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9 AUXILIARY SYSTEMS

9.1 Heating, Ventilating, and Air-Conditioning Systems

The NIST Reactor-Laboratory complex (i.e., Building 235) contains several heating, ventilating, and air-conditioning (HVAC) systems for the reactor facility as well as for other laboratory and office areas. The HVAC systems contain conventional heating and cooling units and other typical components, including their own intake and exhaust fans and filtering systems. Chapter 6, Engineered Safety Features, describes the ventilation systems associated with the Confinement Building for both normal and emergency operations of the NIST reactor. The discussions in this section include other ventilation systems that are routinely in operation to provide conditioned air for the laboratory equipment and for NIST personnel performing their experiments and day-to-day activities in laboratories and in offices within areas other than the Confinement Building. Each of these systems is designed to operate independently for specific areas within Building 235 and has no impact on ventilation systems for the Confinement Building. The areas include the Pump Room (or Pump House/Pump Annex) adjacent to the Confinement Building, the Cold Laboratory Area, the Warm Laboratory Area, and other laboratory and office facilities.

9.1.1 Pump Room HVAC System

The Pump Room adjacent to the Confinement Building (on the north side) has four levels beginning from the basement level up to the first floor of the Confinement Building, where the reactor is located. The Pump Room AC unit is located on the fourth level and supplies conditioned air to areas on all four levels of the Pump Room. See Figure 9.1.

The supply fan SF-13 draws fresh air from outside at nominal flow rates of 5,825 cfm (166 m³/min) during summer and 760 cfm (22 m³/min) during winter and the exhaust fan EF-7 exhausts the Pump Room air directly to the outside at the same rates. During winter months, 5,065 cfm (144 m³/min) of air is recirculated within the Pump Room by sending air from the discharge side of the EF-7 back to the suction side of the SF-13. The fresh air in summer or the mixed air in winter passes through the filter F-13 before entering the suction side of SF-13 and is then conditioned by a multi-zone unit before supplying 1,400 cfm (40 m³/min) to each of the first three levels and 1,625 cfm (46 m³/min) to the fourth level of the Pump Room. The exhaust fan draws the air from all four levels at the same flow rate as the supply fan discharges to these areas.

9.1.2 Cold Laboratory HVAC Systems

The Cold Laboratories HVAC system provides ventilation air to three independent AC systems. The first system, AC Fresh Air System for the Cold Laboratory, is a large air-conditioning system supplying ventilation air to four individual smaller AC systems that supply air to various laboratories, work areas, offices, conference rooms, toilets, and the lobby area. The other two AC systems are: (1) the Basement H&V Exhaust System supplying ventilation air for the basement and work areas, and (2) the Switchgear H&V and Exhaust System, which supplies the

Battery Room. In each of these AC systems the supply fan draws fresh air from outside at the same rate as the exhaust fans discharge room air to the outside.

Supply fan SF-5 in the AC Fresh Air System for the Cold Laboratory Area draws 13,000 cfm (370 m³/min) of fresh air from outside. The air passes through the filter F-5 and the air-conditioning unit before supplying the four individual AC systems for the Cold Laboratory Area. Each of these AC systems mixes the fresh air it receives with a large portion of the room air before passing through its filtering and air-conditioning units.

The Basement H&V and Exhaust System includes the supply fan SF-15 and the exhaust fan EF-8. The system draws 22,000 cfm (600 m³/min) during summer and 2,850 cfm (80 m³/min) of fresh air with recirculating the room air at a flow rate of 19,150 cfm (540 m³/min) during winter. The system circulates conditioned air to the basement area and other offices.

The Switchgear H&V and Exhaust System includes the supply fan SF-16 and the exhaust fan EF-9. This system maintains the air temperature within the switchgear area. The Battery Room has a separate exhaust fan, EF-11, which draws and circulates 1,000 cfm (30 m³/min) of switchgear room air before releasing it directly to the outside. The system draws 15,750 cfm (450 m³/min) of fresh air during summer and 2,050 cfm (60 m³/min) of fresh air with recirculating the room air at a flow rate of 13,700 cfm (400 m³/per min) during winter.

9.1.3 Warm Laboratory HVAC Systems

The Warm Laboratory AC Fresh Air System supplies fresh air from outside to four independent AC systems supplying ventilation air to various hot laboratories and offices in the area. 28,600 cfm (810 m³/min) of fresh air is brought into the building by supply fan SF-9 and 27,750 cfm (790 m³/per min) of air from the Warm Laboratory Area is exhausted directly by the exhaust fan EF-1 through one dedicated section of the stack. About 400 cfm (11 m³/min) of air is released through the area toilets and the remaining 450 cfm (13 m³/min) is used by the building's pressure relief system.

9.1.4 Other Laboratory and Office Facilities

Other laboratory and office facilities within Building 235 have independent AC or ventilation systems for specific areas serving as support function to the NIST reactor operations. The failure of any of these systems has no impact on the emergency safety features for the NIST reactor operations.

9.2 Handling and Storage of Reactor Fuel

9.2.1 New Fuel Storage Area

Unirradiated fuel elements may be stored in one of the following two locations, subject to the NBSR Physical Security Plan:

- a. In the reactor core provided that the reactivity is below the shutdown margin, or
- b. The new fuel storage area in the Materials Access Area (MAA).

The principal issues associated with the storage of unirradiated fuel are those of security and inadvertent criticality. The former is addressed in the NBSR Physical Security Plan. Prevention of criticality is ensured by proper design and use of each storage location. Specifically, the reactor itself is shielded, and approved written procedures are observed to assure that the fuel is loaded properly. The fuel elements in the new fuel storage area are stored in such a way that the physical geometry prevents inadvertent criticality, even if flooded.

Two criticality monitors (only one is required to be operational) that are both on battery-backed power supplies continuously monitor the MAA. These criticality monitors have local indications and alarms for area evacuation purposes.

9.2.2 Storage of Irradiated Fuel

Irradiated fuel may be stored in any of the following locations, subject to the NBSR Physical Security Plan:

- a. In the reactor core, or
- b. In the Spent Fuel Storage Pool.

The above locations are both within the reactor confinement building. Security issues are addressed in the NBSR Physical Security Plan. The spent fuel pool contains two types of storage racks. One type holds intact fuel assemblies and the other type holds the “fuel only” portion of the fuel element. In both designs, the physical geometry prevents exceeding a k_{eff} of 0.9. Shielding is provided by water for the reactor and storage pool. Concrete and lead also provide additional shielding for the reactor.

9.2.2.1 Spent Fuel Storage Pool

The Spent Fuel Storage Pool contains about 35,000 gallons (132,500 liters) of light water (H_2O). Facilities are provided in the fuel storage pool to receive and store irradiated fuel assemblies, load irradiated fuel assemblies in casks for shipment, cut non-fueled sections from irradiated fuel elements, and store these sections prior to disposal. Storage racks and miscellaneous tools are provided.

As fuel is discharged from the reactor to the pool, the elements are placed in storage racks designed to hold full-length fuel elements. The storage racks are placed at the west end of the pool. The elements are hung by their pickup heads from brackets along the back wall of the rack. In the fueled element region of the pool, the back wall of the rack is lined with Boral. Additionally, a Boral plate extends out from the wall 7" (18 cm) between each fuel element. The spacing between rack partitions is 4-1/8" (10.5 cm). Partitions are structural members of the storage rack that provide physical separation between each stored fuel element, to ensure a sub-critical configuration. A latch bar is located near the top of each fuel element partition. Besides

providing a secondary means of preventing the elements from falling out of the rack, the latches prevent the accidental approach of a second fuel element to closer than the 3" (7.6 cm) minimum separation in the rack for criticality purposes. Three racks are designed to hang twelve elements. A fourth rack along the pool wall, containing stainless steel separators instead of Boral partitions, will hold twenty elements. A temporary rack, which is suspended from the pool curb, can hold six elements. The Boral and stainless steel partitions between elements are added to preclude any possibility of criticality. Even without the Boral, calculations indicate that a single row of an infinite number of 350-gram elements in an infinite H₂O pool yields a sub-critical configuration.

For shipping, the fueled sections are cut out of the full fuel element to yield two sections per fuel element of about 13" (33 cm) each in length. These 13" (33 cm) sections are stored in sloping shelves along a fuel rack. The horizontal rows of shelves have a 9" (23 cm) separation, to ensure that the minimum vertical space between the element pieces is 6" (15.2 cm). The vertical columns of shelves are defined by Boral partitions and each column holds four pieces. Racks of stainless tubes suspended from the pool curb provide additional fuel section storage. There are approximately two hundred of these tubes, which are similar in dimensions to the shelves described above.

At the east end of the pool, an area is reserved for the cutting and loading of fuel elements into shipping casks. The room containing the spent fuel storage pool is equipped with an area radiation monitor that alarms both locally and in the control room in the event of an excessive radiation level. In Section 9.9, the pool and its cooling system are discussed in greater detail.

9.2.3 Refueling and Handling of Fuel Elements

The NBSR fuel-handling system provides for the rearrangement of the fuel elements within the core and the removal of spent elements completely from the core. As shown in Figure 9.7, there is water filled space above the reactor to raise a fuel element out of the core where it can be transferred to another position in the core, or to a transfer chute. From the chute it can be lowered into a receiving mechanism in a canal that is considered part of and leads to the fuel storage pool.

There are three phases of the refueling procedure; first, the spent fuel elements are removed from the core and transferred to the spent fuel pool; second, the remaining elements are rearranged as desired in the core; and thirdly, the new fuel elements are loaded into the core.

