CHAPTER 3 – TABLE OF CONTENTS

List of Tables

List of Figures

3 DESIGN OF STRUCTURES, SYSTEMS, AND COMPONENTS

This chapter describes the architectural and engineering design criteria used for various structures, systems, and components (SSCs) of the NBSR. Only those SSCs considered important for ensuring the safe operation of the facility and for the protection of NIST personnel and the public from an exposure to a radiological release are included here. Detailed descriptions of most SSCs and their functions are deferred to the relevant chapters of this SAR, as summarized in Table 3.1.

3.1 Design Criteria

3.1.1 Design of Structures

The structures important to safe operation of the NBSR include the Confinement Building and associated structures within as well as attached to the building, the Liquid Waste Storage Facility and the Experimental Facilities. All these structures are part of the NIST Center for Neutron Research (NCNR) Facility located inside the NIST campus. These structures and the surrounding area are fenced and controlled, restricting access by the public and other NIST employees.

3.1.1.1 Confinement Building and Associated Structures

The Confinement Building, located in the C-Wing of the Building 235, houses both the Reactor Vessel and the Reactor Coolant Systems. It also encloses the Spent Fuel Storage Pool Facility, the D_2O Emergency Cooling Tank, and the D_2O Storage Tank. The Pump Room and the Ventilation Stack are located immediately north of the Confinement Building. The building has doors and elevators, and many electrical and mechanical penetrations, specifically for experimental facilities in the Guide Hall (G-Wing) located adjacent north to the Confinement Building.

It is not considered credible that any accident would lead to significant overpressure within the Confinement Building (Chapter 13). Therefore, the building is not designed as a steel containment vessel, but rather a confinement structure designed to meet the more normal building design requirements including structural-, wind- and snow-loadings. Internally, it is designed to take the large dead weight loads imposed by the Reactor Vessel itself and the heavy biological shields required for experiments.

Under normal conditions, the Confinement Building operates at a pressure slightly below that of the adjacent laboratory building and the outside environment. Each of the two access corridors from the laboratories to the Confinement Building is equipped with a set of double doors to facilitate control of the building's Ventilation Systems. A third door provides access to the Confinement Building elevator from the basement of the laboratory A-Wing. In addition, all three openings are equipped with motor-controlled doors and inflatable gaskets that close automatically, sealing the doors during emergencies. There are two other doors in the Confinement Building. One is a fire exit for emergency use only; it is sealed at all times, and if opened, it shuts and seals back automatically. The other is a large manually operated truck door that is normally sealed with inflatable gaskets, and will not be opened when the reactor is operating.

Although no overpressure is expected, and the underpressure during normal operation is nominal, it is possible that, under emergency conditions when the building is sealed, rapidly rising external atmospheric pressure might create an abnormally high external pressure across the building. The building is designed to accommodate this effect. In addition, the design incorporates a pressure relief valve (ACV-12) that prevents any pressure differential from developing across the building's walls and roof.

3.1.1.1.1 Emergency Provisions

The maximum hypothetical accident (MHA) is postulated to be the complete blockage of flow to a single fuel element assembly, leading to a complete melting of the fuel plates with the release of all fission products to the Primary Coolant System. As the fission products leak out of the Primary Coolant System, a major scram will occur as a result of high radiation levels. This major scram would start a chain of automatic events: the door gasket would seal and the shutoff valves would close, the normal ventilation system would be shut off, and the emergency ventilation system would start. The emergency ventilation system exhausts air from the Confinement Building through absolute filters (i.e., HEPA filters) and a charcoal filter, and then up the stack. A pressure differential sensor across the walls of the Confinement Building controls the operation of the emergency exhaust blowers. The system is designed to maintain the internal pressure at ¼ inch (0.6 cm) of water below atmospheric to assure that any leakage through the building walls is from the outside in. Thus, the average exhaust rate is determined by the leakage from the outside through the confinement walls to the inside.

The leak rate requirements for the building are governed, in principle, by the maximum exhaust rate that can be tolerated from an emergency situation. The building was designed to be as tight as practical with a conservative upper limit on the allowed in leakage rate set at 24 cubic feet per minute (cfm) for a pressure differential across the walls of one inch (2.5 cm) of water (0.27 $meter^3$ per minute per cm). This leak rate is several times smaller than the rate at which the building would have to be exhausted to keep up with a rapidly falling barometer. On the other hand, a rising barometer would require very little or no gas to be exhausted. While the emergency exhaust system is maintaining the proper differential pressure across the Confinement Building walls, a large 5,000 cfm (140 $meter^3$ per minute) internal recirculation system is filtering the building's atmosphere through absolute filters and a charcoal filter. In this way, the fission products in the air within the building are rapidly removed.

Thus, the Confinement Building is not designed to be an absolute containment vessel, but rather, to confine the results of an accident and to control the rate and location at which any fission products are released.

The only normal exclusion area in the Confinement Building is the Process Room that is locked at all times during reactor operations. During shutdown, only authorized personnel can enter this room. The fuel elements are transferred completely internally within the reactor's shielding.

3.1.1.1.3 Structural Design Loads

Structural parameters presented here were used in the structural design calculations, based on the information given in the Structural Design Calculations, Book III, Volume 1, 2 and 3, Burns and Roe Inc.

Internal Pressure

The maximum internal pressure applied to the NBSR Confinement Building structure is 7 to 8 inches (18 to 20 cm) of water that occurs during the building's leak test when the building is purposely sealed and pressurized by external fans. The building is designed to withstand this pressure, with the resulting stresses remaining well within the bounds of all applicable structural design codes delineated in American Concrete Institute (ACI), American Institute for Steel Construction (AISC), Pre-stressed Concrete Institute (PCI) and American Society for Testing and Materials (ASTM) codes and standards.

External loads

Wind, snow, earthquake, soil pressures, and hydrostatic pressures generate external loads on the NBSR Confinement Building. In accordance with good design practice, applicable structural design codes, and site meteorological data, the design wind load is 25 psf (1,200 N/m^2), i.e., approximately 100 mph (160 km/h), and the design snow load is 25 psf (1,200 N/m^2). The structure was designed to meet the Building Officials and Code Administrators (BOCA) Codes for the area, and the professional engineers who designed the building stated that it would withstand an intensity of VII to VIII earthquake (Geology, seismology and hydrology report of NBSR, September 1981). Soil pressure and hydrostatic pressures were calculated on the basis of the data that were obtained from analyzing the site's test borings. A soil pressure of 95 psf (4,550 N/m^2) was used for designing the structural walls, the storage pool, and the canal sidewalls.

Internal and Structural loads

The internal and structural loads in the NBSR Confinement Building result from the dead loads of the reactor proper, the building and reactor operational equipment, the structural components of the building itself, and the live loads of personnel, experimental equipment, and operational equipment. The dead load tabulation for the building structures, exclusive of the reactor is given in Table 3.2, and that for the reactor in Table 3.3. Table 3.4 has the live loads used in the design of the Confinement Building.

3.1.1.1.4 Building Structure Construction

The NBSR Confinement Building is a reinforced concrete structure on a driven steel pile foundation. Except for the main roof beams and eight 10-inch (25-cm) WF beams in the central column, all interior beams and columns were poured in place. The roof's beams are of Type IV pre-stressed steel reinforced concrete, as defined by the PCI Publication "Design Handbook: Precast and Prestressed Concrete."

Above the lower floor, the exterior walls or a large central column transmit all loads; the biological shield and sub pile room walls are an integral part of foundation. At the lower floor level, columns and shielding walls, 3 to 5 feet (1 to 1.5m) thick in most cases, give additional support far in excess of that needed for structural integrity.

Both structural and shielding requirements were considered in designing the exterior walls. The thickness, which resulted from these structural requirements, was far in excess of any shielding requirements and, therefore, the structural requirements were the controlling design parameters.

The roof of the building is designed for shielding from "sky shine," from snow loading, and from the differential pressure loadings that occur during the building's leak rate tests.

Foundation

The primary components of the foundation for the Confinement Building are 362 twelve-inch (30-cm) BP section steel piles at 74 pounds per linear foot (110 kg/m) (Federal specification QQ-S-741a, Type I or Type II, ASTM A7 or A373 with an aggregate length for 12,550 feet). Each pile is of 95 tons (86,000 kg) capacity, driven to refusal by a hammer with a minimum of 15,000 foot-pounds per blow. Refusal was defined as a maximum penetration of 0.25" (0.6 cm) in the last five blows. Control test piles were individually inspected under the supervision of a registered Professional Engineer and in the presence of the Construction Engineer representing the General Service Administration (GSA). The test required that the net settlement at the top of the test pile be not more than 0.005 inch per ton under twice the design load of 95 tons (86,000 kg), and that the increment of settlement for any increment of load shall not exceed 0.01 inch per ton until twice the design load was applied.

Storage Pool and Canal

The wall of the storage pool and canal was formed from sheet piling of the continuous interlock type steel, conforming to ASTM A-328. The reinforced concrete pool and canal walls are designed to tolerate a wet soil pressure of 95 psf (4,550 N/m^2) per foot below floor level and a hydrostatic head of 62.4 psf (3,000 N/m^2) per foot below floor level. The sheet piling was needed to protect the adjacent foundation areas during construction. When the pool is filled, the internal and external pressures partially cancel each other. For dry soil, where the pressure is 65 psf, the walls are essentially unloaded.

Building Leak Proofing

In addition to the normal design features for preventing inward leakage from ground water, and rain, the NBSR Confinement Building was designed to prevent the outward leakage of radioactive materials.

Waterproofing the building is an essential element in leak proofing. A five-ply membrane waterproofing system consisting of five layers of fabric and six layers of pitch covers all exterior basement walls of the building and extends continuously under all basement foundations to form a complete seal. The waterproofing on outside walls that are exposed to damage by back fill is covered by ½ inch (1.3 cm) thick insulating fiberboard (Federal Specification LLL-I-535). All horizontal portions of the waterproofing, except those under concrete slabs, are covered with a ¾ inch (1.9 cm) thick (minimum) layer of Portland cement mortar. Horizontal surfaces of the waterproofing under concrete slabs are protected by 1 inch (2.5 cm) of concrete.

All construction joints, including the roof slab to wall joints, have in them a 6 inch x 3/16 inch (15 cm x 0.5 cm) bulbed polyvinyl-chloride water stop. Water stops located in expansion joints have a strength of not less than 1800 psi (12.4 MPa) and an elongation of not less than 350% when tested in accordance with ASTM D-412, and a cold-bend brittle temperature of not higher than -20ºF (-29ºC) when tested in accordance with ASTM D-746.

Preparing and coating the surface of the building's wall was a major facet of the design and construction techniques used to assure a leak-tight building. All walls received the following elastomeric coatings: rust inhibitive primer for ferrous metal surfaces; polychloroprene primer for concrete and concrete-masonry unit surfaces; fabric reinforcing sheet and polychloroprene sheet for sealing strips and cracks; polychloroprene adhesive for polychloroprene sheet; polychloroprene body coats for all surfaces; and, chlorosulfonated top coating for all surfaces. The body coats were applied in alternate black and red coats to verify complete coverage with each coat. Any point in the surfacing system that showed pinholes, blisters, or other discontinuities was removed down to the body coats and recoated.

This coating system ensured a continuous15 to 20 mil (4 to 5 micron) elastomeric membrane over all containment surfaces, effectively closing any porosity of the masonry structure.

Standards of Materials

The pertinent parts of the GSA Specification for this project (Project No. 18112) are discussed here. This specification covers most of the materials used in the Confinement Building.

Reinforcing steel specified for the NBSR building conformed to Federal Specification QQ-S-632, Type II, and intermediate grade billet steel with deformation conforming to ASTM specification A-305, and a design tensile strength of 20,000 psi (138 MN/m^2). All field splices in reinforcing steel were lapped a minimum of 30 bar diameters. All dowels were embedded in concrete for a minimum of 30 bar diameters.

Coarse aggregate for concrete was specified to Federal Specification SS-A-281b, class 2 or C-33, sized in accordance with ACI-613, Table 2. Portland cement was specified to Federal Specification SS-C-192d or C-150. All structural concrete had specified 28-day compression strength of 3,000 psi (21 MN/m^2). The proportion of cement, aggregate, and water was determined according to ACI-318, Method 2 as modified. The measuring, mixing, and delivering of ready mixed concrete with inspection and certification followed the ASTM C-94 requirements. Slump samples were taken in accordance with ASTM C-172 and tested under direction of the Construction Engineer in accordance with ASTM C-143. Slump was required to be within the recommended limits of ACI-613, Table I. Samples taken for strength tests showed that, in all cases, the specified strength was met or exceeded.

3.1.1.1.5 Penetrations

Tables 3.5 and 3.6, respectively, set out the purpose, number, size, and type of the Confinement Building penetrations for electrical conduits, piping and other mechanical components.

