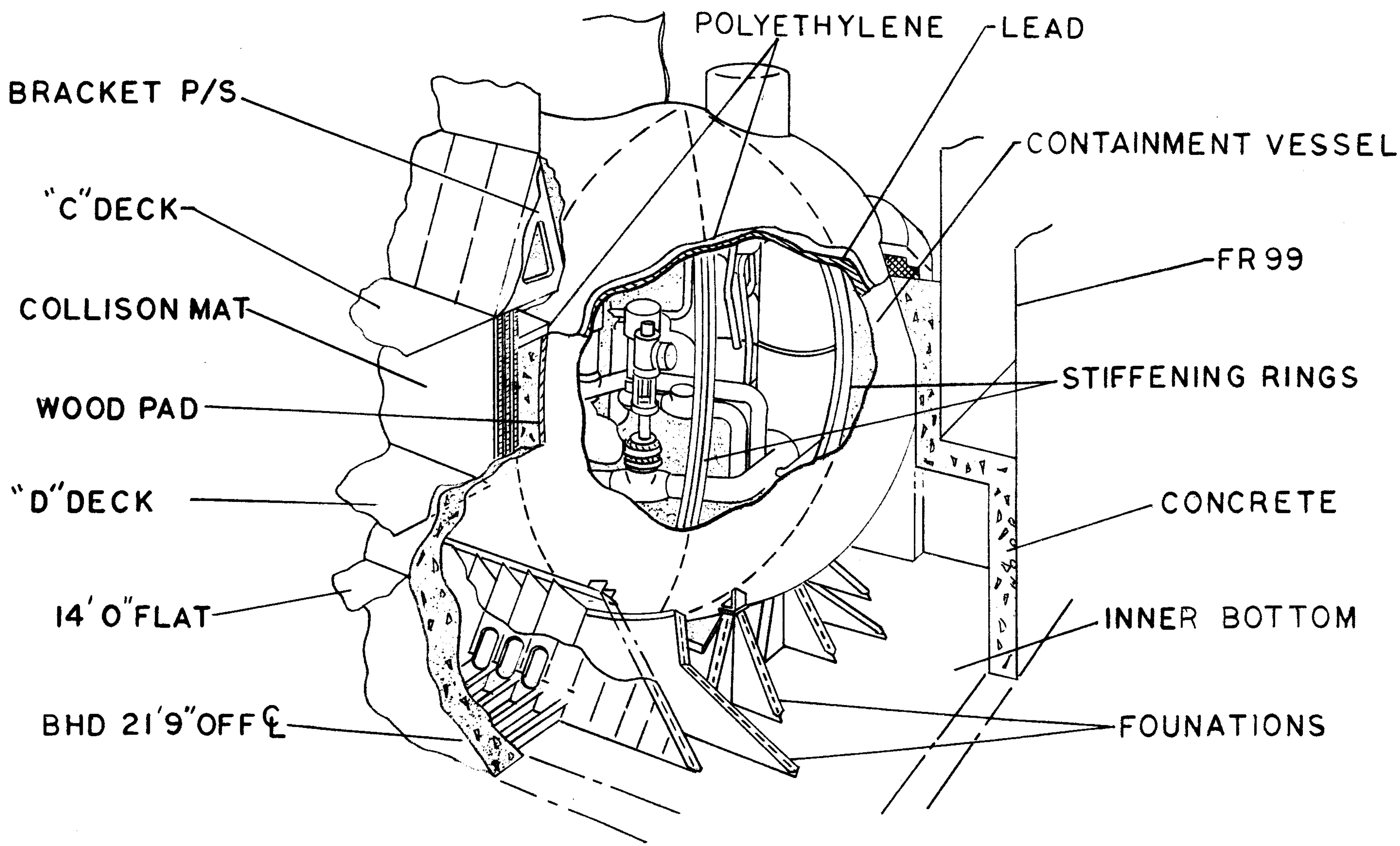


FIGURE 4-4

CONTAINMENT VESSEL LEAK TESTING ARRANGEMENT