During the removal of the spent fuel elements, overheating must be avoided. The water is lowered below the top of the transfer chute and the element is raised into the helium filled region above the core, transferred above the open transfer chute, and lowered directly into the receiving mechanism located in the canal. In the case of normal operation at 20 MW, the decay heat production rate in an NBSR fuel element 20 hours after shutdown is sufficiently low for safe fuel transfer to occur. De-fueling typically commences 3 to 6 days after shutdown, depending on experimentation and required maintenance schedule needs. Safety aspects of the spent fuel handling process are discussed in greater detail in Section 9.2.4.1. When the spent fuel elements have been removed, the valves in the transfer chute will be closed and the elements will then be

rearranged in the core as desired. Finally, the water in the vessel is raised to a level above its normal level to reduce tritium release to the C200 area in the reactor building. This evolution will be explained later in this section. The plug over the transfer chute is then removed, and fresh elements are inserted through this opening into the transfer mechanism for insertion into the core.

9.2.3.1 Transfer Mechanism

The transfer mechanism consists of a set of pickup tools and transfer arms, which penetrate the top shielding plug. There is a pickup tool over each fuel element, and transfer arms are located such that every possible fuel element position can be reached by at least one transfer arm. A simplified elevation view of the system is shown in Figure 9.8. For the purpose of clarity, some of the transfer arms and the details of the pickup heads are not shown. In order to illustrate the operation of the fuel handling system, the fuel transfer plug and related hardware was placed in a test stand and photographed. Several views are shown in Figures 9.2 through 9.6.

Figure 9.2. shows a transfer arm, a pickup tool, and a fuel element head.

Figure 9.3 shows a side view of the fuel transfer plug.

Figure 9.4 shows a top view of the fuel transfer plug mounted in a test stand.

Figure 9.5 shows the fuel transfer plug, bottom view.

Figure 9.6 shows the fuel transfer plug and a fuel element, bottom view.

Wherever a transfer arm location might interfere with an experimental thimble, it is designed to rotate on a cylinder around the experiment. In this way all fuel element transfers can be made without interfering with any of the in-core experimental facilities.

A typical transfer procedure is as follows. A pickup tool is manually lowered until it engages the head of the fuel element. It is then rotated under slight pressure until it slips over large pins (ears) in the fuel element head. The tool is rotated about 45° at which point the ears will be above the J-slot in the tool. Then, it is pushed down and rotated clockwise an additional 45°. This disengages the fuel element latch bar from the top grid plate and allows the element to be lifted as the pickup tool is withdrawn. As the end of the pickup tool nears the top plug, it enters a mechanical maze, which allows the tool to be accurately located and supported while a transfer arm is rotated into place. The position of the transfer arm is shown by a mark on the rotating cylinder outside the plug and uses a mechanical detent to further ensure it is in the proper position to receive the element. When the arm is in place, the element is lowered into it. Small pins in the fuel element pickup head shaft engage the grooves in the transfer arm, preventing the element from rotating as the pickup tool is rotated counter-clockwise approximately 45° to disengage it from the element. The lower portion of the element head also sits in a cupped area of the transfer arm when the element is suspended from the arm.

The transfer arm can then be rotated to a different position where another pickup tool can engage the element and lift it from the transfer arm, to allow the arm to be rotated away. If the element is at a transfer position, it can be placed in another transfer arm and moved to another spot. In this way, the element can be moved to any desired location or placed over the transfer chute for removal. Once in the desired location, the element is lowered into that grid position with the pickup tool.

A mechanical interlock between the index plate and a collar on the pickup tool assures the proper orientation of the fuel element relative to the upper grid plate, as the tool/element is lowered, allowing the rectangular element to be inserted into the rectangular grid plate opening. No distinction is made by the system between the two possible orientations 180° apart. The element is locked in the top grid plate by pressing down and rotating it counter-clockwise, approximately 90°. There is also a mechanical interlock between the tool collar and the index plate, which makes it impossible to disengage the pickup tool from a fully inserted fuel element, unless the locking bar has been rotated to the full lock position.

9.2.3.2 Transfer Chute and Receiving Mechanism

This portion of the transfer system consists of assorted valves and a pivoting hydraulic telescoping cylinder called the “refueling cannon”, because of its shape and horizontal to vertical pivoting capability.

Figure 9.7 is a view of the Reactor showing the fuel transfer chute.

Figure 9.8 is a schematic drawing of the transfer chute, receiving mechanism, and related valves.

The transfer chute has connections for helium and drain lines. The helium is available to dry and cool the element while it is in the transfer chute. This drying time while in the transfer chute is the way cross-contamination of the H₂O, and D₂O is prevented. Three remote operated valves in series separate the D₂O/He atmosphere of the reactor vessel from the H₂O in the pool canal and spent fuel pool. A telescoping cylinder (refueling cannon) is the receiving mechanism, which is on a pivot, so it can swing both horizontally and vertically. A small hydraulic cylinder that is supplied with H₂O from the Demineralized Water Experimental Cooling System controls this motion of the transfer cylinder. In the normal transfer procedure, the D₂O water level is lowered below the top of the transfer chute. This lower level is achieved by opening a fuel transfer overflow line, the top of which drains the D₂O in the reactor vessel to the desired level of approximately 70" (178 cm). Then, the D₂O is drained from the transfer chute and the middle valve (FTV-2) is opened. After sufficient time has been allowed for thorough draining, the bottom valve (FTV-3) is opened and the hydraulic cylinder is raised so its receiving end is above the water level in the canal. The upper valve (FTV-1) is then opened just prior to the element being lowered from its position above the transfer chute. The fuel element is then lowered until the element nozzle engages the matching receiver atop the hydraulic cylinder. The element is then released in the same manner as when releasing an element to a transfer arm. Since the element may be at a temperature above the boiling point of water, it will be necessary to close FTV-1 or FTV-2 to prevent any H₂O steam that is generated by the hot element in the canal from

contaminating the main D₂O system. As soon as the valve is closed, the element is lowered into the canal. When the cylinder is completely withdrawn, it is tipped to a horizontal position and extended so the element can be reached by conventional handling tools from the pool and placed in storage.

If necessary, it is also possible to return a partially spent element to the reactor by reversing the above procedure, as follows. Using the hydraulic cylinder, the element is inserted into the lock between valves FTV-2 and FTV-3 with FTV-1 closed. The element remains in this position for a few minutes to evaporate the H₂O on its surface. Then, the top valve is opened and a pickup tool is lowered to lift the element into the transfer mechanism.

9.2.3.3 Fresh Fuel Insertion

Fresh fuel elements are inserted through the top plug of the reactor. The plug over the transfer chute is removed, after raising the vessel level approximately 6" (15.2 cm) above the normal water level, and a fresh element is inserted through the hole into the transfer arm. Once on the transfer arm, the element can be transferred to any desired location and then placed in the core in the usual fashion.

In order to minimize the amount of tritium diffusing up through the 5" (12.7 cm) diameter hole during the brief time it is open, a cylinder projects below the D₂O water surface from the bottom of the plug so only a very small surface area is exposed to the hole. In this way only a few cubic inches of D₂O saturated helium is available to the hole instead of the whole gas volume over the surface of the vessel water. The presence of this cylinder also minimizes contamination of the helium cover gas by air.

9.2.4 Safety Considerations

9.2.4.1 Safety Provisions for Spent Fuel Handling

Spent fuel handling after reactor shutdown may not occur until a specific period of time has passed. Limiting Condition for Operation 3.7(2) of the NBSR Technical Specifications, requires that a fuel element shall not be placed in the fuel transfer chute or be otherwise removed from the reactor vessel unless the reactor has been shutdown for a period equal to or greater than one (1) hour for each megawatt of operating power level.

Experiments and measurements were carried out during initial startup on spent fuel elements in a dry environment. Eight hours after shutdown from 10 MW, the hottest element of the core, as defined by power distribution measurement, was removed from the vessel and suspended in the drained transfer chute. Its temperature was measured with an infrared pyrometer emissivity monitor. These results showed that the temperature of the spent fuel element stabilizes at approximately 550°F (288°C) without the need to operate any auxiliary cooling.

Extrapolation of these measurements, to an actual fuel element and for 20 MW operation, shows that with 20 hours cooling time after shutdown from 20 MW and without auxiliary cooling, the

maximum temperature for the hottest element would be approximately 800°F (427°C). For power levels below 20 MW, the specified waiting times would result in even lower fuel element temperatures. This 800°F (427°C) temperature is below the fuel blistering temperature range of 842°F to 1022°F (450°C to 550°C).

9.2.4.2 Safety Provisions of Transfer Chute

Great care has been taken to prevent a fuel element from becoming stuck in the transfer chute, and it is considered highly unlikely. Nonetheless, provisions have been made for auxiliary cooling. If the element is anywhere above the bottom valve, the valve can be closed and the chute flooded with water. Helium may be used to cool the element in the transfer chamber if the bottom valve were blocked from closing.

9.3 Fire Protection System

9.3.1 Passive Safety Components

The NBSR confinement building is constructed of steel and concrete. Most of the interior structures within are made of fire-resistant materials, which limit the amount of combustible materials in the facility. The large volume of water in the core tank would quickly extinguish any postulated fire in the reactor core. Also, the reactor safety system is fail-safe. Any upset condition caused by a fire, including loss of power, would result in the shim arms dropping into the core by gravity with spring assist. This assures implementation of safe shutdown of the reactor.

9.3.2 Active Safety Components

The NBSR is equipped with both automatic and manual fire detection capability. Manually operated pull boxes are located on all floors of the Confinement Building, Guide Hall, Pump House, and offices. There are also hose stations, smoke and heat detectors located throughout the facility. All detection devices tie into the NIST fire system, which is annunciated in the control room and throughout the reactor facility with audible and visual alarms, as well as at the NIST fire department.