Penetration design details

Each penetration must meet two distinct sealing criteria; first, the sealing of the penetrating member to the concrete walls of the building, and second, the internal sealing of any leak paths through the penetrating member.

Exterior Seals

All pipe, conduit and tubing are sealed to the building as shown in Figure 3.6. The penetration number and the flange that is welded to it are inserted in the concrete. The outer surface of the flange is flush with the finished inside surface of the concrete. The joint between the flange and the concrete surface is then caulked and sealed with fiber-reinforced neoprene. Finally, the entire outer surface of the penetration is coated with the neoprene hypalon system described in building leak proofing in the Section 3.1.1.1.4.

Doorframes and air-system plena are sealed to the building as shown in Figures 3.7 and 3.8, respectively, and noted in Table 3.6 as “D” and “C”. Steel plates with continuously welded joints were invested in the concrete and the frames or plena were, in turn, fixed to those plates with continuous welds. All exposed welds were then caulked with a hypalon caulking compound, and coated with the neoprene-hypalon system described in the previous Section. All voids in the doorframes were filled with closed-cell urethane, which was foamed into place.

Interior Seals

All electrical penetrations were sealed internally to the building as shown in Figure 3.9. After all conductors were in place, a sealing compound (CHICOX Fiber A05, Crouse-Hinds Company, Syracuse, New York) was poured in to the sealing box under sufficient hydrostatic head to force it into all voids between the conductors and the conduit’s inner walls.

Rubber-seated butterfly valves or dampers seal all the ducts and waste lines internally. All these devices were specified and tested to bubble-tight specifications.

All cryogenic service penetrations are sealed with the same closed-cell urethane material that was used in the doorframes. This material is foamed in place to assure that the voids between the pipes that pass through this penetration are completely filled, and that there is intimate contact with an air-curing silicon rubber compound (Dow Corning RTV102) which is carried up onto the surface of the pipes to form a minimum radius of ¼ inch (0.6 cm).

All access and exit doors are sealed to their frames by inflatable rubber gaskets, as shown in Figure 3.7. Whenever these doors are automatically closed in an emergency, an internal seal pressure of approximately 20 psi (0.14 MPa) inflates the gasket and forms a sealing surface approximately an inch (2.5 cm) wide around the entire perimeter of the door. The large truck door is mechanically restrained to prevent it from being pushed away from the seal when the gasket is inflated.

<u>Inspection of Penetrations</u>

All new building penetrations are inspected independently of the leakage rate tests as part of the normal maintenance of the building and systems.

3.1.1.1 Other Structures

<u>Liquid Waste Collection Facility</u>

The Liquid Waste Collection Facility is located in underground vaults in front of the Building 235 and collects light water from selected drains in the laboratory wings and the Confinement Building. This facility consists of a 1,000-gallon (3,800-liter) tank, two 5,000-gallon (18,900-liter) tanks, various filters, and related pumps and valves. Water collected is sampled and analyzed for its radioactive constituents and then filtered prior to release to the sanitary sewer. Credit is taken for the daily NIST site release volume of approximately 260,000 gallons (984,100 liters) to meet the concentration limits.

<u>Experimental Facilities</u>

The experimental facilities built into the NBSR include beam tubes, the cold neutron source, thermal column, pneumatic tube system, and vertical thimbles. Eleven positions are available within the core structure itself for the insertion of experiments and seven positions are available in the reflector. Nine beam tubes are arranged in a radial pattern within the central plane of the core and see the unfueled gap region neutron flux. Two beam tubes run completely through the reactor on either side of the core just below the radial tubes. The reactor includes a large experimental thimble within which a low temperature liquid hydrogen moderator or cold source is installed. This moderator increases the intensity of long wavelength (i.e. "cold") neutrons available to the beams from this neutron source. Seven neutron guide tubes, which transport cold neutron beams with losses of less than 1% per meter into an adjacent neutron experimental building or neutron Guide Hall, and one beam port (which does not go to the Guide Hall) are served by this source. Five pneumatic tubes make up the "rabbit" system, which operates on CO_2. This system allows the rapid insertion and removal of small samples into various parts of the core, reflector, and thermal column. A large volume of well-thermalized neutrons is also available in the graphite thermal column.

3.1.1.3 Provisions to Avoid or Mitigate Consequences of Fire and Explosion

The Confinement Building and most structures therein are built of steel and concrete and/or aluminum and are highly fire-resistant. In addition, the following features reduce both the likelihood and consequences of a fire:

1) The reactor is fail-safe and would shut down if fire should damage its protection system.
2) The large volume of water in the reactor vessel would protect the core from a fire.
3) Inventories of flammable materials (e.g., paper, wood, solvents.) in the building are controlled and minimized for industrial safety. With the assistance of trained personnel, non-essential combustible materials are identified and removed.
4) There are fire detection and alarm systems throughout the building. Pull boxes within the building provide for manual notification. The building is equipped with fire extinguishers.
5) Closed circuit cameras survey certain areas from the control room.

3.1.2 Design of Systems

The systems important to safe operation of the NBSR include the Reactor Control System, Reactor Coolant Systems (specifically the Primary Coolant System), the Reactor Protection System, the Engineered Safety Feature (ESF) Systems and their actuation systems, the Instrument Air System, the Electrical Distribution System, and the Liquid Waste System. In addition to the Confinement Building discussed in the previous section, the ESF systems include the Ventilation System for the Confinement Building and the Emergency Cooling System. The Reactor Coolant Systems includes the Primary Coolant System, the Secondary Coolant System, the Primary Coolant Purification System, and the D_2O Experimental Cooling System.

All mechanical, electrical, and instrumentation & control (I&C) systems were designed and constructed in accordance with the standards and codes at the time of their installation at the NBSR. All piping and pipe supports were designed, purchased, fabricated and installed in accordance with the standards prevalent at the time of their purchase (1963 thru 1966), e.g. American Standards Association (ASA); American Welding Society (AWS); American Standards for Testing Materials (ASTM).

For all interior electrical work including, cables, cable trays, electrical power and control equipment, instrumentation, grounding and communication systems is designed and installed per: American Institute of Electrical Engineers (AIEE); National Board of Fire Underwriters (NBFU); National Electrical Code (NAC, NBFU No. 70); National Electrical Manufacturers Association (NEMA); Edition Electric Institute (EEI); Insulated Power Cable Engineers Association (IPCEA); American Standards Association (ASA); American Society for Testing Materials(ASTM); National Electrical Safety Code; National Fire Protection Association's (NFPA's) "Code for Protection Against Lightning;" and, the rules and regulations of the local utility companies.

The original plant specification did not address seismic requirements for cable trays. However, the cable tray loading is limited to 40 lbs. per foot (60 kg/m) for a 24-inch (61-cm) wide tray, with supports a maximum of 6 feet (1.8 m) apart center to center. A fully loaded tray has a maximum mid point deflection of 0.25 inch (0.6 cm).

Main power input transformers, the feeder switchgear, and MCC A-1 are in the basement of the A-Wing of Building 235 (also referred to as the B-2 Level). MCC A-2 is in the fan room (B-200) for the B-Wing. MCC A-3, MCC B-4, and MCC D-C are located in the basement of the Confinement Building (also referred to as the B-3 Level). MCC A-5 and MCC B-6 are on the Reactor Mezzanine in the Confinement Building (also referred to as the B-1 Level). MCC A-7 and MCC B-8 are in the second floor of the Pump Room (D-200). These systems were installed in accordance with the NEC, AIEE, and NEMA standards of the time (1963 thru 1966).

3.1.2.1 Reactor Control System

The NBSR has four semaphore-type shim safety arms and one regulating rod. The four shim safety arms are identical; each is 1-inch (2.5 cm) thick by 5-inches (12.7 cm) wide by 52 inches (132 cm) poisoned length. The hollow interior is filled with helium, and the 0.040-inch (1 mm) thick cadmium poison is clad with aluminum both inside and outside. The arms are mounted on hanger brackets just under the upper grid plate. The drive shafts that penetrate the reactor vessel below water level drive the shim arms directly. The vessel penetrations are sealed with rotating seals and the drive mechanisms are mounted in recesses in the biological shield. Each arm has its own drive mechanism and clutch, but they can be inserted as a bank. The maximum withdrawal rate for one shim arm or the whole bank of four is the same, 0.04 degrees per second.

The criterion is that on receipt of a scram signal, all four shim safety arm clutches are de-energized and the corresponding shim safety arm is inserted into the core. The shutdown-margin criterion assumes that the most reactive of the four shim safety arms fails to insert.

The regulating rod consists of a solid aluminum cylinder, 2½ inch (6.4 cm) in diameter by 29 inch (74 cm) long. It is located in one of the 3½-inch (9 cm) vertical thimbles directly in the core. The vertical drive mechanism, a standard commercial design, is mounted in the top plug.

In the event of a difficulty in inserting any of the shim safety arms, provision is made for lowering of the top reflector to a level just above the top of the core. Reactivity calculations show the top reflector's worth is sufficient to shut down the reactor (Chapter 4, Section

4.5.1.3.3). The criterion is that on receipt of a manual signal, the reflector be dumped, thereby inserting sufficient negative reactivity to shut the reactor down.

3.1.2.2 Primary Coolant System

The Primary Coolant System (PCS) is designed to transfer 20 MW of heat from the core to the Secondary Coolant System while operating at a nominal flow of 9,000 gpm (34,000 lpm) with a reactor inlet temperature of 100°F (38°C) and an outlet temperature of 114°F (46°C). A maximum pressure of approximately 65 psig (0.5 MPa) occurs at the D_2O Main Circulating Pump discharge. The piping and fittings of the system are designed for 125 psig (0.9 MPa) and temperature of 150ºF (65°C). The heat exchangers are designed for 150 psig (1 MPa) at 200ºF (93°C). The piping system was hydro-tested for 1.5 times the design pressure of 125 psig (0.9 MPa), i.e., for 187.5 psig (1.3 MPa).

Figure 3.10 shows the PCS that circulates heavy water through the reactor. Figure 3.11 shows the PCS integrated with other heavy-water systems.

Table 3.7 summarizes the materials specifications and design information. The table includes the design pressures, materials of construction, and ratings for the components of the primary coolant system and associated components including the Reactor Vessel.

The Main Heat Exchangers (HE-1A, 1B, 1C) and D_2O Purification Heat Exchanger (HE-2)

The Main Heat Exchangers and D_2O Purification Heat Exchanger are plate and frame type, single-pass, counter-flow heat exchangers. They are made up of cold pressed 316 type stainless steel plates peripherally welded to form cassettes. These cassettes are assembled together by nitrile gaskets and compressed between heavy carbon steel frame plates by tightening bolts. These plates are aligned by an upper carrying bar and lower guide bar. Heavy water flows through the cassettes' cavities and secondary light water flows outside them, where gaskets are installed. These heat exchangers were tested hydrostatically at 225 psig (1.6 MPa).

D_2O Main Circulating Pumps

The D_2O Main Circulating Pumps (DP-1, 2, 3, 4) are single-stage, centrifugal type, constructed from stainless steel. They are designed to supply 3,100 gpm (11,700 lpm) at 116 feet (35m) of total head, and are remotely operated from the control room. D_2O Shutdown Pumps (DP-5 and 6) are also stainless steel, single-stage, and centrifugal type pumps. They are designed to supply 800 gpm (3,000 lpm) at 24 feet (7m) of total head.

Piping and Valves

The primary system piping and fittings are made of 6061-T6 aluminum. All welds were made and radiographed by certified welders; all were accepted by American Society of Mechanical Engineers (ASME) standards. Most valves in this system are diaphragm type with hypalon diaphragms. Control valves are either air or electrically operated and are remotely controlled from the control room. A relief valve is installed on the reactor's outlet piping to prevent overpressurization of the primary system. This valve can pass 202 gpm (765 lpm) at a set pressure of 50 psig (0.35 MPa), while limiting the system pressure to an increase of no more than 10% above the set value. Annually, this valve is tested as a Technical Specification 4.2 requirement. The heat-exchanger isolation valves are fugitive-emission-controlled butterfly valves 316 type stainless steel.

Necessary instrumentation is installed for remote read-out of the reactor inlet flow to each plenum, its outlet flow, ΔT, vessel level, overflow, and primary-to-secondary ΔP in the main heat exchangers. Pressure is measured at various points in the system, generally by local gauges, which do not give read-out in the control room. Electrical power for the instruments comes from the instrument power bus located in the main control panel.

3.1.2.3 Engineered Safety Feature Systems

The Engineered Safety Feature (ESF) systems include the Emergency Cooling System, and the Confinement Building and its Ventilation Systems. The design of the Emergency Cooling System involves the Reactor Vessel components discussed in Section 3.1.3.1, the D_2O Emergency Cooling Tank and associated piping and valves and their controls (see Section 3.1.3.2).