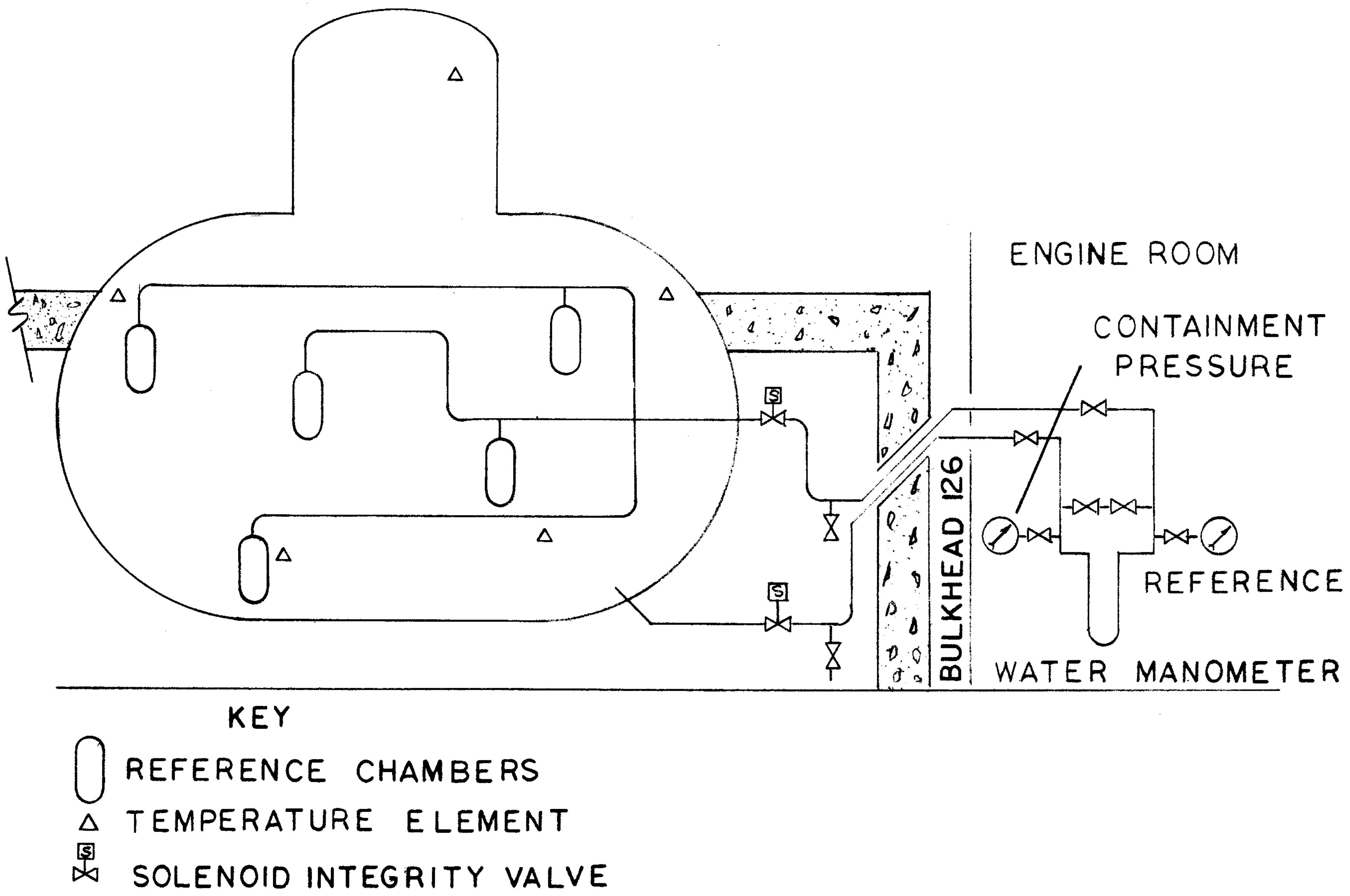


Figure 4-5. Containment Leak Rate