9.3.3 Fire Prevention Measures

Inventories of flammable materials at NBSR, such as solvents, wood, and paper are minimized. If an experiment requires the use of a flammable or explosive substance, its use and allowed quantity are carefully reviewed. Additionally, the building is subject to periodic safety inspections. The NIST fire department also performs regular inspections and surveillance checks on both the NBSR building fire extinguishers and the hydrant system.

9.3.4 Fire Response Team

NIST maintains its own onsite fire department. They are operational 24 hours per day, seven days per week. They are fully trained on the risks present at the NBSR, and meet the NFPA requirements for fire fighting training. Additionally, NIST has a cooperative agreement with the local fire departments in the surrounding area.

9.4 Communication Systems

There are multiple means of communication at the NBSR. The site telephone system has two handsets available in the control room, with multiple handsets located throughout the buildings.

In addition to the NIST telephone system, there is also a page phone system. This is a two-line system that allows direct communication between two, or more page phone handsets. The page phone is also connected to a speaker system that allows announcements to be made to the entire building. These page phone handsets are located throughout the facility, including two in the control room. The NIST telephone system can also be used to access the page phone speaker system, allowing announcements to be made from any of the site telephone handsets.

Another method of communication is sound-powered phones. There are plug-in jacks located throughout the confinement building. This allows communication from locations where a telephone or page phone is not readily accessible.

The refueling system has a separate microphone/speaker system to allow communication between the refueling pool, control room, and reactor top. This system is primarily used during refueling, or operations involving fuel element manipulations in the storage pool.

NBSR also maintains a number of handheld radios for portable communications. NIST emergency personnel have monitoring capability. NIST has an emergency alarm system that allows one-way communications. Speakers located throughout the NBSR building allow NIST emergency personnel to communicate with the entire building, if it becomes necessary for emergency purposes.

9.5 Cover Gas Control and Processing

9.5.1 General Description

The Helium Sweep Gas System (Figure 9.9) provides an inert helium atmosphere over all vessels and tanks that normally contain heavy water (D_2O). These tanks are the reactor vessel, the D_2O storage tank, the emergency cooling tank, and the purge tank. The system also maintains the proper oxygen concentration in the sweep gas, and recombines any disassociated D_2O , which might be present.

One of two helium blowers circulates helium at approximately 20 cfm (0.6 m³/min) through a recombiner chiller and a section of line wrapped with 110 VAC tape heaters that goes into the recombiner. Heavy water vapor formed in the recombiner condenses and drains into the D₂O storage tank. Dry helium is then distributed to various components of the D₂O systems. A helium gasholder is provided to maintain a constant pressure on the system. Makeup is provided by six bulk helium tanks located outside, to the southwest of the confinement building. Two bottle banks consisting of four cylinders each serve as a backup supply. An installed cold trap condenser, using liquid nitrogen, is available as a heat sink for purging operations, thus recovering any D₂O vapors.

The thermal column system also uses helium as a cover gas, but its cover gas system is completely independent of the main helium system. A helium gas bottle located in the process room supplies this cover gas.

9.5.2 Component Description

The helium chiller is constructed of 3/16" (0.5 cm) aluminum plate, with a removable head capable of withstanding an internal pressure of 2.5 psig (117 kPa). NIST site chilled water supplies the cooling medium that removes moisture from the helium gas as the helium temperature is lowered. After sufficient moisture has been removed, tape heaters are used on the inlet pipe to the recombiner to pre-heat the incoming helium.

The helium blowers are pumps that use a circular rotor within a D₂O filled elliptical case. D₂O is supplied from the D₂O purification system. The blowers are electrically interlocked with a flow switch that prevents blower operation without this D₂O supply. D₂O fills a blade chamber when the rotor nears its closest point to the casing. As the rotor continues to turn, more space opens up between the blades and the casing. This allows D₂O to move out of the blade chamber and be replaced with helium from an inlet port within the center of the rotor. When the rotor again nears its closest point to the casing, D₂O fills the blade chamber, thereby forcing helium out of the discharge port located in the central core of the rotor. These blowers can pump about 20 cfm (9.4 liters/sec) of helium at a discharge pressure of 5 inches of water.

The helium recombiner is a cylindrical vessel made of 1/4" (0.6 cm) thick aluminum plate capable of withstanding an internal pressure of 15 psig (102 kPa) and a temperature of 200°F (93°C). The vessel has a removable flanged head to facilitate changing the 15 lbs (6.8 kg) of 1/8" (0.3 cm) diameter alumina-palladium pellets. These pellets are held in place with a .031" (.08 cm) diameter #7 mesh wire cloth basket. The pressure drop through the recombiner is 0.726 inches of water at a 20 scfm helium flow rate.

The cold trap is a cylindrical vessel made of schedule 10, 304 stainless steel, and will withstand an internal pressure of 15 psig (102 kPa). Thirteen 1-inch diameter tubes filled with liquid nitrogen are suspended from the upper flange. Sweep gas enters from the side, passes across the tubes, and exits from the bottom.

The gasholder is a 6061 aluminum cylinder, with a 5'11" (1.8 m) inside diameter and is 6'8" (2 m) high. Inside the holder is a traveling piston, which moves up and down to accommodate volume changes in the system. The piston has a rubber fabric seal, which travels with the piston and to prevent helium leakage. The piston is weighted to obtain the desired pressure on the system. Mechanical linkage connects the piston to a pointer and micro-switch arrangement for level indication, high and low volume alarm, and operation of a relief valve. In addition, there is a backup relief valve that is mechanically connected to the gasholder diaphragm. A carbon filter, made up of activated charcoal enclosed in an aluminum tank fabricated from 1/4" (0.6 cm) plate, is used when samples are drawn from the cold trap. The helium seal filter made of activated charcoal cartridges contained in a 1/4" (0.6 cm) thick aluminum tank, prevents the release of radiolytic gases to the process room.

9.5.3 Instrumentation and Control

Instrumentation is provided to indicate the volume of gas contained in the gasholder and helium flow in the system. Temperature controls and indicators for heater and recombiner internal and outlet temperature are also provided. There is remote indication of recombiner inlet/outlet pressure on the Control Room console, and local indicators of inlet pressure of the helium blowers, bulk tank pressure, bulk tank supply header pressure, and bottle bank header pressure.

9.6 CO₂ System

9.6.1 General Description

The CO₂ Gas System (Figure 9.11) provides a means of purging all air from the cavity between the reactor vessel and the thermal shield. The pneumatic irradiation or rabbit system is also purged and filled with gas from the CO₂ system, which operates slightly above atmospheric pressure, with a flow rate of 5.5 cfm (2.6 liters/sec). The purpose of this purging with CO₂ is to remove the air, preventing argon activation in areas of high neutron flux.

The CO₂ gas is supplied from a bulk storage tank located outside of the confinement building. The cavity purge is supplied directly from this tank through a flow controller set at approximately 5.5 scfm. This flow controller is located on the B1 mezzanine level within the confinement. If the cavity purge system reaches a pressure of 5" of water (0.2 psia), COV-43 opens and relieves pressure to the irradiated air system.

The first pressure regulator in the system is designed to maintain a system pressure of 25 psig. COV-29, a singled-seated, diaphragm operated, air-to-open valve, controls gas holder level automatically. Downstream of COV-29 there is a pressure regulator that limits pressure to approximately 5" (0.2 psia) of water. The gasholder is recharged and used to maintain a slight positive pressure on the rabbit system and take up any volume changes due to expansion and contraction of the gas. When the gasholder reaches a level of 45" (1.4 psia), relief valve COV-44 opens and relieves pressure to the irradiated air system. Another relief valve, which is mechanically connected to the diaphragm of the gasholder, relieves to the confinement

atmosphere. CO₂ to the cold neutron source facility and the flexo-rabbit system is also supplied from this system.

9.6.2 Component Description

The bulk storage tank supplies the CO₂ gas for this system. Pressure is maintained automatically within a preset range by either operating a set of heaters to raise tank pressure or operating a vaporizer refrigerator system to reduce the tank pressure.

The gasholder is a carbon steel cylinder that is 6'8" (2 m) high and has a 5'11" (1.8 m) inside diameter. Inside the holder there is a traveling piston, which moves up and down to accommodate volume changes in the system. The piston has a rubber fabric seal, which travels with the piston and prevents CO₂ leakage. The piston is weighted to obtain the desired pressure on the system. Mechanical linkage connected to the piston and a pointer provides volume indication on the side of the gasholder. Microswitches located on the side of the holder and actuated by the pointer produce remote high and low level alarms in the control room.

9.6.3 Instrumentation

Instrumentation is provided to sense system pressure and gas holder diaphragm levels. Pressure indicator controller PIC-101 senses the system pressure and controls relief valve COV-43, which will open on a high-pressure signal to prevent over-pressurization of the system. There is local pressure indication on the gasholder, with indication and both high and low pressure alarms available in the control room.

9.7 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 the NBSR ensure the air is clean and dry. This system uses air receiver tanks that can supply some loads in the event that the NIST air supply and both air compressors are lost. Additionally, the actuators for the dampers/valves that isolate confinement each have individual air receivers that can be used by the reactor operator to position them in the event that NIST air and both air compressors fail.

An air line enters NBSR through the cold lab basement, and is distributed from there to supply instrument air to pneumatic valve operators, ventilation control valves, various air ejectors, and other components in the reactor confinement building, the Guide Hall, the Pump House and laboratory spaces. Multiple pressure valves and regulators in the system are used to adjust air pressure to the desired level. In addition, the seals for the confinement isolation doors, HVAC damper control solenoids, valves on the Beam Tube and Neutron Guide, the water treatment system, fuel transfer system, and storage pool level controls are all supplied by this air system. 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. 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. The basement atmosphere provides the local suction. When the air pressure drops below 85 psi (578 kPa), it is annunciated in the control room and the operator can verify low air pressure by reading the compressed air pressure gauge, either in the control room or locally. 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. This system is depicted in Figure 9.12.