The Confinement Building housing the reactor is designed to confine any radioactive material released in an accident so that it may be exhausted in a controlled manner through an emergency ventilation system that filters out the radioactive materials before the air is exhausted up the stack to the environment. Consequently, the building does not have to be as leak-tight as a total containment building. However, it is designed to be as tight as possible with a conservative upper limit on the allowed leak rate of 24 cfm with a pressure differential across the walls of 1 inch of water (0.27 meter^3 per minute per cm).

Redundant detectors in the normal ventilation system detect any release of radioactive material into the confinement system and initiate closure of the building. The sliding steel doors are closed automatically and sealed by inflatable gaskets, and all normal ventilation ducts are sealed shut to isolate the confinement building. The emergency ventilation fan is automatically started and maintains the building at a negative internal pressure differential across the wall of about 0.25 inch (0.6 cm) of water, so that any leakage is into the building. At the same time, a large internal clean-up system of 5,000 cfm (140 meter^3 per minute) capacity can be activated to circulate air within the building through filters to clean it up and minimize the release of radioactive iodine to the environment.

Figure 3.12 is a flow diagram of the Confinement Building ventilation systems. The figure shows both the normal and emergency systems, as well as the system for testing the leak rate. The Confinement Building is air-conditioned with air that is partially recirculated except for the process equipment area of the reactor basement, which is separately heated and ventilated. All ventilation ductwork that penetrates the building has automatically sealing closure valves. The building, with a volume of approximately 600,000 cubic feet (19,300 meter^3), was designed and constructed for minimum air leakage. Details of both normal and emergency ventilation systems are discussed in Chapter 6.

<u>Emergency Conditions Assessment</u>

Under emergency conditions, the normal intake of fresh air and the normal recirculation of internal air stops, and the emergency systems start automatically. There are two emergency systems: one exhausts air from the building through activated carbon filters and up the stack; the other recirculates the air internally through activated carbon filters. The first system controls leakage into the building by automatically maintaining a negative pressure differential across the building wall of one quarter inch of water. The second system recirculates the air within the building through filters, removing radioactive contaminants.

The emergency exhaust system uses the normal exhaust system's ductwork. Air is withdrawn from four separate regions at rates proportional to the volume of space they occupy. The four regions are noted below with the percentage of the total exhaust from each of them.

Second Floor (above grade)	40
First Floor (grade level)	20
Process Room (below grade)	15
Pool Area (below grade)	25

The air from all these regions passes through a common duct, filter, and fan system before entering the stack.

The recirculation system is designed to clean up the reactor building air from all regions with an effective two-hour time constant. It also thoroughly mixes the gases from all regions at approximately the same rate.

In general, the delivery and exhaust ducts were located to satisfy two functions: the delivery and exhaust with good mixing of internal air under normal conditions of high flow, and the exhaust of containment air under emergency conditions of low flow. Also, in general, the exhaust registers were positioned away from any conceivable break in the Primary Coolant System from which released fission product gases could emanate.

A break in the inlet or outlet plenum piping is analyzed and discussed in Section 13.2.3.

The ventilation system under emergency conditions is fully automatic and highly redundant. In addition, there is an emergency control and monitoring station outside the Confinement Building. This station has controls for all fans in the emergency system, namely EF-2, SF-19, EF-5, and EF-6 (both AC and DC controls for the latter two fans), and has position indicators for all automatic confinement valves, ACV-1 through ACV-12. The building differential pressure can be observed at this panel and an indicator shows when exhaust air flows from the emergency exhaust system. Finally, there are two radiation monitors that indicate at this panel to show radiation levels within the reactor building. They are discussed fully in Chapter 7.

3.1.2.4 Reactor Protection System

The reactor protection system consists of both nuclear and process safety systems. The NBSR nuclear safety system consists of seven independent channels, two for source-range, two for intermediate range, and three for power range. There is also a nuclear control channel; however, it does not have any safety functions.

The reactor is protected by the rapid insertion of the shim safety arms to immediately shut it down. There is also a shim arm withdraw-prohibit function and a shim safety arm rundown function, and, while they are important, they are not considered part of the reactor protection system.

The source range nuclear instrumentation channels are used only when the reactor flux level is too low for the intermediate range channels to measure, which occurs only after long shutdown periods (greater than 6 months). The source range channels measure the rate of change of flux in the reactor and cause a withdraw-prohibit if the period is too short on either channel.

The intermediate range channels also measure the reactor flux and period, causing a withdraw-prohibit, rundown, or scram, if the period is too small on either channel. The intermediate-range scrams are bypassed once the power level is greater than 10%.

The three power range channels monitor reactor power from 0 to 150%. They generate a rundown or scram if power is too high. Two of the three power channels must be high to cause a rundown condition. The scram logic is switch-selectable to allow the operator to choose whether one or two channels are required to cause a scram.

The NBSR process safety system monitors various reactor parameters, such as flow, level, and temperature and causes a scram if any of these values fall outside acceptable limits. Any single parameter outside its limit triggers a reactor scram. Numerous power supply voltages are also monitored and cause a scram if the power supply fails. Table 3.8 gives the surveillance frequencies for the above instruments.

3.1.2.4.1 Redundancy and Diversity

The design of all of the nuclear channels is similar. They consist of a detector outside the reactor core, a high-voltage power supply, amplifiers, indicators, and bistable outputs. Each channel is completely independent. Two source range, two intermediate range and three power range channels provide redundancy. The intermediate range and power range each can shut down the reactor. The detectors are spaced around the reactor, minimizing the possibility of a common mode failure and providing accurate representative indication of reactor power.

The process safety systems are also redundant and diverse. There are two scram busses, either one of which can cause a reactor scram. Each bus receives an input from at least one unique temperature, flow, and level signal that can trigger a scram. Monitoring different processes, such as temperature, level, and flow, provides an acceptable level of diversity. The system is designed such that a single failure of any active component will not prevent a shutdown.

The plant was designed prior to the IEEE standard on reactor protection; however, the plant was built in accordance with the latest electrical standards available at the time of construction. Since original construction NIST has incorporated separation of similar systems and components where possible.

3.1.2.5 Electrical Distribution System

The Electrical Distribution System is designed to supply all of the electrical power necessary to operate the NBSR during both normal and emergency conditions. This includes all of the experiments, offices and other support spaces associated with the reactor. Electrical power is supplied to the NBSR by three independent, underground, 13.8kV primary feeders. Each primary feeder is connected to a separate 13.8kV/480V distribution transformer. The secondary of each transformer provides power to one of three specific sections of the main 480V switchgear buses (SSA, SSB and SSC). Other major components of the electrical distribution system include two Emergency Diesel Generators, a station battery, two uninterruptible power supplies (UPS), transformers, and associated distribution equipment. The redundancy of vital loads and the protective scheme of the breakers in the Electrical Distribution System prevent any single equipment failure from causing a total loss of power for the entire building. As described in Chapter 8, the electrical distribution system consists of three major sub-systems: the Facility (or Building Services) Distribution System, the Reactor Distribution System and the Emergency Distribution System.

3.1.2.6 Instrument Air System

The NBSR is supplied with a source of 100 psig (680 kPa) air from the main NIST compressed air facility. Multiple air driers, dehumidifiers and filters at this facility ensure the air is clean and dry. This system uses air receiver tanks to supply necessary loads in case the air compressor is lost. The system also supplies the service air connections for air-operated tools. A pressure switch monitors the air pressure in this system at the supply pipe coming into the building. If this air supply is lost, air can be supplied by either of two standby electrically powered air compressors located in the cold lab basement (A-Wing). These air compressors are powered from the diesel-backed emergency power buses. One compressor is powered from MCC B-6, and the other is powered from MCC A-5. A standby compressor will automatically start when the system pressure drops to 90 psi (612 kPa). At 80 psi (544 kPa), the second standby compressor starts.

3.1.2.7 Liquid Waste System

All potentially contaminated liquid waste drains (from the reactor building's sump and hot- and warm-laboratories drains) lead into the three-minute delay holdup tank which discharges liquid waste into the 1,000 gallon (3,800 liters) tank, as shown in Figure 3.13. When the level in this tank reaches approximately 600 gallons (2,270 liters), it automatically starts discharging into one of the two 5,000 gallon (18,900 liters) tanks. A high level in either of these tanks (approximately 3,200 gallons (12,000 liters)) is indicated in the Health Physics office and in the control room. Before samples are taken from either of these tanks, the contents are sparged by blowing compressed air into them, for 30 minutes for routine releases, or for 5 minutes after a Health Physics alarm. All tanks, process equipment, and instrumentation are installed in an underground vault in front of Building 235.

The waste sample is analyzed for the activity of gross alpha, and tritium, and a release status determined. If the levels are at or below the applicable limits (NBSR 9, Addendum 1, page 2-18 and 2-19) the liquid waste can be released. It is discharged at the rate of 25 to 45 gpm (95 to 170 lpm) through the bank of bag filters into the lime stone pit and ultimately, to the sanitary sewer. If the levels are above the applicable limits, further analysis is required together with the approval of the Senior Health Physicist before it is released. An additional bank of bag filters and an optional Ion Exchange (IX) column is provided in the system for lowering radioactivity in the liquid effluent, if needed. Solid contents are collected in the filter bags and along with the bags are disposed of as solid radioactive waste.

The criterion for the liquid-waste discharge is that the liquid effluent cannot be released at concentrations in excess of 10 CFR 20 values.

3.1.3 Design of Major Components

This section discusses the design considerations for the Reactor Vessel and its core. All mechanical, electrical and I&C components used in various systems described in the previous section were procured and installed in accordance with the industry standards and codes at the time of their installation.

3.1.3.1 Reactor Vessel and Its Core

Figures 3.14 and 3.15 show the reactor elevation and plan view, respectively. The reactor vessel is an aluminum tank 7 feet (2 m) in diameter and 16 feet (5m) high with an elliptical cap at the bottom and a flange at the top. The core is contained in the reactor vessel where fuel elements are located on 7-inch (18-cm) centers in a hexagonal array, which makes the NBSR a well-thermalized reactor. Many in-core experiments can be introduced in addition to the beam tubes and thimbles located in the reflector.

The vessel is supported from the top flange that rests on the shim ring of the cylindrical thermal shield surrounding the vessel. A nominal gap of one inch (2.5 cm) is maintained between the reactor vessel and the thermal shield. The outer top plug assembly rests on the vessel flange, and thus, clamps the flange between itself and the thermal-shield shim ring; the outer plug assembly and the vessel flange also are independently fastened to it. A stainless steel “O” ring gasket forms a seal against the leakage of helium or heavy water at the interface of the reflector’s top plug assembly and the reactor vessel flange (upper face). A second stainless steel “O” ring gasket forms a seal against leakage of carbon dioxide at the interface of the reactor vessel flange (lower face) and the shim ring of the thermal shield.

The reactor vessel flange is clamped between the top shim ring of the lead-lined steel cylinder and the Reactor Top Plug Assembly with twenty-four 1 inch (2.5 cm) diameter bolts. An independent attachment of the flange to the top shim ring of the lead-lined steel cylinder is accomplished with twenty-four ¾ inch (2 cm) bolts.

The reactor vessel is designed and installed in strict conformance with the following Codes, Standards, Specifications and regulations:

- American Society of Mechanical Engineers (ASME), Boiler and Pressure Vessel Code (B&PVC), Section VIII.
- ASME Code Cases 1270N and 1273N.
- American Standards Association (ASA).
- American Society for Testing Materials (ASTM).
- Aluminum Association (AA).
- American Welding Society (AWS).

Two grid plates, 62 inches (157 cm) apart, support the fuel elements. The top of the lower grid plate is 9 inches (23 cm) below the bottom of the core, and the bottom of the top grid plate is 24 inches (61 cm) above the top of the core. The fuel elements are kept in place against the upward water flow by a locking mechanism held down by the upper grid plate. The side reflector is 20 inches (51 cm) thick, while the thickness of the top reflector is determined by a 3 inch (7.6 cm) diameter overflow pipe that maintains water level at 118 inches (300 cm) above the top of the core. This large space above the core allows fuel elements to be moved into the fuel element transfer chute.

An emergency dump line, concentric with the fuel-element transfer chute, can be used to drop the water level to 1 inch (2.5 cm) above the core. Another low-level overflow concentric with a 3 inch (7.6 cm) overflow pipe is sited at the elevation of the upper grid plate. This overflow is used whenever fuel elements are being transferred in a helium atmosphere (low-water level) rather than underwater.