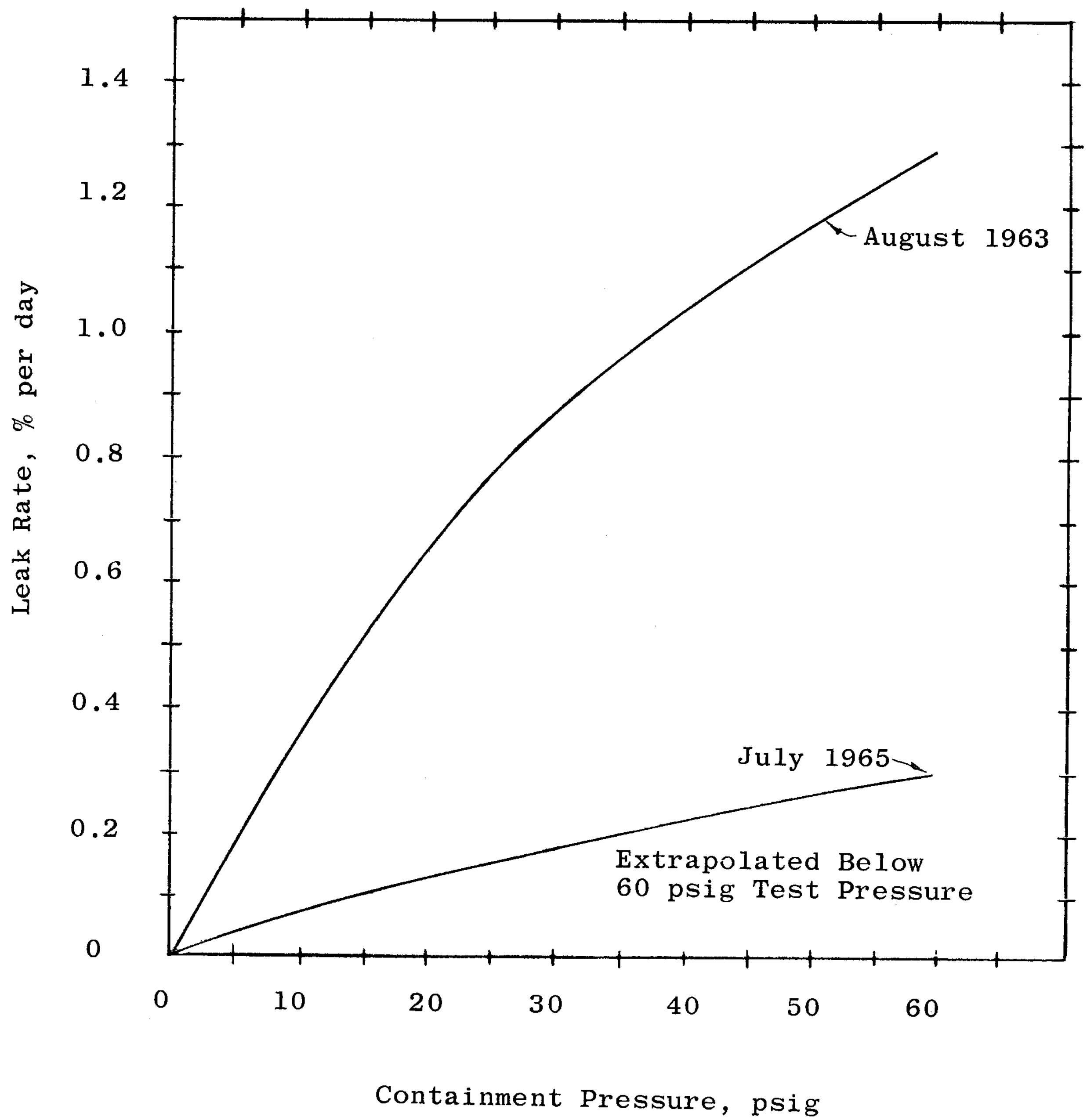


FIGURE 4-6

TYPICAL SIMPLIFIED SCHEMATIC OF DOUBLE VALVE