9.8 Plant Chilled Water System

The chilled water system is supplied from and returned to the main NIST chilled water facility. Most of the chilled water used at the NBSR is in support of the experimental facilities. Chilled water also supplies cooling to chillers in many rooms of the reactor building for climate control. The chilled water enters the building at approximately 45°F (7°C). Most of the piping is insulated to prevent condensation.

The secondary side cooling of the fuel storage pool heat exchanger, HE-8, is provided by the chilled water system. Chilled water is passed through a filter system to limit fouling of the heat exchanger. A manual valve controls the chilled water flow rate. The storage pool heat exchanger is described in greater detail in Section 9.9. The helium chiller previously described in Section 9.5 is also supplied by the chilled water system.

9.9 Storage Pool Cooling

9.9.1 General Description

Figure 9.13 depicts the Fuel Storage Pool Cooling System. This system removes the decay heat from the spent fuel in the storage pool and provides a means of maintaining the water clarity and purity by removing any particulate matter that may be present. Demineralized water is circulated through the system by one of two storage pool circulating pumps. One pump is normally operated with the other in standby. The running pump takes its suction from a collection basin and provides 75 gpm (4.7 liters/sec) to the storage pool heat exchanger (HE-8). The storage pool water inlet temperature to HE-8 is approximately 72°F (22°C) and the outlet temperature is about 50°F (10°C). This can vary depending on the temperature of the chilled cooling water entering the secondary side of heat exchanger. The outlet flow is split with 65 gpm (4.1 liters/sec) returning directly to the storage pool and the other 10 gpm (0.6 liters/sec) is sent through a cleanup loop, consisting of a booster pump, pre-filter, ion exchanger, and after-filter. This water is then returned to the storage pool. Priming of the pumps to ensure adequate suction head for each pump is accomplished by filling each circulating pump's volute from a demineralized water source from the water treatment system.

Reactor fuel elements and other reactor related components are manipulated and stored in the storage pool. Spent fuel and other irradiated material movements are conducted underwater to

afford adequate shielding of personnel. All spent fuel remains in the pool until it is shipped off site.

The storage pool contains demineralized, light water from the water treatment system. Water losses from the pool are automatically made up by a storage pool level control system. A level instrument senses the storage pool level and sends an appropriate signal to valve WTV-1, which in turn controls the makeup flow of demineralized water from the water treatment system. A level instrument in the pool basin (or pump pit) will send a signal to shut WTV-1 on a high level indication. WTV-1 will return to normal only after this instrument resets at a normal pump pit level. A float type level instrument in the pump pit acts as a backup to ensure closure of WTV-1.

9.9.2 Component Description

The storage pool is 18'2" (5.5 m) deep, 20' (6.1 m) long, and 10' (3 m) wide. When filled to its operating level with water it contains approximately 30,000 gallons (113,550 liters). A canal extends from one end of the pool to the sub-pile room for the purpose of passing spent fuel from the reactor vessel dropout chute to the storage pool. A collection basin is located at the other end of the storage pool, which is used for potential storage pool overflow. This collection basin provides the net positive suction head for the circulating pumps. A 6" (15.2 cm) high curb is also provided around the edge of the storage pool.

Two identical 75 gpm (4.7 liters/sec) centrifugal pumps driven by 2 hp motors at 1,730 rpm provide for the circulation of the storage pool water. Both pumps are controlled from the control room by means of hand-operated switches. One pump is normally running and the other is in standby. Should the running pump trip, the standby pump will start automatically. Pump 1 is powered from motor control center MCC-A3, and pump 2 is powered from MCC-B4, which provides a measure of redundancy.

The storage pool heat exchanger is of plate-and-frame construction, and has a flow pattern that is single pass and counter-flow. Hot storage pool water flows at 75 gpm (4.7 liters/sec) through channels formed by a series of gasketed embossed plates. On the opposite sides of the plates, chilled secondary water flows at 65 gpm (4.1 liters/sec) in a counter direction through identical channels, with each plate serving as the heat exchange medium. The heat exchanger has a carbon steel frame and stainless steel plates. The heat exchanger's maximum heat transfer rate is 450,000 Btu/hr (131.9 kW) from the storage pool to the chilled water system.

There is one 10 gpm (0.6 liters/sec) centrifugal booster pump driven by an electric 1 hp motor that circulates the storage pool water through the purification section of the system. The pump is normally running and manually controlled from the control room. It is powered from MCC-B4.

Two 5 micron, cellulose fiber, cartridge filters are installed at the inlet and outlet of the ion exchanger. The filter housing and metal internals are made of 304 stainless steel and designed to withstand a pressure of 125 psig (850 mPa).

One 6.5 ft³ (0.2 m³) mixed bed ion exchanger maintains the purity and clarity of the storage pool water. This ion exchanger uses an HOH resin. The vessel is made of 304 stainless steel and is designed for operation at 110 psig (748 mPa) and 110°F (43°C).

The storage pool circulation system consists of 2" (5.1 cm) diameter aluminum piping and valves, except for the purification section, which is 1-1/2" (3.8 cm) diameter aluminum piping and valves. Most of the system is wrapped with insulation to reduce cooling losses and condensation. All components in this system have isolation capability, and the purification system filters have bypass capability.

9.9.3 Instrumentation

Storage pool system instrumentation provides the capability to monitor storage pool water level, pool cooling flow, purification flow, pressure drop across the filters, and conductivity of storage pool water. A low water level in the storage pool will alarm in the control room.

9.9.4 Design Considerations

The storage pool cooling system is designed to remove the heat generated by two full core loadings of spent fuel and an additional number of spent fuel sections that would exist from element cutting operations. The temperature of the pool water is maintained at approximately 50°F (10 °C).

Impurities are removed from the water to provide the required optical clarity for manipulation of spent fuel or refueling operations. Since some of these impurities would be radioactive, their removal will reduce the radiation levels emanating from the pool surface. The filters remove suspended solids that are 5 microns or larger in size. The system operates with a turbidity not to exceed 2 ppm and a pH of 6 to 8. Principle metal components in contact with the pool water are made of stainless steel and aluminum.

9.10 Thermal Shield Cooling System

9.10.1 General Description

The Thermal Shield Cooling System, shown in Figure 9.10, removes the heat deposited in the thermal shield. During normal operation one of two pumps will circulate 350 gpm (22.1 liters/sec) of demineralized water through the system to cool portions of the lead thermal shield. During normal operation, the control switch for the second pump is placed in the standby position so that it will start automatically in the event the running pump stops. Both pumps and their respective discharge valves are controlled from the control room.

Thermal shield cooling water circulates through the primary side of heat exchanger (HE-6) where it gives up heat to the secondary side coolant. Shell side cooling is provided by the secondary cooling water system. At 20 MW the thermal shield cooling water inlet temperature is approximately 95°F (35°C) with the outlet at 90°F (32°C). At the heat exchanger outlet, 10 gpm

(0.6 liters/sec) is diverted from the main cooling header to a purification system consisting of a pre-filter, two ion exchange columns, and an after-filter. The purification system is made operational when either ion exchanger inlet valve (TSV-3 or TSV-4) is opened. Both valves can be operated remotely from the control room. The purified water is returned to the thermal shield cooling system storage tank.

In the main header, 350 gpm (22.1 liters/sec) of thermal shield cooling water goes to the upper ring header and the lower ring header (first floor trench), which are the distribution points for the thermal shield cooling water. From the lower ring header approximately 35 gpm (2.2 liters/sec) is provided for cooling five lower piping shielding sleeves and the bottom shield bedplate. The upper ring header provides approximately 315 gpm (20 liters/sec) to 189 cooling tubes imbedded in the 2" (5.1 cm) lead thermal shield. These tubes supply beam tube sleeves and lead shielding near the nuclear detectors, the cryogenic facility beam tubes, and the thermal column.

Cooling water from the return headers is collected in the 1,450 gallon (5,678 liters) storage tank that provides the suction head for the circulating pumps and acts as a surge tank to accommodate any expansion or contraction of the coolant. In the return header to the storage tank there is automatic valve TSV-6, which opens and closes as pumps are started and stopped. This is to keep the tubes filled with water when the pumps are shutdown and prevents water hammer in the system when the pumps are started.

9.10.2 Component Description

There are two identical 670 gpm (42.2 liters/sec) single stage centrifugal pumps, which circulate the thermal shield coolant through the system. They each have a bronze casing and impeller with a stainless steel shaft. The pumps are controlled from the control room and are interlocked so that if one should stop, the other pump will start automatically, with the control switch in the standby position. The pumps have Soft-Start type controllers that reduce the initial water surge when a pump is started by increasing the time it takes for the motor and pump to achieve full speed. Both pumps are also interlocked with Storage Tank Return Valve TSV-6. This valve will open when either pump is started and will close when both pumps are off, unless the valve control switch has been placed in the open position, which will cause the valve to remain open. Each pump has a discharge valve (TSV-1 and TSV-2) that may be opened from the control room and they also have a standby pump start/open valve interlock. Circulating pump No.1 receives its electrical power from MCC-A5 and pump No. 2 is powered from MCC-B6.