Core Array

The grid plates provide locations for 37 fuel-element positions and four, 2½ inch (6.3 cm), semi-permanent irradiation thimbles. Figure 3.15 shows the normal configuration of the core. Seven of the fuel positions are especially adapted for 3½ inch (9 cm) experimental thimbles and the remaining 30 positions are for normal fuel elements. With the normal loading of 30 fuel elements, each of the seven experimental thimbles is surrounded by 6 fuel elements. However, only six of the seven experimental positions are available for in-core irradiation, since the seventh is used for a regulating rod.

Experimental Facilities in the Reflector

Chapter 10 describes the experimental facilities in detail. Here, the location of the main facilities is pointed out. All the radial beam ports are located in the central plane of the reactor and look at the section of the core that does not contain fuel. The large beam tube contains the liquid hydrogen cold source. Two through tubes pass below the radial beam tubes at the bottom of the lower core. The reflector also contains four rabbit tubes and positions for installing up to seven vertical thimbles.

Reactor Control

Four shim safety arms of the semaphore type (Figure 3.16) and one regulating rod control the reactor. As shown in Figure 3.15, the safety arms are located just below the upper grid plate. Their poison segment is 0.040-inch (1-mm) thick cadmium-clad aluminum. The shim safety arms are fabricated in accordance with "Specifications for N.I.S.T. Reactor Shim Safety Rods." The regulating rod consists of a 2½ inch (6.3 cm) diameter solid aluminum cylinder.

Emergency Shutdown Mechanism

There are two emergency shutdown mechanisms. The primary one is the shim safety arm system. This is backed up by the second mechanism that dumps the top reflector to a level one inch (2.5 cm) above the core. The top reflector is takes about 40 seconds to dump.

D_2 O Cooling Water Reservoirs

Should there be a major rupture of the Process Room piping that would drain the Reactor Vessel, D_2O will be held in two places within the reactor vessel itself (Figure 3.15). The Inner Reserve Tank (IRT), an annular-shaped tank, located in the top reflector can be drained only through two pipes at its bottom. These pipes feed the emergency cooling distribution pan that routes emergency cooling water to the interior of individual fuel elements in the core. The D_2O Holdup Pan holds water around exterior of fuel assemblies. Water can be drained from this pan only through fuel element seats in the lower grid plate. The end fittings of the fuel elements and any other tubes inserted into the lower grid plate are conical to minimize leakage of water down through the fuel element seats. This pan tends to keep the lower core submerged in the cooling water, and also collects any of the water from the IRT that splashes over the top of the distribution pan or runs down the outside of the fuel elements.

3.1.3.1.1 Reactor Design Considerations

Pressure

The reactor is operated with a cover of helium gas on the top of the vessel at a pressure of 3 to 5 inches (7.6 to 12.7 cm) of water. The gas is supplied from high-pressure helium cylinders that feed through suitable pressure-regulating manifolds to a closed recirculating system. This system, which includes the vessel and a helium gas holder as well as all D_2O storage tanks, is protected by a safety valve set at approximately 90% full on the helium gas holder, a 10 inch (25 cm) loop seal, and a gas holder high-level valve, which will blow off the system whenever the gas holder reaches the top of its travel.

Piping Reactions

The vessel and its associated piping are free to move under the influence of thermal expansion. Only the reactions from the bellows-type CO_2 seals are transmitted to the vessel. Sliding pad-type supports absorb most of the force from all reactions resulting from primary system flow in the external piping. The resulting loads on the vessel are small and, in conjunction with all other loadings, do not raise stress levels above the maximum allowable working stress for the various reactor sections.

Impact Loads

No impact loads are transmitted to the vessel. The shim safety arm shock absorbing systems are mounted on the biological shield so that only the extremely small reactions between the outer races and the balls of the safety arm bearings are transmitted to the vessel. The pressure surges that might be generated in the NBSR by power transients are small, and would not cause pressure in the vessel to exceed the 50 psig (0.35 MPa) design value.

Seismic Loads

The vessel was designed in accordance with BOCA Codes for seismic. The combined stress levels resulting from this loading plus all other design loads were well within the allowable limits for the various vessel sections. This horizontal acceleration is in the range of a VII to VIII earthquake on the Modified Mercalli Intensity scale (Geology, Seismology and Hydrology of NBSR Site, September 1981).

Thermal Loading Condition

In designing the vessel, consideration was given to the loadings resulting from constraining forces or members, and from both steady state and transient thermal conditions, including emergency conditions.

The low heating rates that the vessel experiences due to steady-state heating, and the excellent thermal conductivity of the aluminum combine to yield negligible stresses from internal temperature gradients. Areas of distinct interest for thermal expansion are the grazing tube-to-shell joints and the responses of the grazing tubes' columns due to restraint on their ends. Both these areas and the resulting stresses were considered in designing the vessel, and do not exceed the stresses allowed by the Code.

The NBSR vessel is fabricated entirely of aluminum alloys. Therefore, there are negligible stresses resulting from differential expansion between dissimilar materials.

Also, the very small temperature differentials between the components of the coolant and vessel cause insignificant thermal-transient loadings.

3.1.3.1.2 Prevention of Core Damage

Emergency Safety Features

A serious consideration for the NBSR is decay heating of the fuel elements in the event of loss of coolant. Therefore, highly reliable provisions for emergency cooling were incorporated into the facility design. Thus, the IRT was included inside the Reactor Vessel in the D_2O top reflector. The IRT can hold up coolant and distribute it at a proper rate to cool the fuel elements should the Reactor Vessel be drained accidentally. This tank is indicated in the plan and elevation views in Figures 3.14 and 3.15. Since the IRT's top level is below that of the overflow pipe, it will be filled up if the reactor's moderator level is properly maintained and overflow line is carrying flow, a condition for starting up the reactor. Since this tank is separate from the Reactor Vessel, it is independent of any accident which interrupts flow to the reactor such as caused by failure of the primary coolant piping or equipment. There are no valves in the lines distributing the emergency coolant from this tank to the fuel elements. Flow is maintained by gravity. The volume of water held by this tank and its overhead reservoir provides approximately 2½ hours of cooling to remove all decay heat released after reactor shutdown from sustained full power. The overhead D_2O Emergency Cooling Tank is located approximately 30 feet (9m) above the Reactor Vessel. It is kept full and overflowing to the IRT.

Reactivity Coefficients

The NBSR has a negative reactivity coefficient associated with both the temperature of the primary coolant and the formation of voids in the coolant (Chapter 4).

3.1.3.1.3 Reactor Parameters

Reactivity Insertion Rate Limit

The NBSR is designed to insert or withdrawn the shim safety arms individually or as a group. Their withdrawal rate is 0.04 deg/sec. The criterion for the maximum possible rate of reactivity is that no core damage results from a continuous reactivity insertion at rates discussed in Chapters 4 and 13.

Maximum Safe Step Reactivity Addition

The criterion is that fuel melting does not occur as a result of a power transient created by the maximum safe-step reactivity addition. This accident is analyzed in Chapter 13.

Core Monitoring

The criterion is that it must be possible to monitor the reactor power, the primary coolant flow, and the outlet primary coolant temperature at all times. Upon loss of offsite power, using the emergency electrical-power distribution system to supply essential instruments, or using battery-powered instruments will meet this criterion.

3.1.4 Quality Standards

The quality standards used during initial construction were those codes and standards in effect at that time. The quality control program that is in effect today is outlined in Section 12.9 of this SAR.

3.2 Meteorological Damage

Section 2.3 of this report summarizes the meteorological history of the NBSR site. The principal characteristic is an absence of extreme conditions. The reactor confinement building confers more than adequate protection against weather-related phenomena.

3.2.1 Wind Loading

The available wind data for NBSR site are rather extensive (Section 2.3). They indicate a predominance of southwesterly and northwesterly winds. In the 41 years, June 1905 to 1945, only twice were wind speeds in excess of 50 miles per hour (80 km/hour) for 5 minutes or more. A peak wind gust of 100 miles per hour (160 km/h) was recorded on June 9, 1928 during a violent thunderstorm. However, the maximum wind speed recorded through 2002 over last 39 years at the Dulles Airport is 55 mph (88 km/h). The estimated 50-year and 100-year return peak winds for the NBSR site are about 90 mph (144 km/h) and 102.5 mph (164 km/h), respectively (Section 2.3.5). The design wind load on the building structure, based on 100-mph (160 km/h) wind, is taken as 25 psf (1,200 N/m^2). This is within the uncertainty levels of the estimated worst-case peak winds of 90 mph (144 km/h) and 102.5 mph (164 km/h).

3.2.2 Snow and Ice Loads

The mean annual total precipitation recorded in Rockville weather station over 30 years is about 43 inches (109 cm). Rainfall in excess of 3 inches (7.6 cm) in 24 hours occurs in rare occasions during summer months. The average annual snowfall in Rockville area is near 19 inches (48 cm), and the greatest recorded single 2-day snowfall is 27 inches (68 cm). The corresponding 2-day-total 100-year return period snow load is 21.1 psf on the ground. For the months of December through March, the average maximum daily precipitation is 2.34 inches (6 cm) of snow water equivalent (SWE). As detailed in Section 2.3.1.6, the corresponding rain-on-snow load on the flat-roofed Confinement Building is calculated to be 22.8 psf (1,090 N/m^2) for a 100-year return period. However, the Confinement Building was designed and built for a snow load of 25 psf (1,200 N/m^2), which is greater than the estimated 22.8 psf (1,090 N/m^2).

3.3 Water Damage

Meteorological study of the NBSR site concluded that there was an extremely low probability of the occurrence of extremely heavy rainfall and tornadoes. It is safe to say that the NBSR site is not subject to flooding (Section 2.4). Moreover, even if water were to accumulate around the Confinement Building's exterior, it would not impact reactor safety because the building itself, including the foundation, is watertight.

3.4 Seismic Damage

The NBSR is located in a zone of low seismic activity. The building and reactor systems have been analyzed and shown to be able to withstand the stresses generated by a 0.1 g earthquake loading (NBS, 1966b). The probability of an earthquake resulting in accelerations larger than 0.08 g is less than 2% in 50 years (Section 13.2.8).

3.5 Inspections, Testing and Maintenance

The NBSR structures, systems, and components whose integrity is important to preventing the release of radioactive material, preventing core damage, and controlling reactivity, are designed to facilitate inspections, testing, and maintenance. Some examples include

- Acceptance of fuel elements.
- Visual inspection of material condition of all in-core components.
- A pressure test of confinement building to ensure compliance with the allowed leak-rate specification.
- Verification of shim blade drop times.
- Channel checks and calibrations of the nuclear and process safety systems.

There are written, and reviewed, procedures for conducting inspections and tests of all systems. Also, approved written procedures are followed for maintaining major equipment, such as control devices (Chapter 12).

Table 3.8 lists the surveillance tests, inspections, and calibrations related to the key structures, systems, and components discussed in this chapter.

3.5.1 Specific Inspection and Testing Activities

3.5.1.1 Confinement Building Leakage Rate Tests

The Confinement as opposed to the containment concept was shown to mitigate the worst reactor incident (Chapter 13) that results in a negligible overpressure. The Confinement Building and its ventilation systems were designed to provide sufficient confinement or retention of radioactive gases so that they can be filtered and passed up the stack at a reasonably low rate for subsequent atmospheric dispersion. The tighter the building, the slower the gas or internal atmosphere needs to be pumped through the filter and the stack.

The actual specification for the NBSR was based on the best state-of-the-art known to the NBS design group at the time of construction. It may be expressed either by relaxation time, which is 64 minutes, or by the flow rate resulting from an over- or under-pressure, which is 24 cfm per inch (0.27 meter^3 per minute per cm) of differential pressure. At the time of acceptance, the building was demonstrated to exceed both criteria (NBSR 7C "Supplement to Preliminary Hazards Summary Report, August 1962").

Two types of measurements were performed (NBSR 7C "Supplement to Preliminary Hazards Summary Report, August 1962"). In both, the intake and exhaust valves were closed and the confinement system tested with the air-conditioning systems operating to stabilize the temperature at 70^{o}F within the building. In one test, the blower flow rates required to establish a differential pressure of +7.5", +4.0" and –2.5" of water were less than 24 cfm per inch. In another test, the building was pumped or exhausted to the same three differential pressures and the relaxation times were shown to exceed 64 minutes.

3.5.1.2 Inspection of Penetrations

Independently of leakage rate tests, new building penetrations are inspected as part of the normal maintenance of the building and systems. It was found most practical to locate leaks by directly observing the suspect penetration after applying a leak-detecting liquid. It is planned to continue such inspections each time the confinement system's leakage-rate is measured, even though the specification might immediately be met.

3.5.1.3 Building Drains Monitoring

All liquid waste in the reactor building is treated as potentially contaminated. Therefore, the drains in the reactor building are carefully limited and controlled. All the systems supplying water to the face of the reactor for experimental use are closed systems with their own return lines. For all drains in the radiological laboratories and the health physics (HP) room, regular sink and cup drains are installed. The HP sink has a deep trap to maintain the integrity of the Confinement Building. In addition, a few open drains were strategically located in certain areas in case of accidental spills.