AND TELL-TALE MONITORING ARRANGEMENT

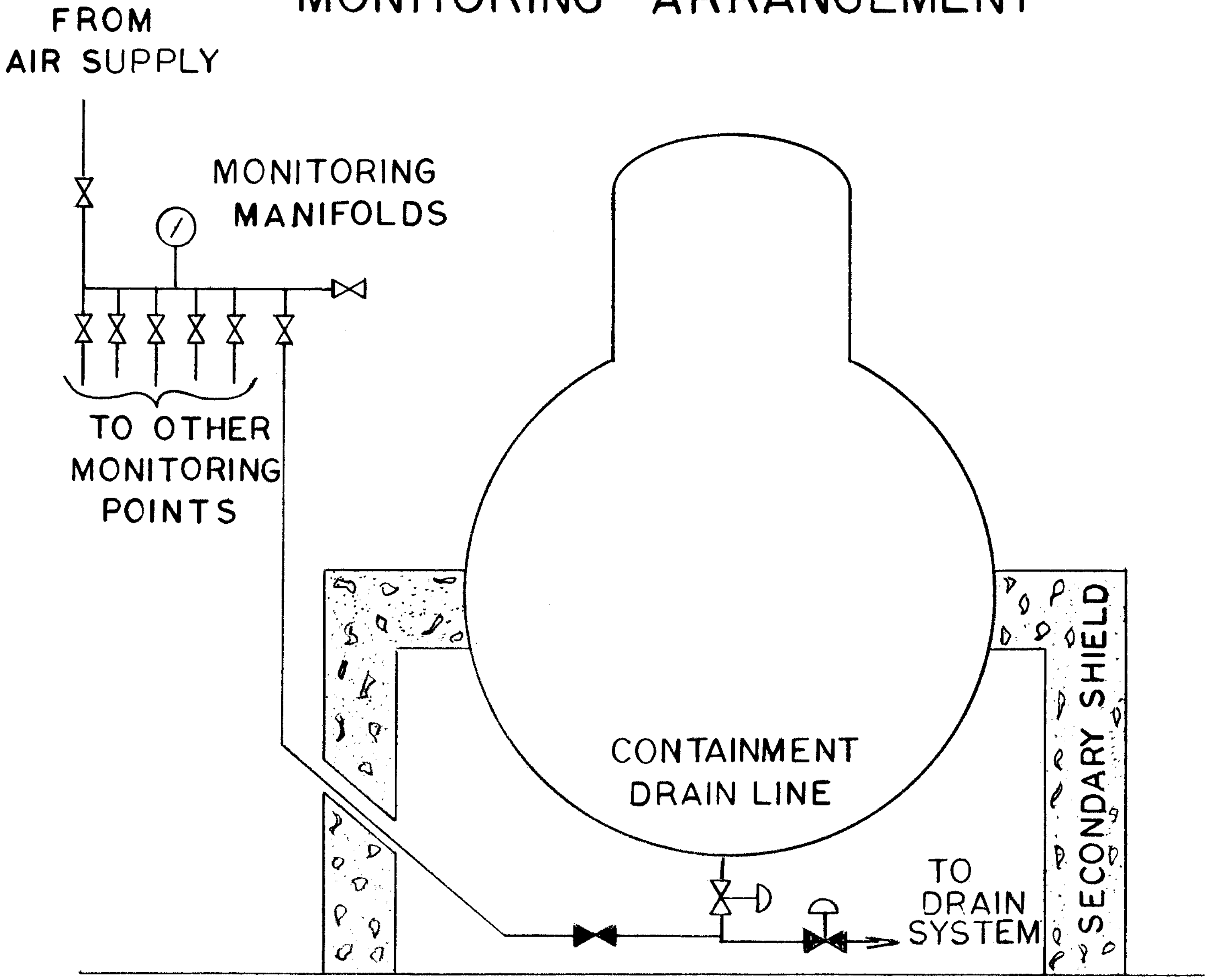