HE-6 is a 2.8×10^6 Btu/hr (762 kW) plate-and-frame heat exchanger that transfers heat from the thermal shield cooling water to the secondary cooling water. Hot thermal shield water flows through channels formed by a series of gasketed embossed plates. On the opposite sides of the plates, cold secondary water flows in the other direction through identical channels, with each plate channel forming the heat exchange medium. Secondary cooling water circulates on one plate side at the rate of 500 gpm (32 liters/sec) and thermal shield cooling water on the opposite side of the same plate at the rate of 350 gpm (22.1 liters/sec). The shield cooling water enters the heat exchanger at 95°F (35°C) and leaves at 90°F (32°C) during 20 MW operation. A temperature controller automatically throttles the amount of incoming secondary water through

the heat exchanger. Flow of thermal shield cooling water is regulated by a second temperature controller that automatically throttles the amount of incoming thermal shield water through the heat exchanger. Design pressure of the heat exchanger is 125 psig (850 kPa) at 250°F (121°C).

The shield cooling storage tank is constructed of copper and has a design pressure rating of 15 psig (102 kPa). It has a level transmitter that provides for a remote read-out in the Control Room.

Filters in the purification system are replaceable, 5 micron, cellulose fiber type units. There are six cartridges to a unit. Both the filter housing and internals are constructed of 304 stainless steel and designed to withstand an internal pressure of 125 psig (850 kPa).

There are two 6.5 ft³ (0.2m³) mixed bed ion exchange columns in parallel that maintain the purity of the shield cooling water. Either bed can be placed in operation from the Control Room by opening or closing valves TSV-3 and TSV-4. The ion exchanger vessel is made of type 304 stainless steel and is designed to operate at 110 psig (748 kPa) and 110°F (43°C). Each ion exchanger is filled with mixed bed HOH resin.

9.10.3 Instrumentation and Control

Primary instrumentation in this system includes the measurement of temperature, flow, and conductivity.

System temperature indication is provided by five installed sensors: TI-24 in the return ring header; TIA-23 in the return floor header; TI-22 at the storage tank inlet; TIA-16 at the heat exchanger outlet, and TIA-17 on the secondary outlet of the heat exchanger. All channels have indicators and alarms, except TI-22, which does not have an alarm.

FIA-16 is an orifice element that measures the flow through the purification section of the system. It indicates and provides a low flow alarm on the console in the Control Room. FIA-15 measures the flow in the main coolant supply line. It is a Venturi type element that supplies a D/P cell, which in turn provides indication, and a low flow alarm. The low flow alarm will cause a shutdown.

Conductivity is measured at two locations in the system, CIA-6 at the outlet of the heat exchanger, and CIA-7 on the outlet of the ion exchangers. This instrumentation provides both indication and alarm functions in the Control Room.

LIA-8 measures the level of the storage tank. It provides both indication and alarm functions in the Control Room.

There are six control valves in the system: TSV-1 and TSV-2, the circulating pump discharge valves; TSV-3 and TSV-4, the ion exchanger inlet valves; TSV-15, the heat exchanger bypass valve; and TSV-6, the coolant storage tank return valve. These valves are air operated, and are

remotely operated from the Control Room. All valves, except TSV-15, have limit switches that indicate valve position.

9.11 Thermal Column Tank Cooling System

The Thermal Column Tank Cooling System shown in Figure 9.14 provides cooling to the bismuth shield and enhances the thermalization of neutrons for use in the graphite thermal column. This cooling system is completely independent of the primary D₂O system. The system consists of the main Thermal Column Tank, which is constructed to fit the outside curvature of the reactor vessel and contains an interior tank that is filled with approximately 7,600 pounds (3,447 kg) of bismuth and has a heavy water coolant volume of 240 gallons (908 liters). Other system components are a surge tank, two pumps, a heat exchanger, and a filter system. A flow controller provides both indication and control of the flow in the system. A low flow condition will cause an alarm and a rundown of the reactor shim arms.

Heavy water coolant enters the thermal column tank and flows upwards and above the top of a bismuth shield. It leaves the tank at the bottom of this shield. The water flows into a surge tank that provides suction to the thermal column pumps. The tank has a low level alarm and a low level trip for the pumps that prevents cavitation due to low suction head from decreasing tank level. These pumps move the heavy water coolant through a filter system, a heat exchanger, and back to the main thermal column tank. The secondary cooling system provides secondary side cooling of the heat exchanger. Although the thermal column tank remains nearly full of D₂O, a small cavity on the other face of the bismuth shield has the water level maintained by an elevated "U" bend in the outlet line. Another "U" bend vented to the gas space of the D₂O storage tank provides for overpressure relief. Normally there is a 1" (2.4 cm) gas space between the top of the bismuth shield and the top of the thermal column tank. A helium bottle maintains a constant helium pressure blanket on the system.

9.12 Experimental Demineralized Water Cooling System

The Experimental Demineralized Water Cooling System shown in Figure 9.15 circulates demineralized water through a closed loop to provide a supply of cooling water at each experimental facility, if needed. One of two circulating pumps circulates the coolant through a heat exchanger (HE-7), where the heat from the system is transferred to the secondary cooling system. Normally the system is operated only to supply water pressure for the refueling cannon, since fuel transfer operations generate little heat.

Subsequent to passing through the heat exchanger, the coolant goes to a header where water is made available for cooling experiments, the cold neutron source facility, and the refueling cannon. A pressure-control bypass valve (DCV-1) regulates the recirculation flow to prevent system overpressure when flow is stopped to an experiment, and to prevent low system pressure when flow is established to an experiment. This automatic bypass regulates the experimental cooling by maintaining system pressure under varying load conditions. From the supply header 10 gpm (0.6 liters/sec) is diverted to the purification section of the system where the coolant undergoes filtration and ion exchange. This 10 gpm (0.6 liters/sec) is returned to the storage tank

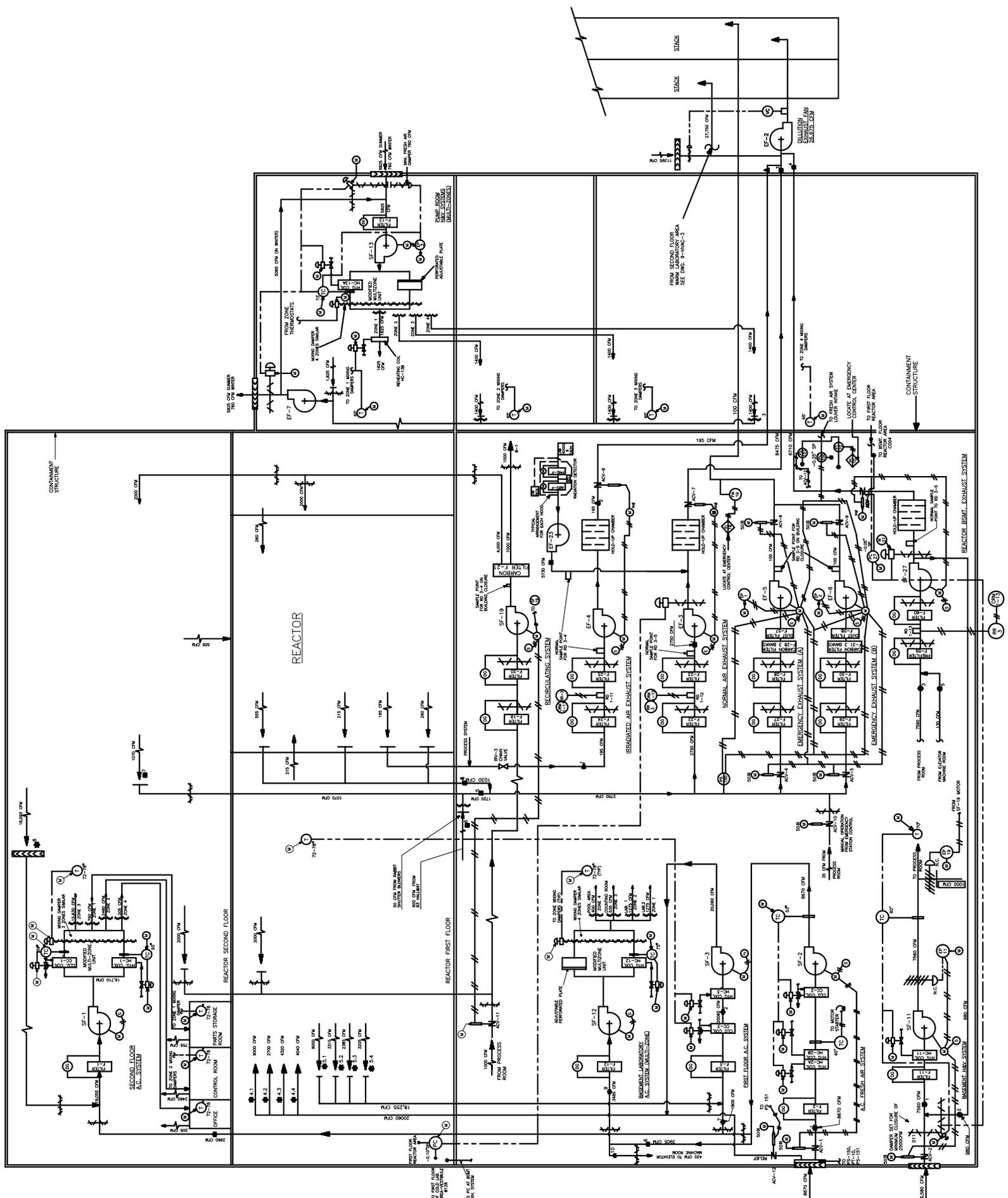
with the coolant from experiments and the bypass. In addition, there is a 1" (2.5 cm) supply and return line to the subpile room for the installation of cooling for future experiments.

The storage tank has a capacity of 2,400 gallons (9,084 liters). It acts as a surge tank to accommodate the expansion and contraction of the coolant, and provides the suction head for the two circulating pumps. These centrifugal pumps are powered from MCC A-5 and MCC B-6. The storage tank is vented to the irradiated air system, and make-up water to the system is supplied from the water treatment system.