All these drains join into one system that empties into a sump tank. As this tank fills, the wastewater is automatically pumped into the radioactive waste system in the adjacent laboratory building.

Two roof drains also penetrate the reactor building. However, they are not part of the building drainage system since they simply pass through it and out again into the storm sewer system. They are completely sealed from the interior of the reactor building so that they do not breach the confinement system. In a few cases small flow of domestic cooling water is drained directly into these storm sewer drains. Each is a closed system from the domestic water supply to the drain maintaining the Confinement Building isolation.

3.6 References

Geology, Seismology and Hydrology of the National Bureau of Standards Research Reactor Site, Gaithersburg, Maryland, September 1981.

NBSR 9 – Final Safety Analysis Report on the National Bureau Of Standards Reactor.

NBSR 9A – Supplement A of the Final Safety Analysis Report on the National Bureau Of Standards Reactor, October 1966.

NBSR 9B – Supplement B of the Final Safety Analysis Report on the National Bureau Of Standards Reactor, December 1966.

NBSR 9 Addendum 1 – Final Safety Analysis Report on the National Bureau Of Standards Reactor, November 1980.

Structural Design Calculations, Book III, Volume 1, 2 and 3 by Burns and Roe Inc.

Technical Specifications for the National Bureau of Standards 20 MW Research Reactor

Table 3.1: Structures, Systems, and Components Important to Safety

Type	Identification	Reference SAR Chapter
STRUCTURES	Confinement Building	6
	Ventilation Stack	6
	Spent Fuel Storage Pool	9
	Experimental Facilities	10
	Liquid Waste Storage	11
SYSTEMS	Reactor Control System	4
	Primary Coolant System	5
	Engineered Safety Feature Systems	6
	Reactor Protection System	7
	Electrical Distribution System	8
	Instrument Air System	9
	Liquid Waste System	11
COMPONENTS	Reactor Vessel and its Supports	4
	Piping and Pipe Fittings, Valves, Heat Exchangers	5, 6, 9, 10,11
	Instrumentation & Control (I&C) Components	7
	Cable and Cable Trays, Electric Power Distribution Components	8

Table 3.2: Design Dead Loads (Structures)

ITEM	**DEAD LOAD (Thousands of Pounds)**
Roof	
Precast Sections	1215
4” slab	270
Roofing and Insulation	65
3000-gallon D_2O Tank	28
20-t on Crane	78
2nd Floor	
12” slab	900
Concrete Beams	594
2Disassembly Caves at 20 Tons	80
15 Ton Annular Crane	30
Pump Room Roof	86
1st Floor	
5 ft. slab	2100
15 ft. slab	700
Concrete Beams	16
5-ton Crane	22
Secondary Pump Room Floors	
3-6 ”. slabs	138
Mezzanine Floor	
8” slab	233
Beams	64
2”-4” slab	178
Neutron Guide Penetration Wall	1226
Monitor and Fan Rooms	
6” Slab	53
24” Fill	182
Corridor	
6” Slab	9
Pump Room	
6” Slab	72
Basement	
6” Floating Slab (excluding reactor & pool area)	525
3’ Fill under Floating Slab	2100
3’ Concrete Pile Cap under Building	3470
Walls	
Above 1st Floor	5140
Below 1st floor	13,207
Exhaust Stack	615
Internal Columns	96
D_2O Storage Tank Pit	180
Spent Fuel Storage Pool	180
Canal	156
TOTAL	34,008

Table 3.3: Design Dead Loads (Reactor)

ITEM	DEAD LOAD (Thousands of Pounds)
Thermal Shield	193.0
Aluminum Vessel – Shell only	3.2
Core Support Structure	4.07
Control Arms and Drives	0.63
Cold Neutron Facility	2.5
Top Cover plate	11.3
Top Plugs	90.3
Biological Shield	1530.0
TOTAL	1835.0

Table 3.4: Confinement Building Design Live Loads

ITEM	LIVE LOAD (Thousands of Pounds)
Roof	
Snow Load	202
Load on 20-t on Crane	40
2nd Floor	
Movable Concentrated Load – 2 @ 20 tons	40
Load on 15-t on Crane	30
Floor Load @ 150 psf	1210
Snow Load on Pump Room's Roof @ 25 psf	29
1st Floor	
Floor Loads 6800 sq. ft. @ 1000 psf	6800
Floor Loads 620 sq. ft. @ 2000 psf	1240
Load on 5-ton Crane	10
Floor Loads on Secondary Pump Room's Floor	486
Floor Load on Mezzanine Floor	350
Floor Load Monitor, Fan Room	105
Floor Load in Corridor	12
Floor Load – Counting Room & Lab. @ 100 psf	240
Floor Load – Pool and Process Area @ 400 psf	1610
Floor Load – Secondary Pump Room, Basement @ 300 psf	175
14,000-gallon D_2O in Storage Tank	130
27,000gallon H_2O in Pool	230
6,000-gallon H_2O in Canal	50
4,600-gallon D_2O in Vessel	43
TOTAL	13,022

Table 3.5: Confinement Building Electrical Penetrations

NAME	SIZE In inches	EXTERIOR SEAL	INTERIOR SEAL
Lights	1	B	A
	1¼	B	A
	1½	B	A
	2	B	A
	2½	B	A
	3	B	A
	3½	B	A
	4	B	A
Alarm and Communication			
	1	B	A
	1¼	B	A
	2	B	A
Telephone	2	B	A
Instrumentation	1	B	A
Power to Equipment	1	B	A
	1¼	B	A
	1½	B	A
	2	B	A
	2½	B	A
	3½	B	A
	4	B	A

NOTE: Seal Type A – see Figure 3.9.
Seal Type B – see Figure 3.6.

Table 3.6: Confinement Building Mechanical Penetrations

NAME	SIZE, in inches (unless indicated)	EXTERIOR SEAL	INTERNAL SEAL
Chilled Water	5	B	Closed system
	¾	B	Closed system
Steam	4	B	Closed system
Condensate Return	2	B	Closed system
Demineralized Water	1	B	Closed system
Domestic Water	3	B	Closed system
	2	B	Closed system
	¾	B	Closed system
Air	½	B	Closed system
	¾	B	Closed system
	1	B	Closed system
	1¼	B	Closed system
	2	B	Closed system
Oxygen	¼	B	Closed system
Experimental Penetrations	2½	B	Capped
Building Test Instrumentation Sleeves	¼	B	Capped
Door (Personnel)	6'- 4½" x 8'- 2¼"	D	Inflatable Gasket
Door (Truck)	12'- 4" x 14'- 2"	D	Inflatable Gasket
Door (Emergency)	3'- 5" x 7'- 2½"	D	Inflatable Gasket
New Cryogenic Facility	2' x 2'	B	Compressed2'x2' Rubber Gasket
View Panel – Emergency Door	6" x 6"	D	Inflatable Rubber Gasket both Sides
Building Leak Test and Exhaust	8	B	Manual Damper with Rubber Seat
Air Intake and Exhaust	7'- 6" x 10'- 0"	C	36"& 42" Valves
Air Intake	7'- 5" x 2'-8"	C	36" & 30" Valves
Air Exhaust	1' x 1'	C	6" Valves
Air Exhaust	6" x 6"	C	4" Valves
Door to Elevator	7'- 0" x 8'- 3"	D	Inflatable Gasket
Door - Personnel	5'- 4¼" x 7'- 2¼"	D	Inflatable Gasket
Neutron Guide Tubes	18		Valves
Secondary Cooling	½	B	Closed system
	2	B	Closed system
	3	B	Closed system
	4	B	Closed system
	6	B	Closed system
	20	B	Closed system
Gas	¾	B	Closed system
Helium	¾	B	Closed system
	1½	B	Closed system
CO_2	2	B	Closed system
	¾	B	Closed system
Drain, Roof	4		Closed system
	3		
	6		
Suspect Waste	1½	B	1½" Valve
Hot Waste	4	B	4" Valve
D_2O	½	B	Closed system
	1	B	Closed system
Service Feed Through	12		Compressed rubber gasket

NOTE: Seal Types: B – see Figure 3.6; C – see Figure 3.8; D – see Figure 3.7.

Table 3.7: Design Information for Primary Coolant System Components

Component (Codes & Standards)	Materials of Construction	Design or Test Pressure	Rating	Remarks
Primary Heat Exchangers (HE-1A, HE-1B and HE-1C) (ASME B&PV Code, Section VIII)	Plates: 316 type Stainless Steel Frame: Carbon Steel Gaskets: Nitril	Primary and Secondary sides design Pr. & Temp: 150 psi at 200°F Hydrostatic Test Pressure: 225 psi	Each HE designed to remove $35x10^6$ BTU per Hour. Primary flow: 4,800 gpm Temp. Range: 114°F to 100°F Secondary flow: 5,000 gpm Temp. Range: 84°F to 98°F	Plate & frame type design with primary flow through welded plate cassettes and Secondary Flow between cassettes held by gaskets. HE-1C is spare but can be readily put in the line, when required.
Primary Piping, Pipe Fittings and Valves (ASME/ANSI B31.1)	6061 T6 Aluminum. Several control valves and valves at the heat exchangers are Stainless Steel Valve Gasket and Diaphragm: Hyplon	Design Pressure: 125 psi Hydrostatic Test Pressure: 187.5 psi		All pipe fittings are forged 6061 T6 aluminum. Certified welders make all welds. Welds are radiographed and accepted on the basis of ASME codes.
D_2O Main Circulating Pumps (Total 4 units)	Stainless Steel		Delivering 3,100 gpm at 116 feet of Total Head	Single stage centrifugal units
Shutdown Pumps (Total 2 units)	Stainless Steel		Delivering 800 gpm at 24 feet of Total Head	Single stage centrifugal units
D_2O Purification heat exchanger (HE-2) (ASME B&PV Code, Section VIII)	Plates: 316 type Stainless Steel Frame: Carbon Steel Gaskets: Nitril	Primary and Secondary sides design Pr. & Temp: 150 psi at 200°F Hydrostatic Test Pressure: 225 psi	Each HE designed to remove $1.18\ x10^6$ BTU per Hour. Primary flow: 65 gpm Temp. Range: 100°F to 90°F Secondary flow: 170 gpm Temp. Range: 84°F to 98°F	Plate & frame type design with primary flow through welded plate cassettes and Secondary Flow between cassettes held by gaskets.
Reactor Vessel (ASME B&PV Code, Section VIII)	6061 Aluminum	Design pressure and temperature 50 psig at 250°F. Hydrostatically tested at 75 psig.		Reactor vessel is unpressurized except for small pressure of 4 inches of water due to helium blanket.

Table 3.8: Surveillance Tests, Inspections and Calibrations

U. UNSCHEDULED

Leak Tightness Verification of Confinement Building or its Penetrations After Any Additions, Modifications, or Maintenance Activities (TS 4.1.3)

Operability Check of Reactor Coolant Systems or their Connected Auxiliaries After Any Additions, Modifications, or Maintenance Activities (TS 4.2.3)

Operability Check of the Repaired Portion of Reactor Control or Safety Systems Following Maintenance on Any Portion of the System (TS 4.3.6)

5. 5-Year (≤6 years)

Discharge Test of Station Battery (TS 4.8.4)

B. Biennially (≤30 months)

Efficiency Test in Excess of 99% of Absolute Filters in Emergency Exhaust System (TS 4.6.3)

Filter Efficiency Test of Charcoal Adsorber Banks in Emergency Exhaust & Recirculation Systems (TS 4.6.4)

A. Annually (≤15 months)

Channel Test of Confinement Closure System Using External Source (TS 4.1.1A)

Integrated Leak Test of Confinement Building (TS 4.1.2)

Testing of Primary Coolant System Relief Valve (TS 4.2.2)

Reactivity Worth Measurements of Each Shim Arm and Regulating Rod (TS 4.3.1)

Channel Calibration (TS 4.3.4): RD3-4, RD3-5, RD4-1, FRC-3, FRC-4, FIA-40, LRC-1, LIA-40, NC-1, NC-2, NC-3, NC-4, NC-6, NC-7, NC-8, PC-3, PC-27, PC-150, PS-150, PS-151

Operability Verification of Emergency Cooling Sump Pump with Light Water (TS 4.4.2)

Calibration of N-16 Monitors (RD3-1) with External Source (TS 4.5.1A)

Calibration of Area Monitors (RD1-1 to 10) (TS 4.7.1)

Calibration of Fission Products Monitor (RD3-2) (TS 4.7.2)

Testing of All Emergency Power Equipment Under a Simulated Complete Loss of Outside Power (TS 4.8.3)