Figure 4-7. Roughing Filter Details

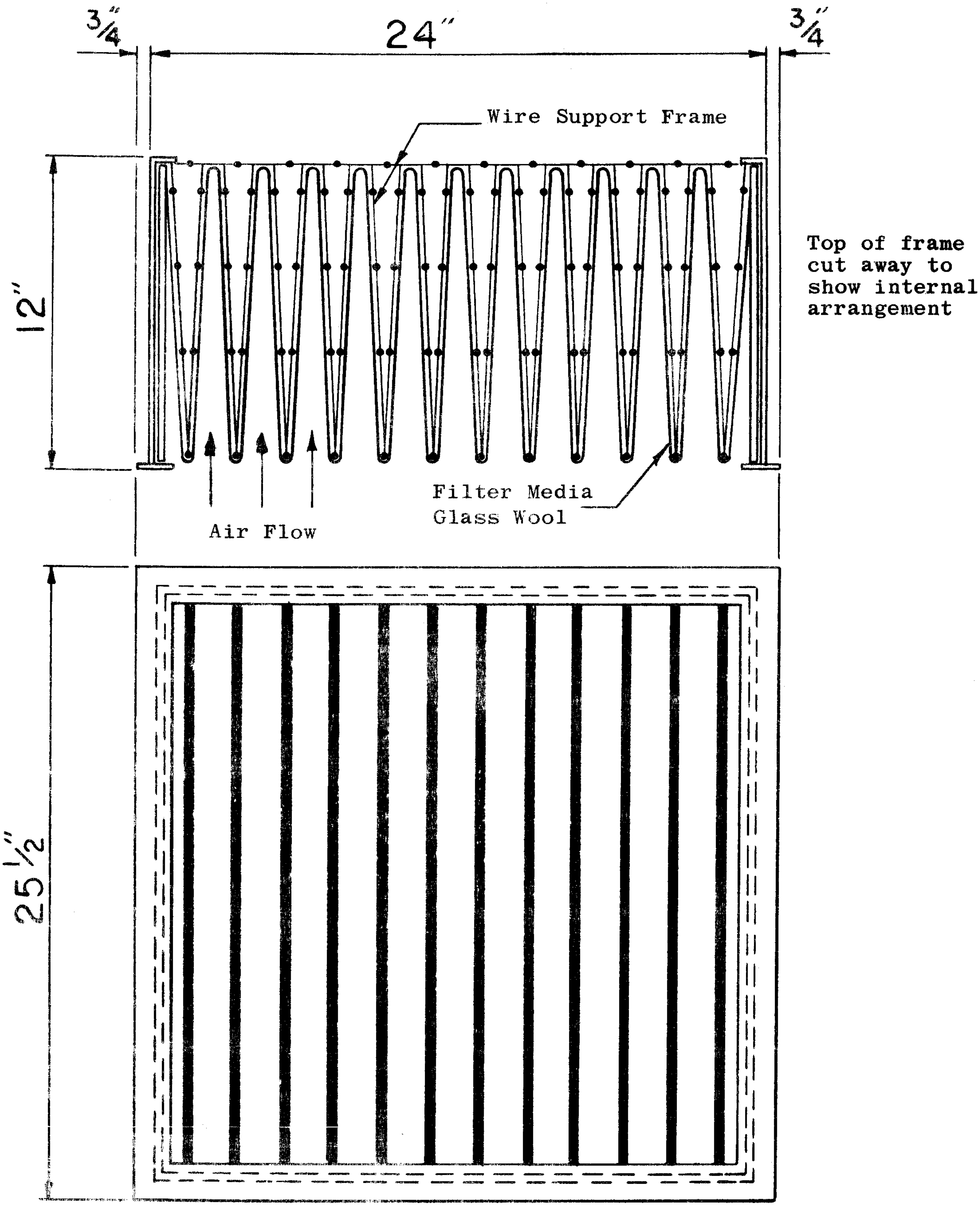


Figure 4-8. Absolute Filter