9.13 D₂O Experimental Cooling System

The D₂O Experimental Cooling System distributes heavy water from the Primary Coolant Purification System to cool the NBSR experimental equipment and is discussed in detail in Section 5.7.

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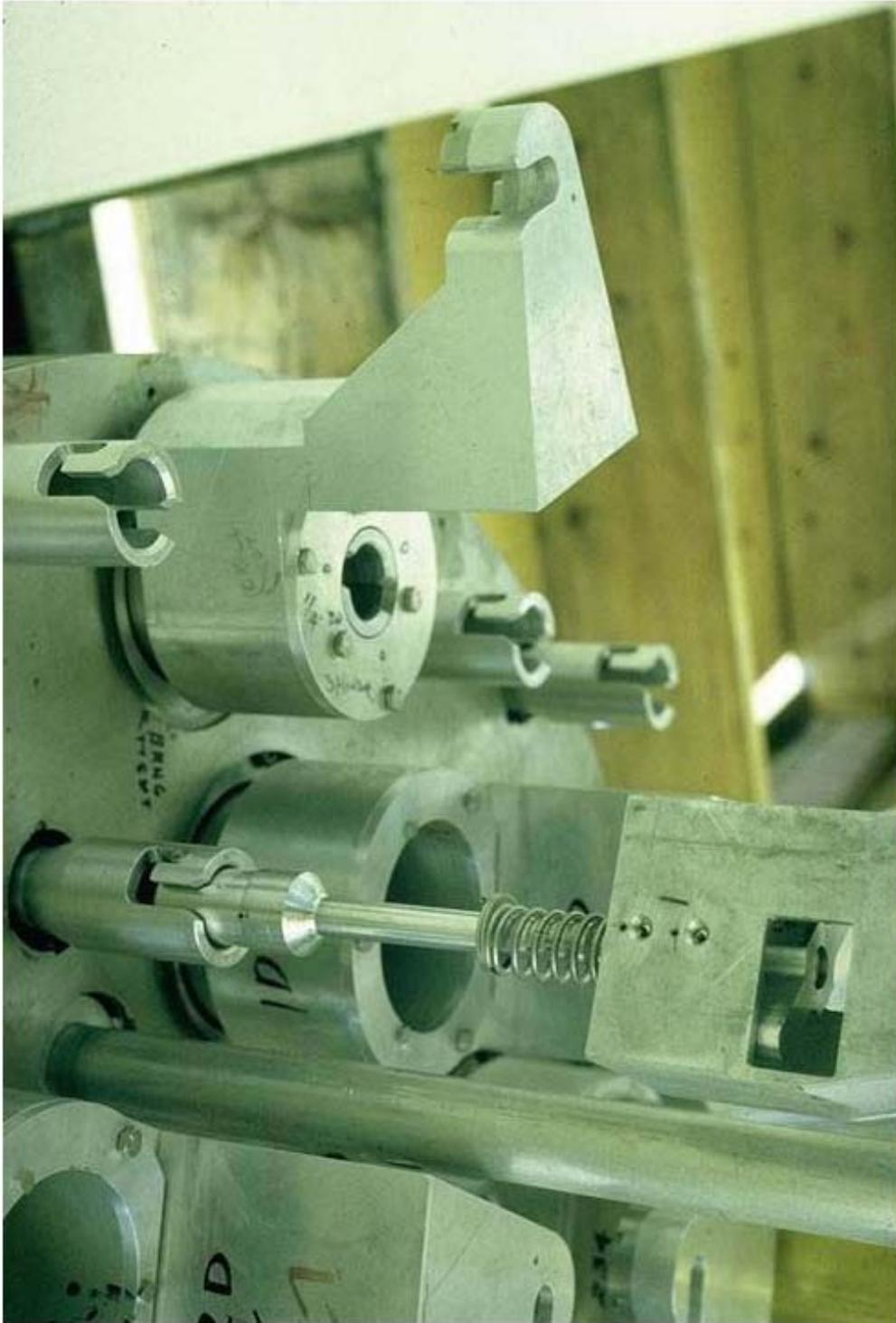