S. Semiannually (≤7½ months)

Withdrawal and Insertion Speed Testing of Each Shim Arm and Regulating Rod (TS 4.3.2)

Scram Time Test for First 5 Degrees of Each Shim Arm Drive (TS 4.3.4)

Exercise of Light Water Injection Valves (PW-6, 7, 8 & 9) (TS 4.4.3)

Voltage and Specific Gravity Test of Each Cell of Station Battery (TS 4.8.4)

Q. Quarterly (≤4 months)

Channel Trip Test of Confinement Closure System Using Each of Four Signals (TS 4.1.1)

Operability Check of Reactor Safety System Channels Using Internal Test Signals, Prior to Each Startup Following Shutdown in Excess of 24 Hours or Atleast Quarterly (TS 4.3.4)

Exercise of Control Valves (DWV-32, 33, 34 & 35) in D_2O Emergency Cooling System (TS 4.4.1)

Starting Function Check of Emergency Cooling Sump Pump (TS 4.4.2)

Operability Test of Emergency Exhaust Filter System, Including Building Static Pressure Controller and Vacuum Relief Valve (TS 4.6.1)

M. Monthly (≤1½ months)

Operability Check of N-16 Monitor with External Source (TS 4.5.1)

Sample Test of Secondary System for T-3 When N-16 Monitor is Operable (TS 4.5.2)

Operability Test of Controls in Emergency Control Station (TS 4.6.2)

Source Testing of Area Monitors for Operability (TS 4.7.1)

Source Checking of Fission Products Monitor for Operability (TS 4.7.2)

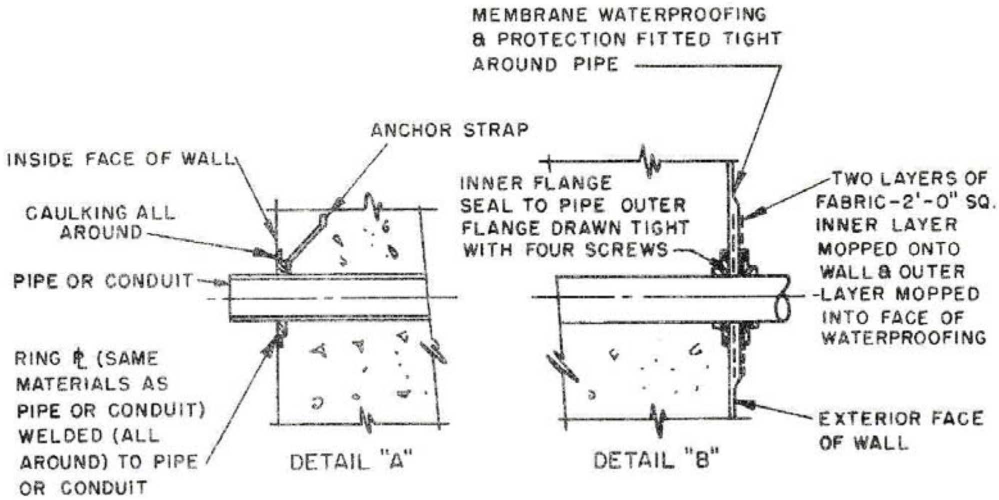
Testing of Each Diesel Generator for Automatic Starting and Operation Under Partial Load (TS 4.8.1)

W. Weekly (≤10 days)

Starting Capability Test of Operable Diesel Generator, Should One of the Generators Become Inoperative (TS 4.8.2)

D. Daily

Sample Test of Secondary System for T-3 When N-16 Monitor is NOT in Service (TS 4.5.2A)

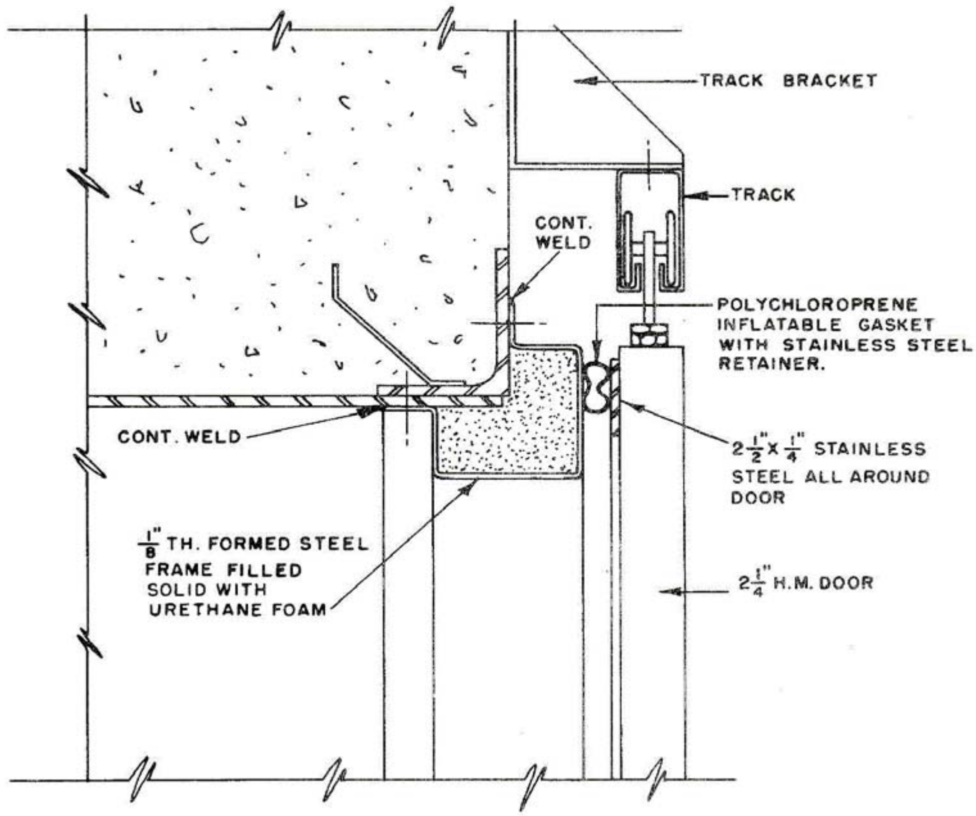


<u>TYPICAL PENETRATION DETAILS</u>
<u>THRU CONFINEMENT WALLS</u>

NOTES: DETAIL “A” APPLIES TO THE INSIDE FACE OF WALLS OF THE CONFINEMENT BUILDING AT ALL PIPE & CONDUIT PENETRATIONS. DETAIL “B” APPLIES TO THE OUTSIDE FACE OF THE CONFINEMENT WALLS AT ALL PIPE & CONDUIT PENETRATIONS WHERE MEMBRANE WATERPROOFING IS REQUIRED.

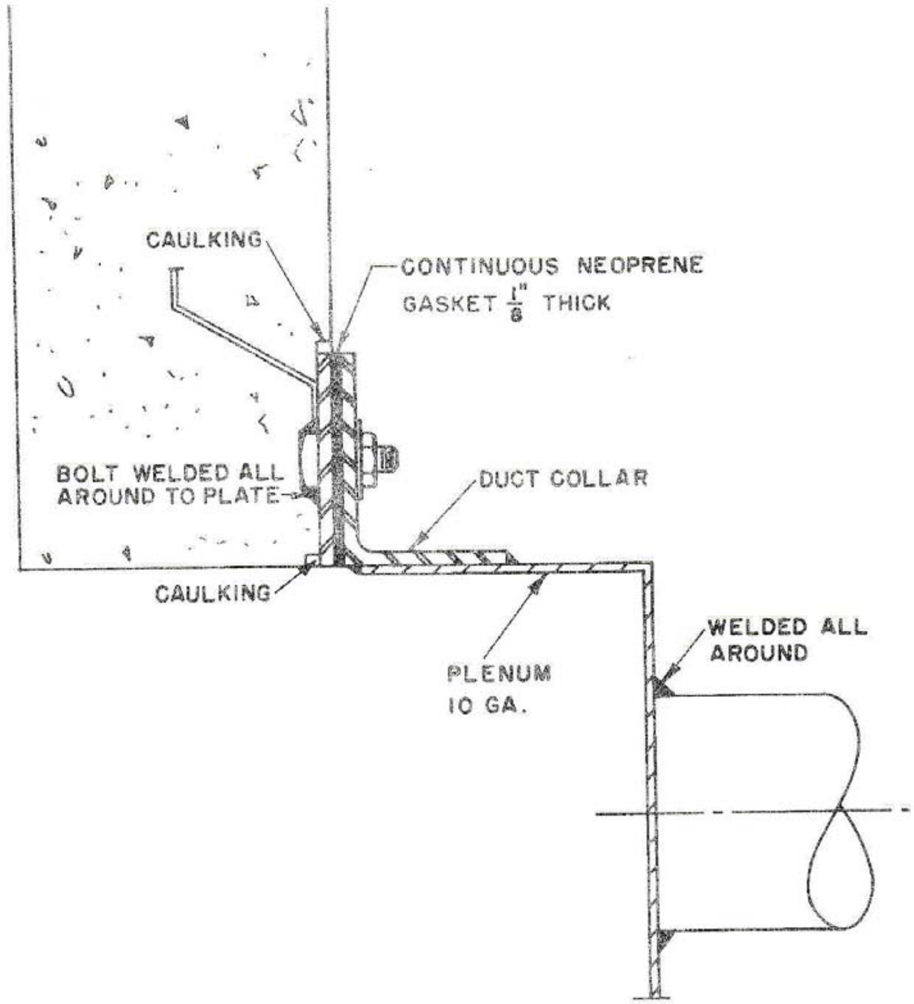
LISTED AS SEAL TYPES “A & “B” IN TABLES 3.5 AND 3.6.

Figure 3.6: Details of Mechanical Penetrations



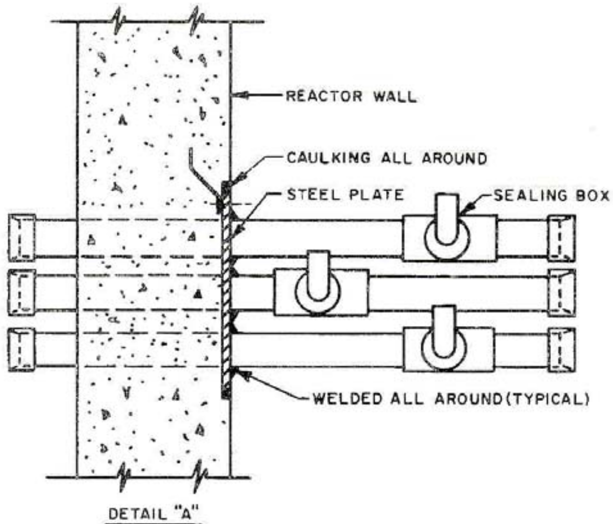
NOTE: LISTED AS SEAL TYPE "D" IN TABLE 3.6.

Figure 3.7: Details of Door Seals



NOTE: LISTED AS SEAL TYPE "C" IN TABLE 3.6.