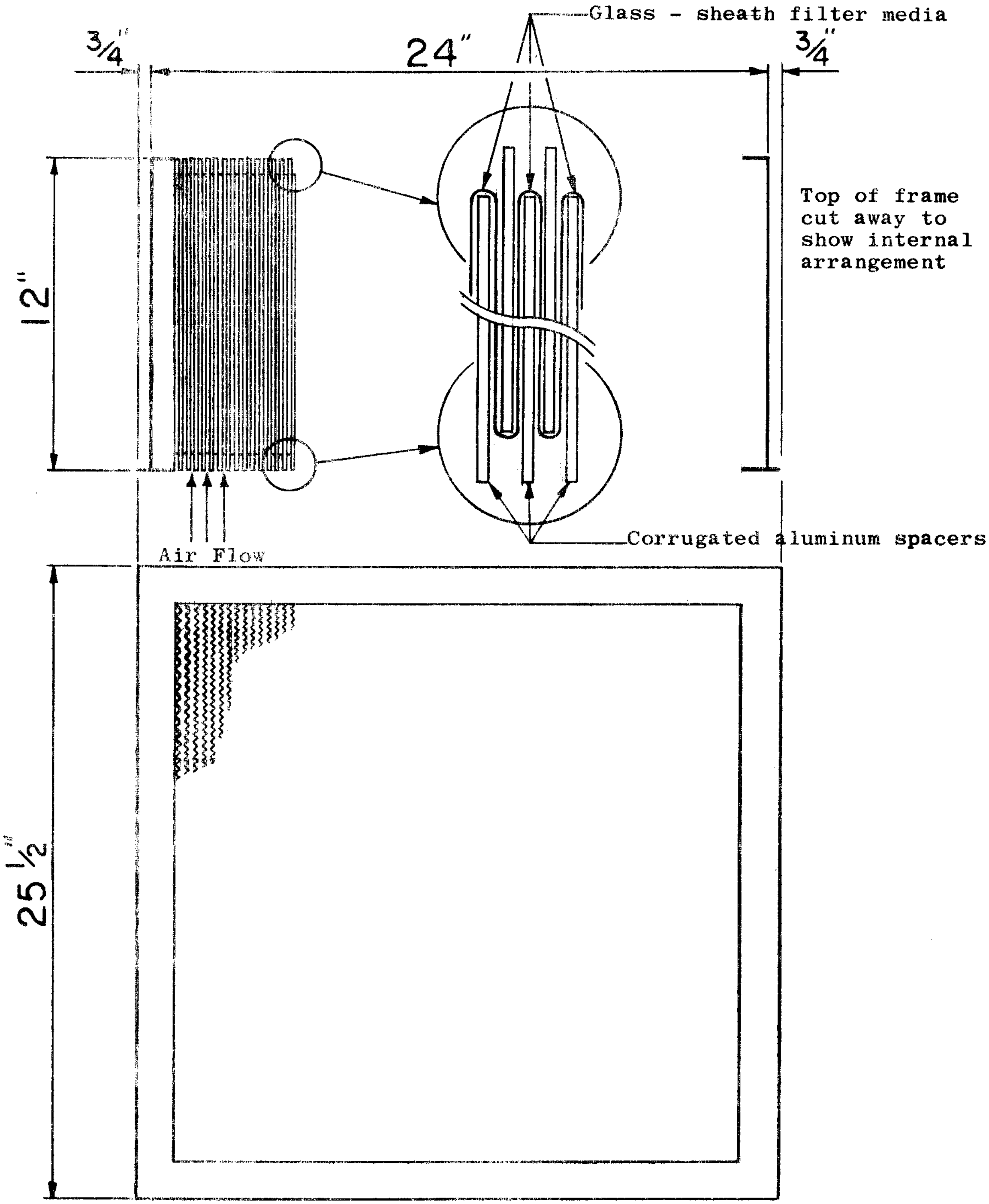
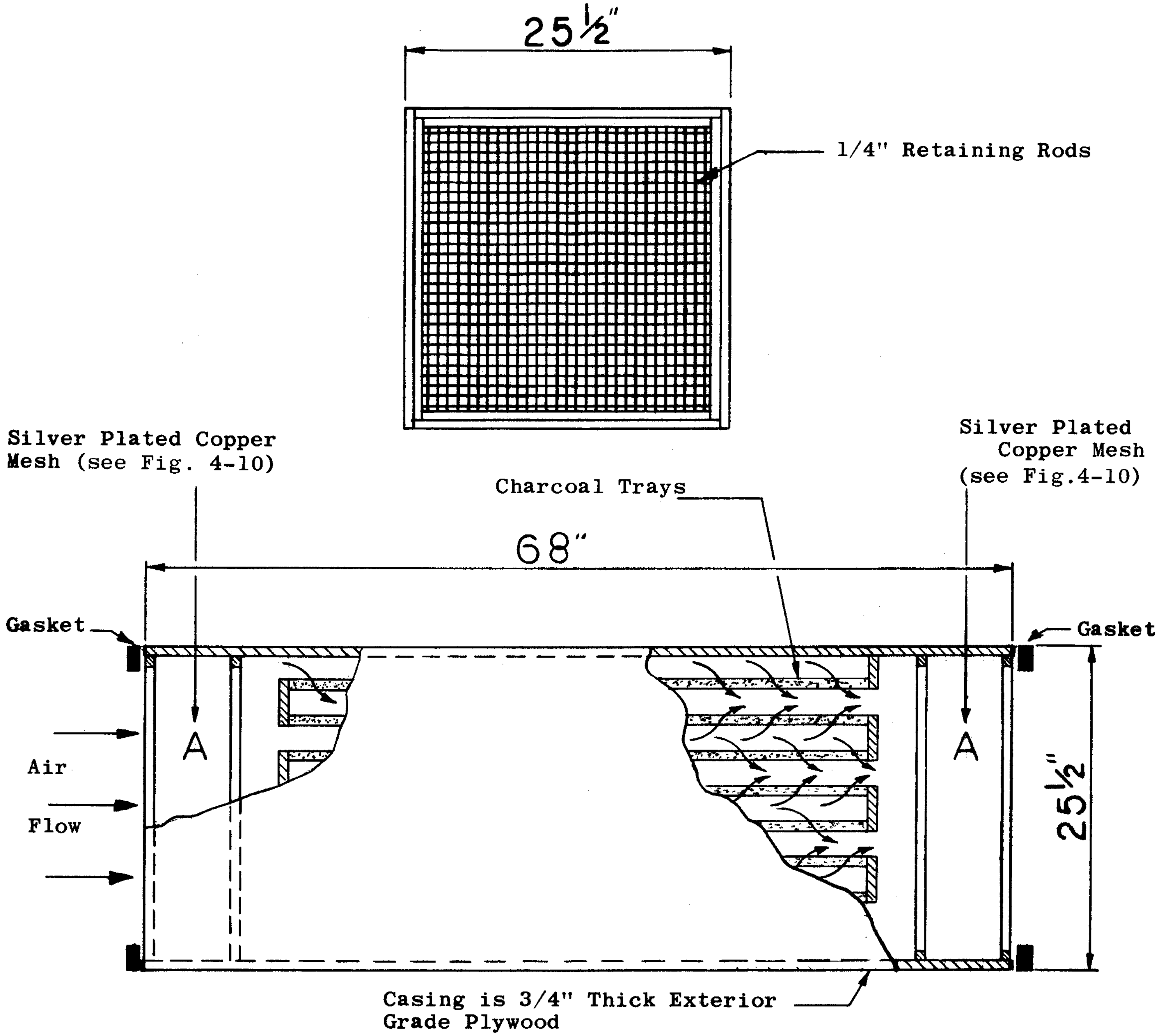