Figure 9.2: Details Of Transfer Arm, Pickup Tool, And Fuel Element Head

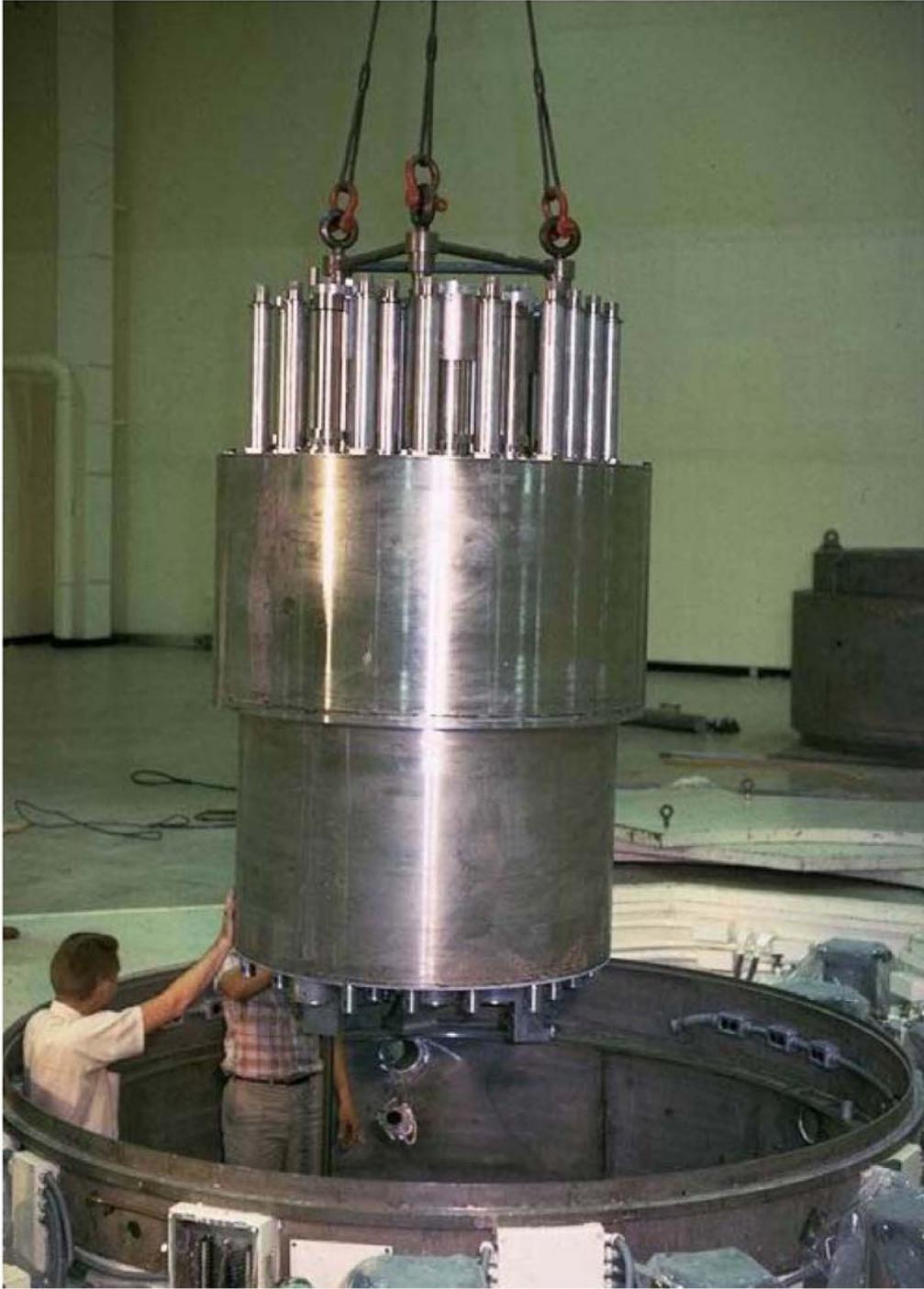


Figure 9.3: Fuel Transfer Plug Side View

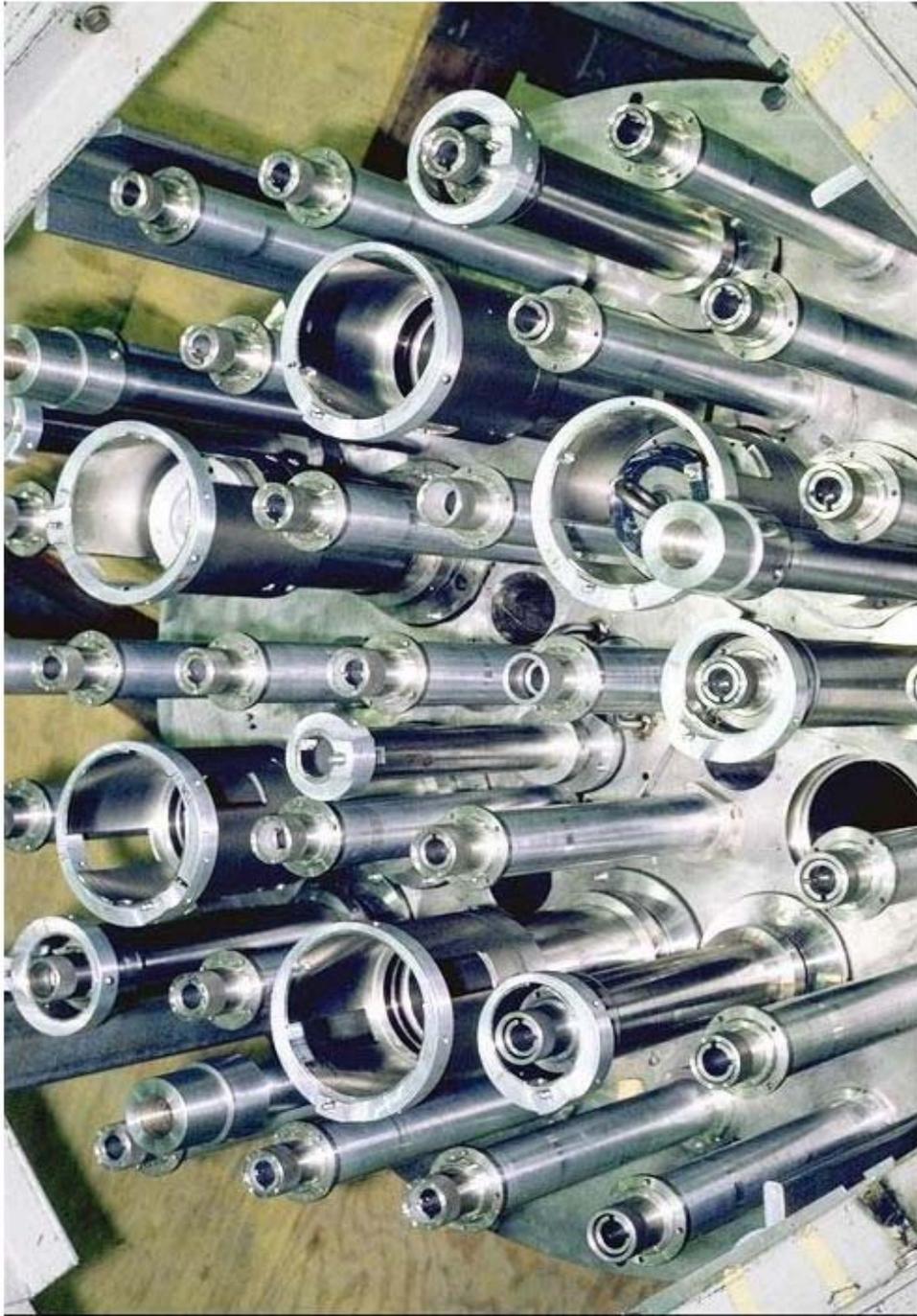


Figure 9.4: Fuel Transfer Plug Top View – Mounted In Test Stand

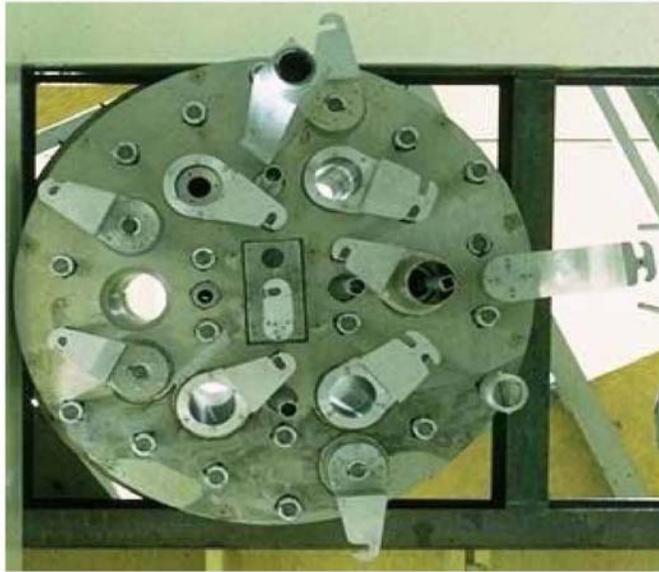


Figure 9.5: Fuel Transfer Plug Bottom View