Figure 3.8: Details of Air Plena Seals



TYPICAL PENETRATION DETAIL THROUGH CONFINEMENT WALLS

Figure 3.9: Details of Electrical Penetrations

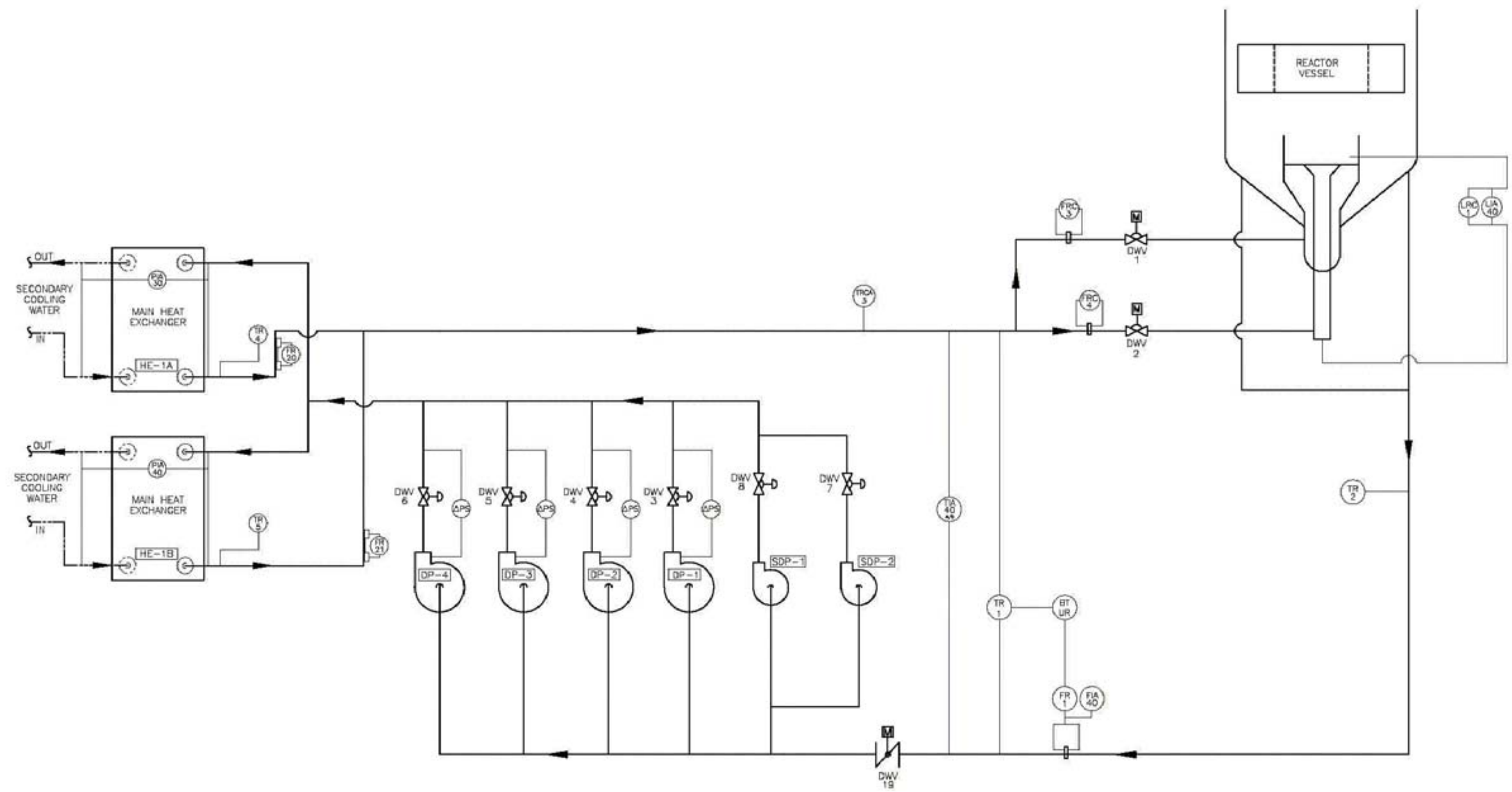


Figure 3.10: Simplified Primary Coolant System

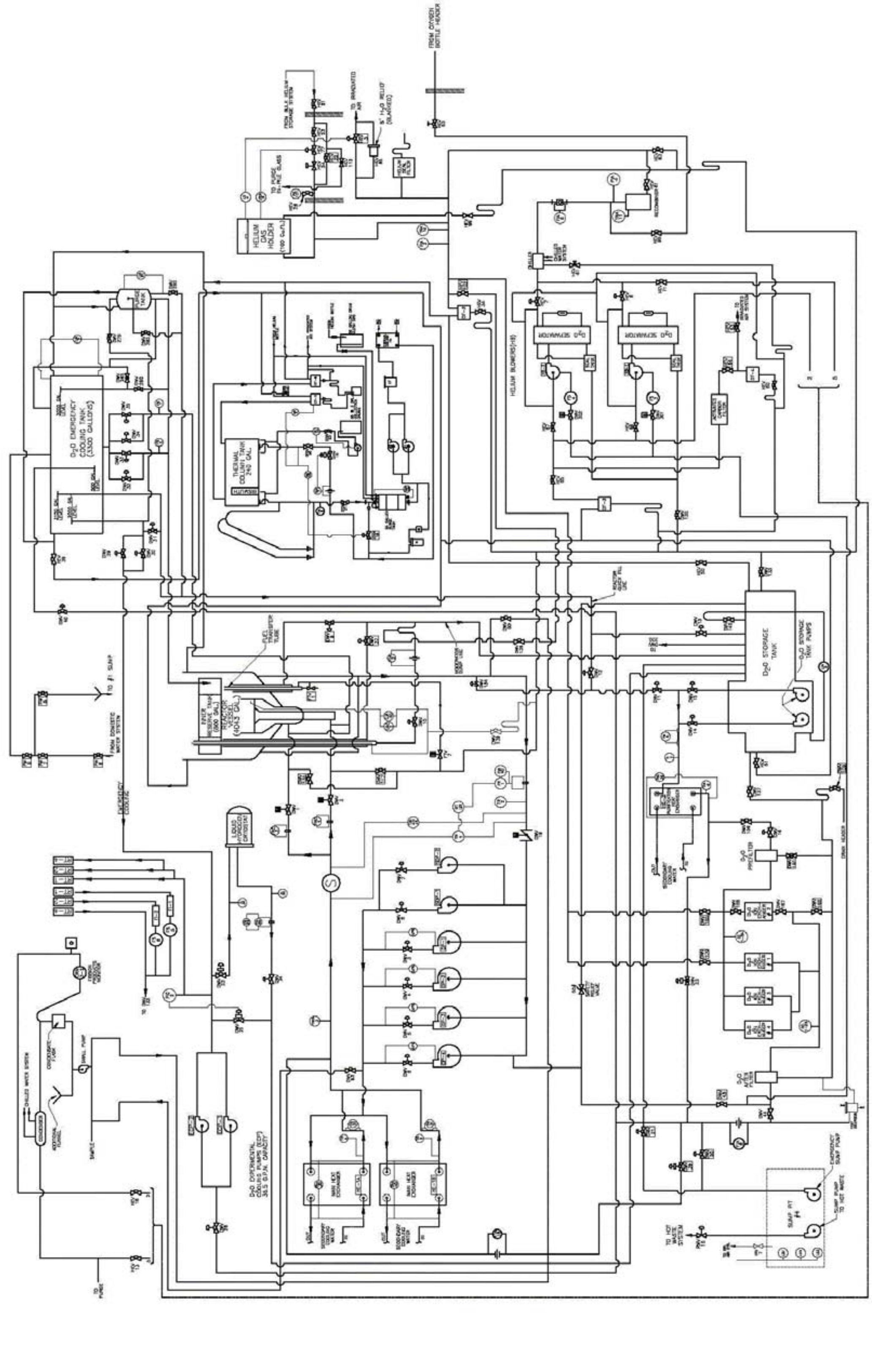


Figure 3.11: Integrated Primary Coolant System

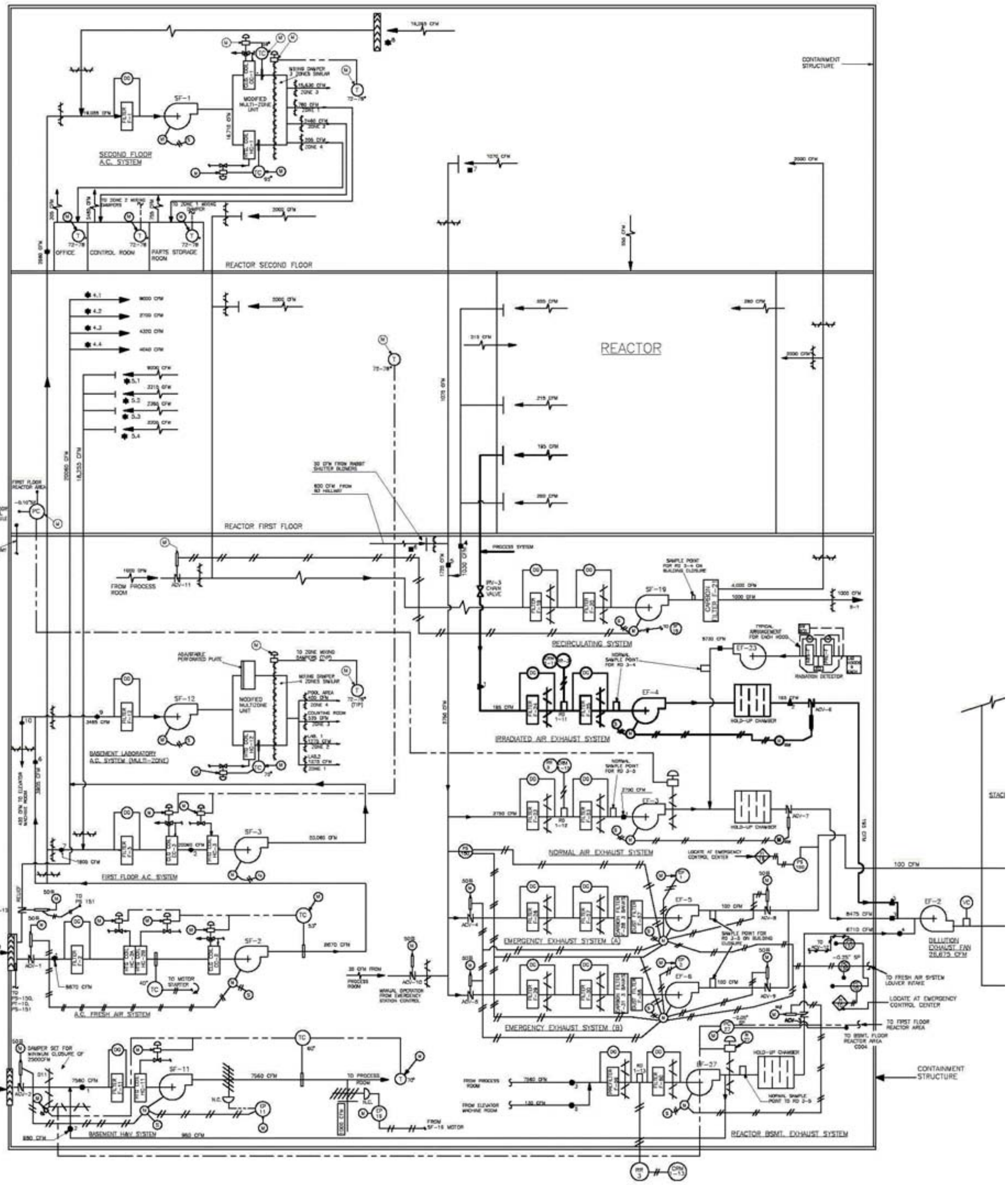


Figure 3.12: Confinement Building Ventilation System – Flow Diagram