Figure 4-9. Iodine Adsorber Assembly



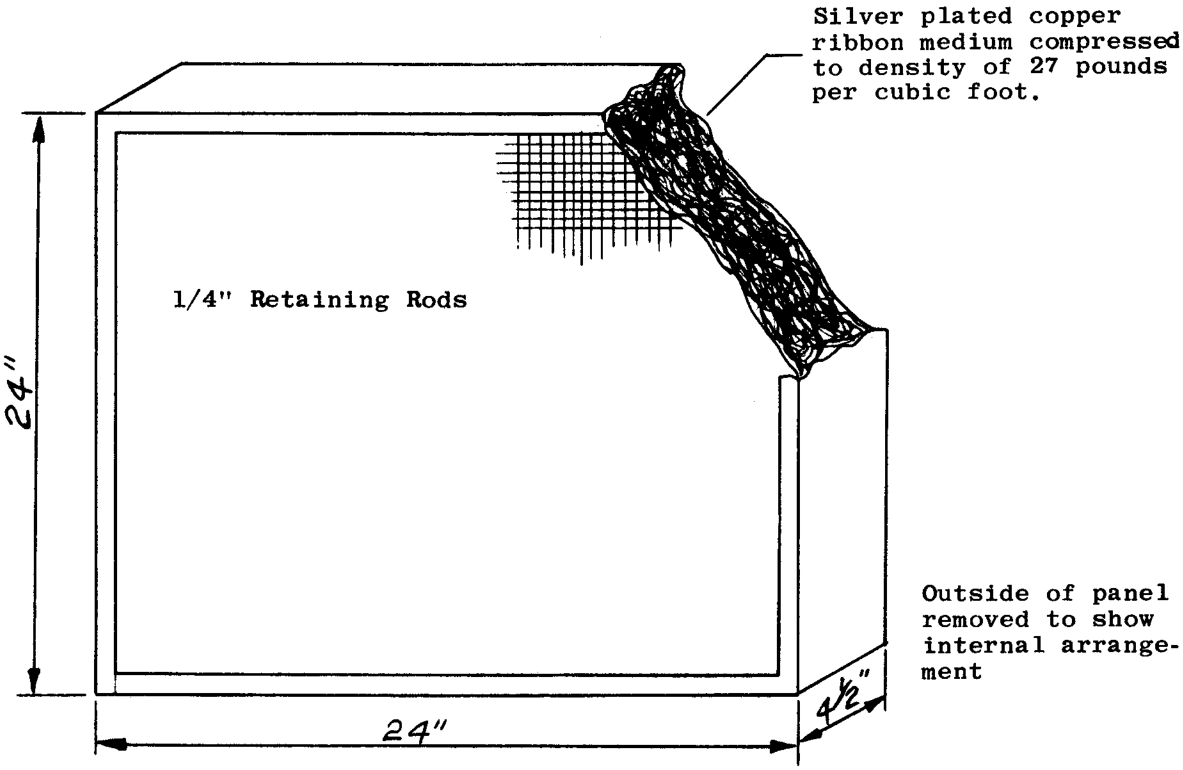
Notes:

1 - Each unit contains ten perforated metal trays enclosing granular activated charcoal.