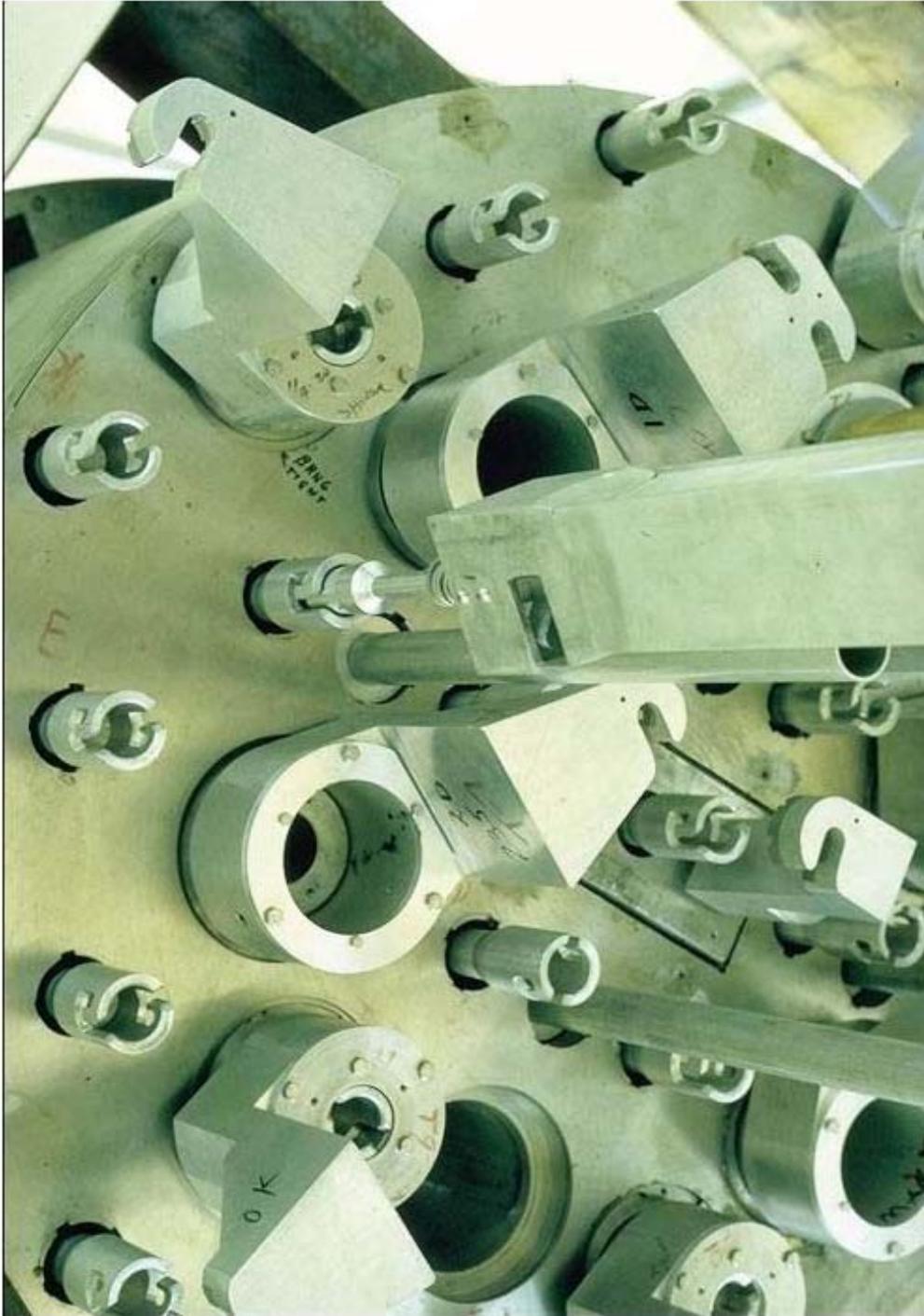


Figure 9.6: Fuel Transfer Plug – Bottom View with Fuel Element

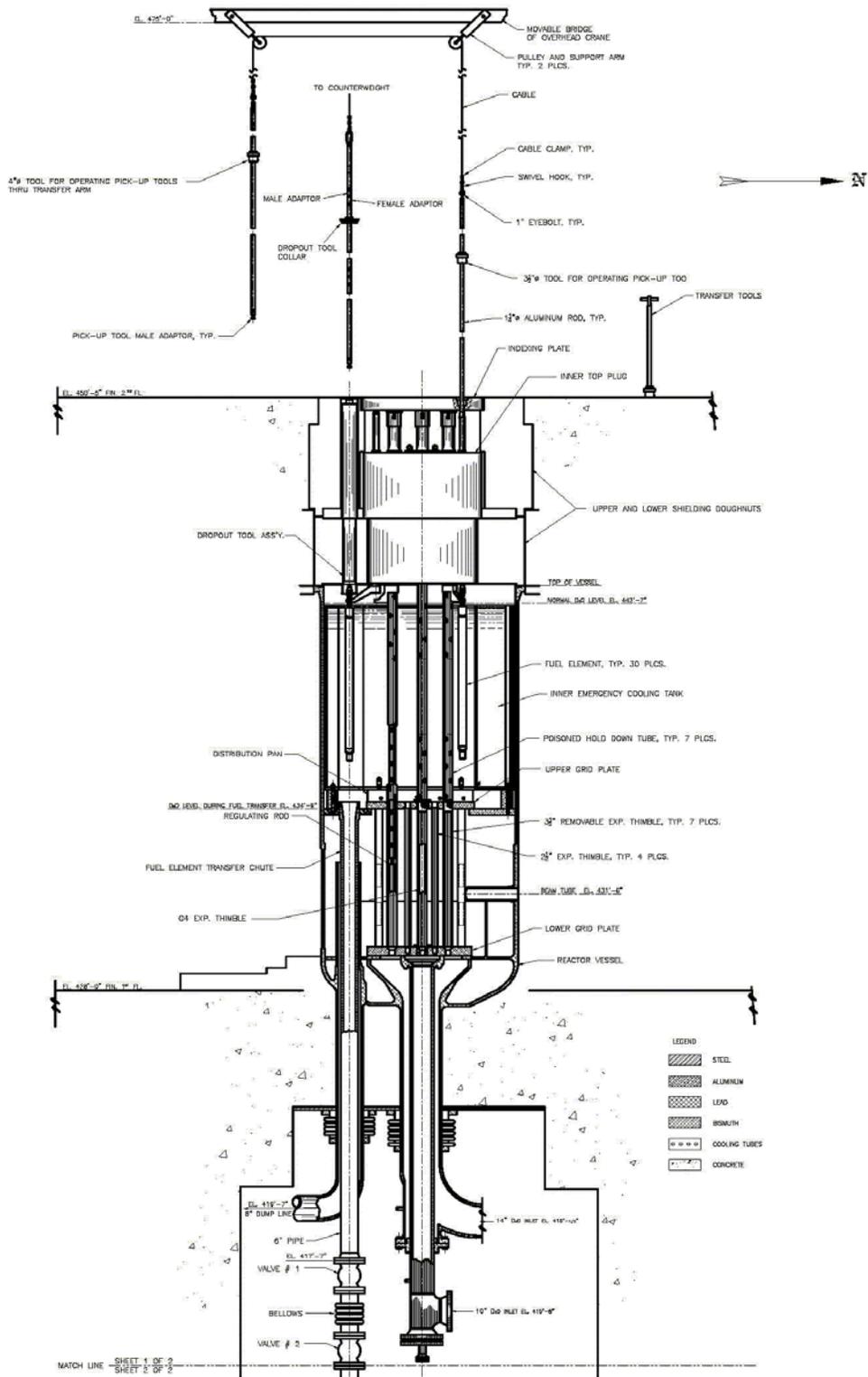


Figure 9.7: Elevation View of Reactor

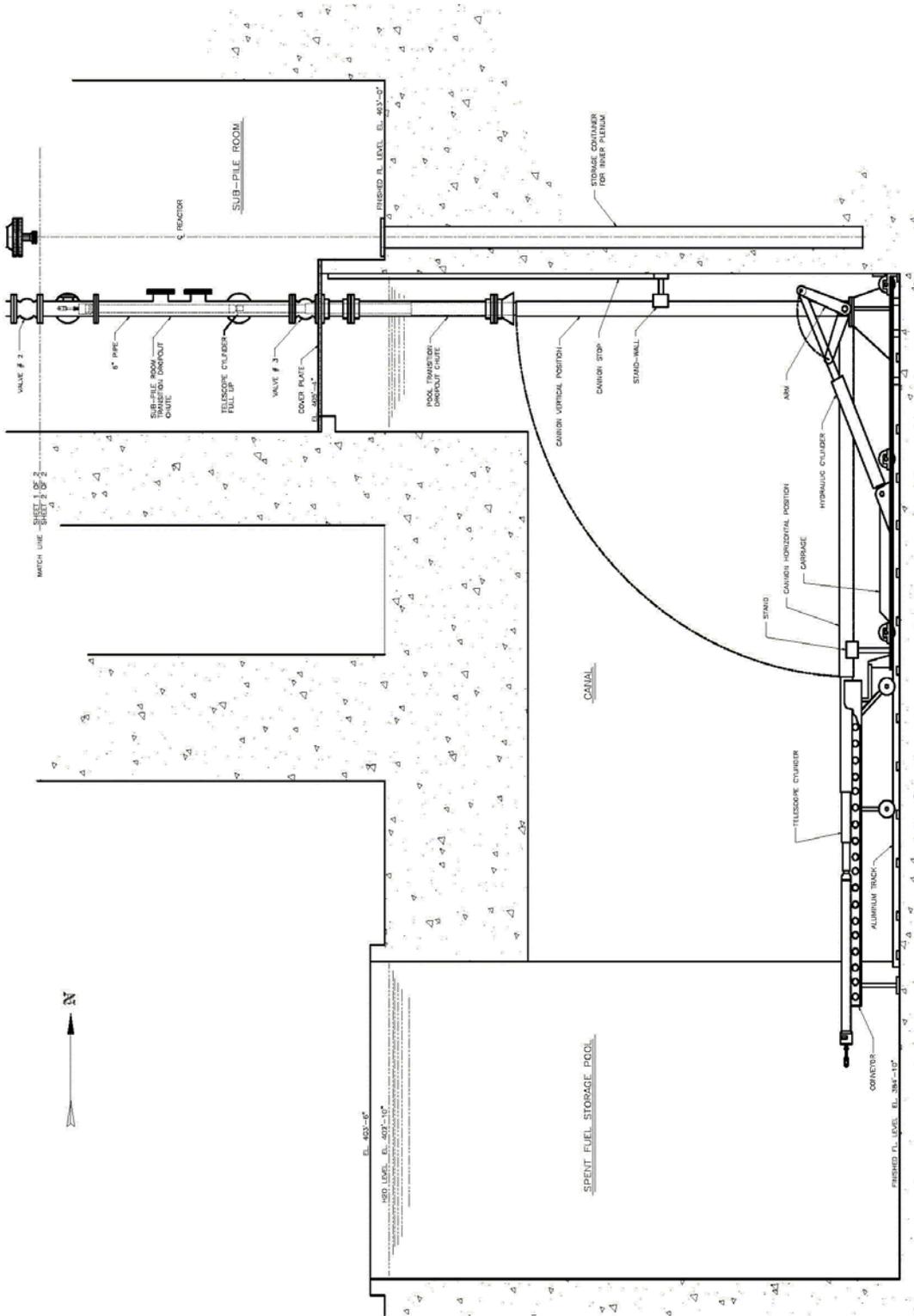


Figure 9.8: Elevation View of Fuel Transfer System

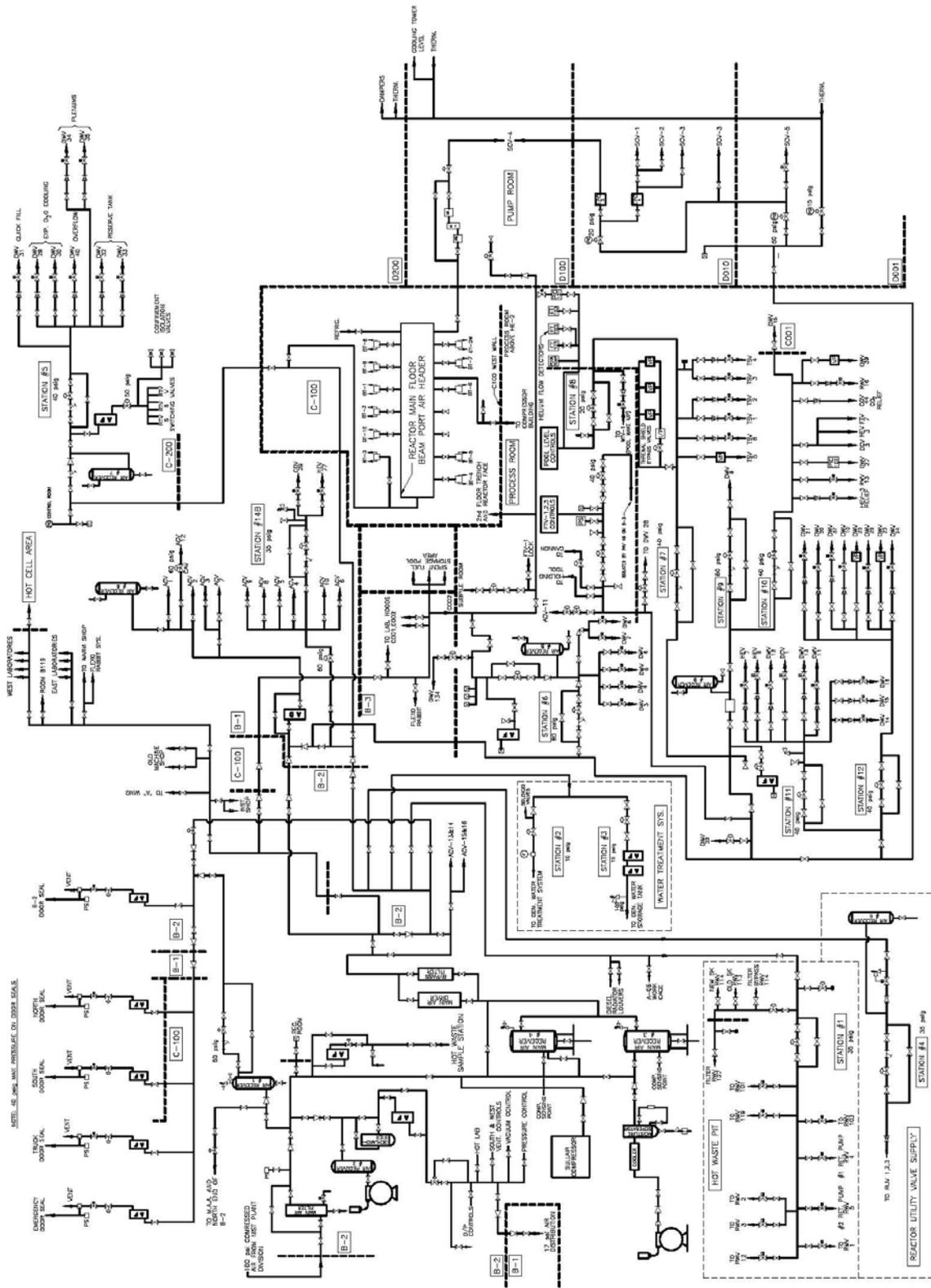


Figure 9.12: Instrument Air System