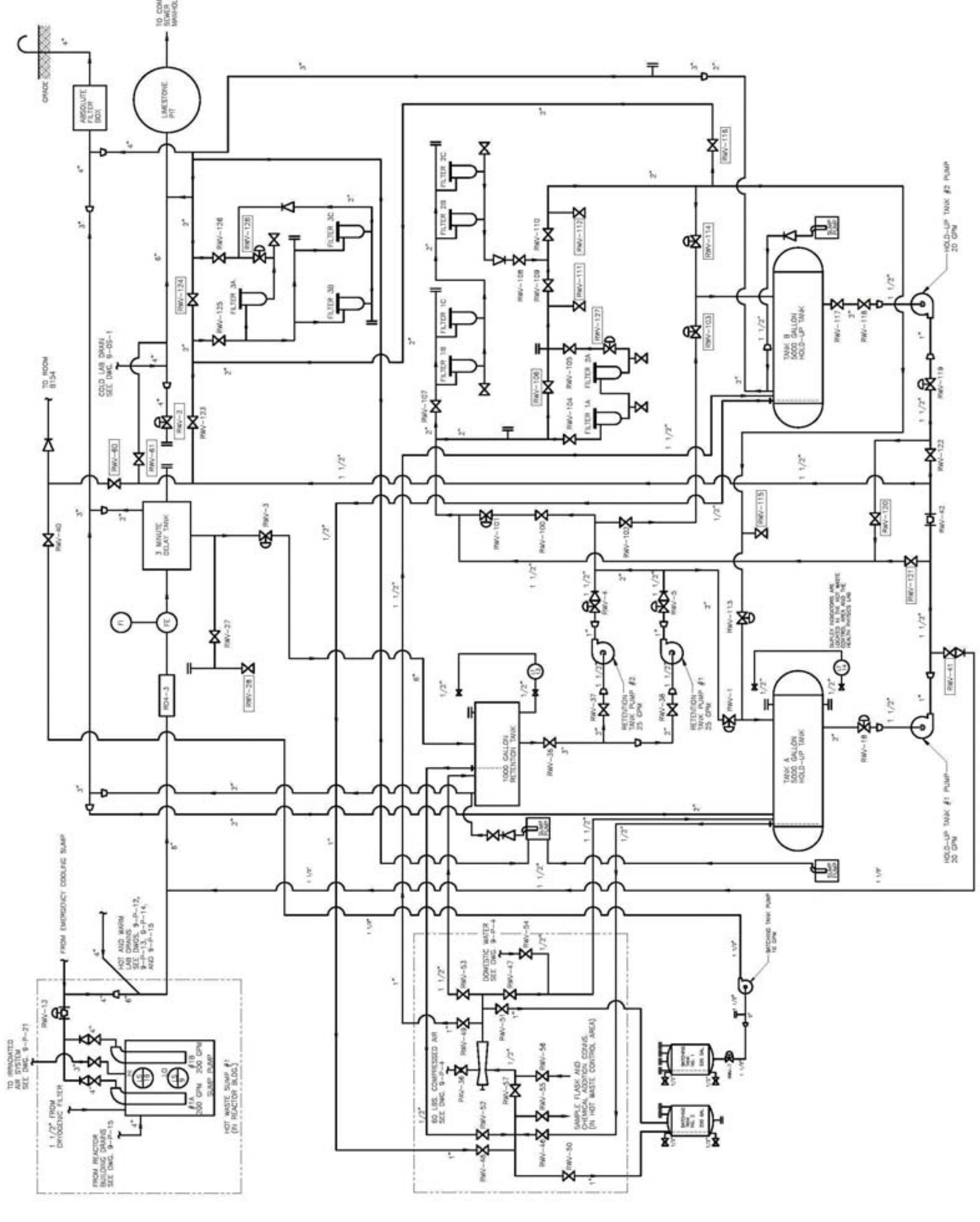


Figure 3.13: Liquid Waste System

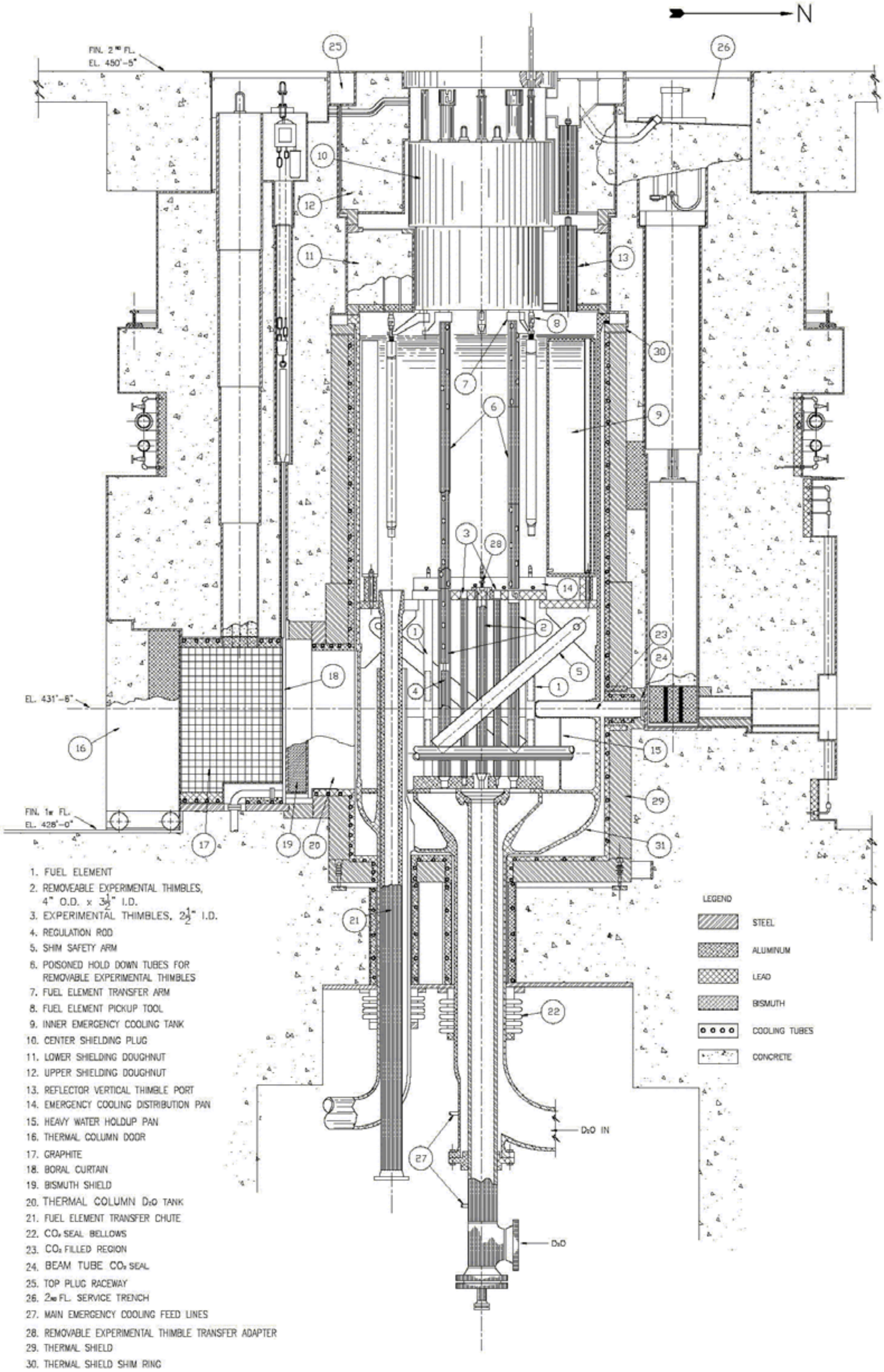


Figure 3.14: Confinement Building – Ventilation System – Mechanical Arrangement

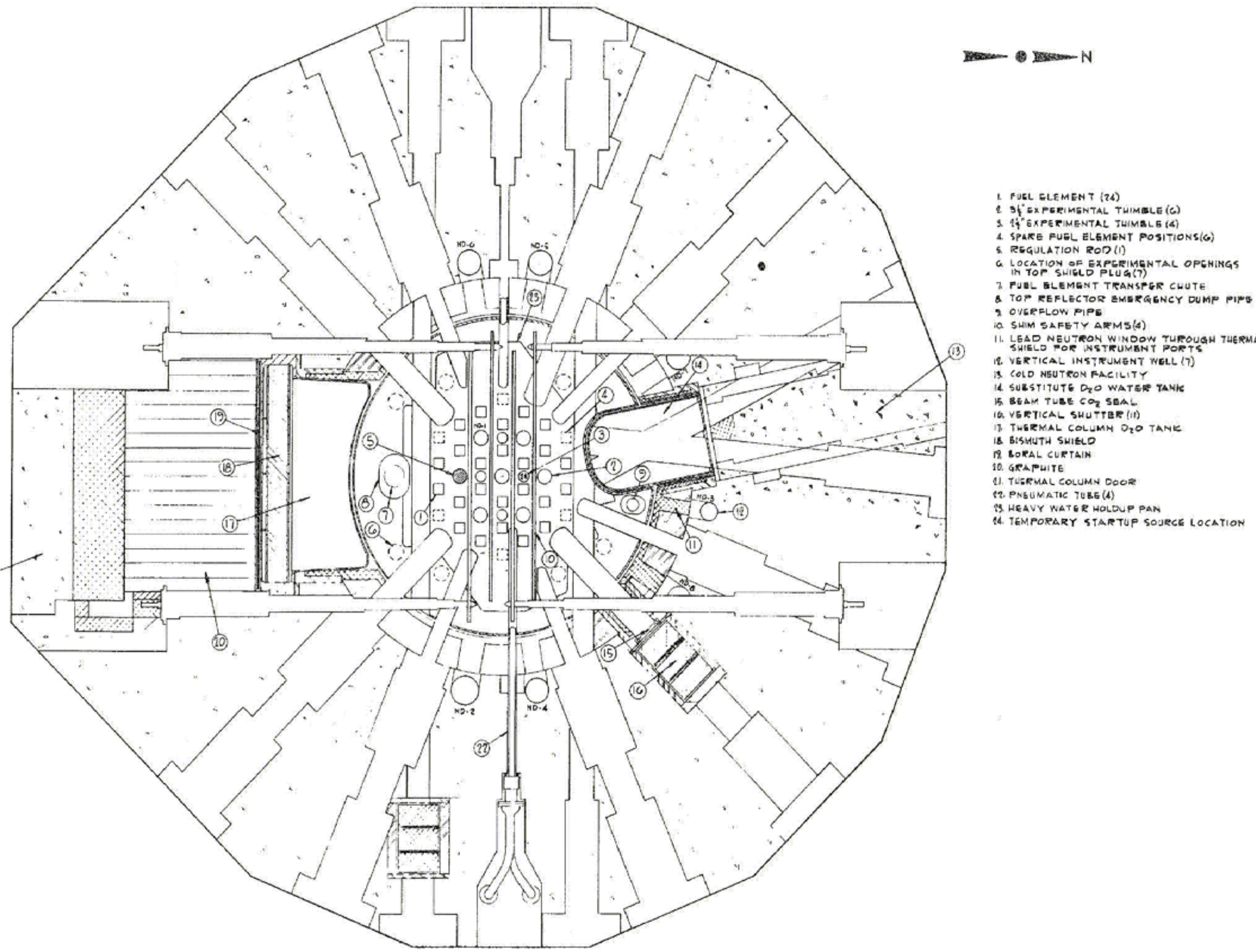


Figure 3.15: Reactor Vessel – Plan View

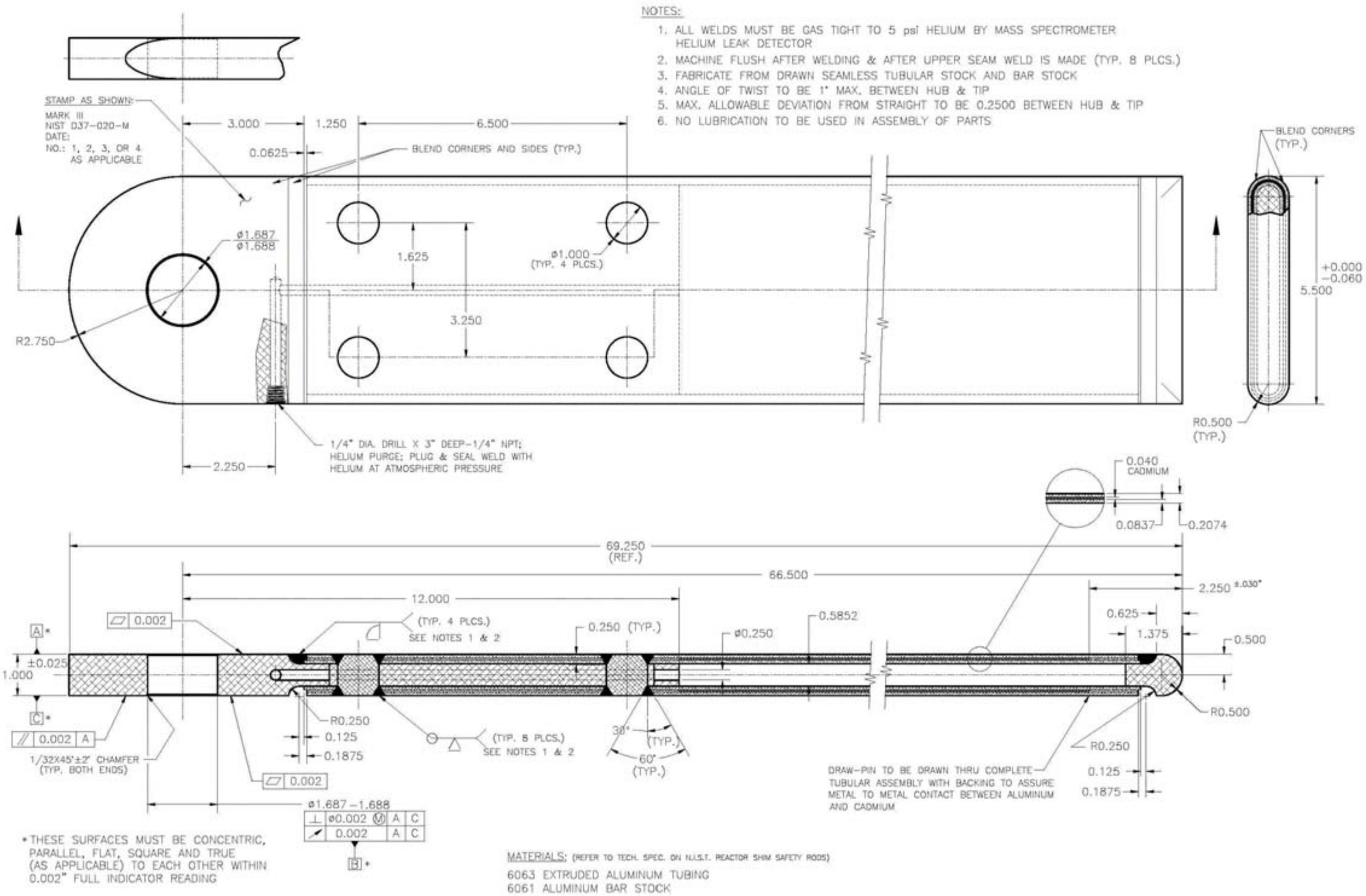


Figure 3.16: Shim Safety Arm – Design Details