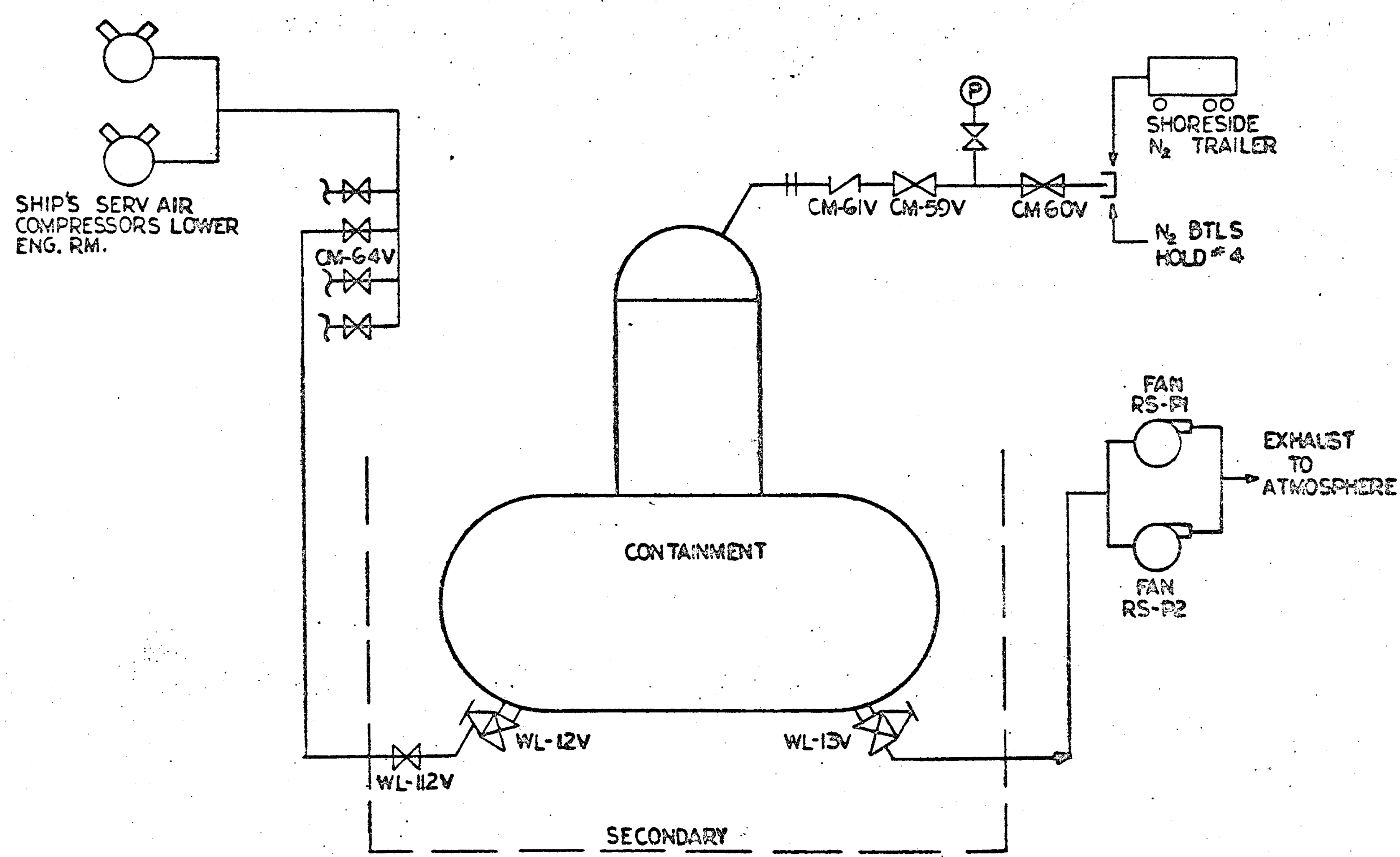
2 - Each tray contains 32 pounds of charcoal and operates at 0.90 inches to 1.1 inches W.G. pressure drop at 120 C.F.M.

3 - Total weight of charcoal - 320 pounds. Pressure drop of complete unit is 3.38 inches W.G. at 1000 C.F.M.

Figure 4-10. Iodine Adsorber Detail



Silver Plated Copper Mesh Element (A)



CONTAINMENT INERTING

FIG. 4.11