NRIC National Reactor Innovation Center

ZPPR Test Bed (ZTB) Pre-Conceptual Design Report

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ACRONYMS

ANSI	American National Standards Institute
COP	Concept of operations
DBA	Design Basis Accident
DMZ	Demilitarized Zone
DOE	U.S. Department of Energy
EBR-II	Experimental Breeder Reactor-II
ECC	Emergency Control Center
EML	Electron Microscopy Laboratory
ETB	EBR-II Test Bed
FMF	Fuel Manufacturing Facility
IMCL	Irradiated Materials Characterization Laboratory
INL	Idaho National Laboratory
kWe	Kilowatts of electric power
kWth	Kilowatts of thermal power
MBSE	Model-based Systems Engineering
MEAAL	Master Equipment and Activities List
MFC	Materials and Fuels Complex
NDC	NPH Design Category
NEICA	Nuclear Energy Innovation Capabilities Act
NPH	Natural Phenomena Hazards
NRIC	National Reactor Innovation Center
P&ID	Piping and Instrumentation Diagram
PFCN	Private Facility Control Network
PLC	Programmable Logic Controller
R&D	Research and Development
RDP	Reactor Demonstration Project
SBS	System Breakdown Structure
SSC	Structure, System, or Component
SDC	Seismic Design Category
SE	Systems Engineering
SME	Subject Matter Expert
VESDA	Very Early Smoke Detection Apparatus
VFD	Variable Frequency Drive
WBS	Work Breakdown Structure
ZPPR	Zero Power Physics Reactor
ZTB	ZPPR Test Bed

1. INTRODUCTION

The National Reactor Innovation Center (NRIC), established by the U.S. Department of Energy (DOE) in August 2019, accelerates the demonstration and deployment of advanced nuclear energy through its mission to inspire stakeholders and the public, empower innovators, and deliver successful outcomes through efficient coordination of partners and resources. NRIC is a national program led by Idaho National Laboratory (INL), enabling collaborators to harness the world-class capabilities of the U.S. National Laboratory System. Committed to demonstrating advanced reactors by the end of 2025, NRIC is designed to bridge the gap between research, development, and the marketplace to help convert some of the Nation's most promising advanced nuclear reactors into commercial applications by 2030.

To meet these needs, NRIC is developing two reactor demonstration test beds at Idaho National Laboratory (INL), the Zero Power Physics Reactor (ZPPR) Test bed (ZTB) and the EBR-II Test bed (ETB). ZTB will support the demonstration of systems that operate at less than 500 kWth. The baseline objective is for the ZPPR Cell to act as a confinement structure capable of siting reactors that utilize Safeguards Category 1 material for operations. The major areas addressed in the pre-conceptual design include:

- Installation of an access door
- Electrical Power
- Heat Removal
- Ventilation in the Cell
- Reactor Installation.

Along with the design for ZTB, a concept of operations (COP) has also been developed. The COP is intended to facilitate a common understanding of ideas, challenges, and issues. As systems continue to evolve in complexity, the NRIC program will utilize and update the COP to develop and sustain a common vision of the system for stakeholders.

1.1 Purpose and Scope of the Pre-conceptual Design Activities

NRIC has developed a pre-conceptual design for ZTB during Fiscal Year (FY) 2020. The purpose of the design is to:

- Develop a set of Functional and Operational Requirements (FOR) for ZTB
- Investigate and identify critical issues
- Develop initial system concepts
- Identify high-cost, high-impact activities
- Develop a Level 5 cost estimate to implement ZTB.

2. SYSTEMS ENVISIONED TO ENABLE ZTB TEST BED PROGRAM

2.1 Description of Systems

The systems described in this section of the pre-conceptual design report are those main systems necessary to meet the requirements identified in FOR-538 [1]. The pre-conceptual design does not cover all aspects of all systems but concentrates on the aspects necessary to demonstrate viability of the ZTB project. An overview of the ZTB exterior structure is shown in Figure 1.

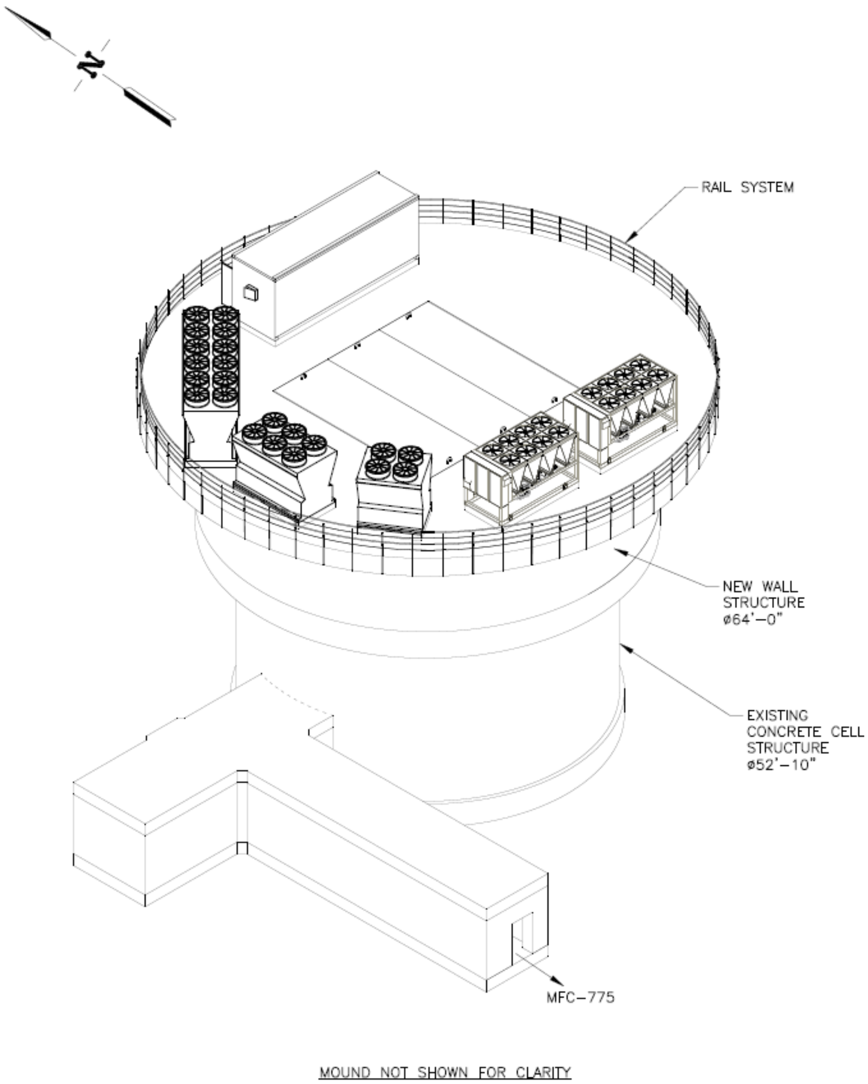

Figure 1. ZTB Exterior Structure Overview

2.1.1 Assumed Safety Classification

While it is understood that the final safety classification of all equipment associated with the ZTB will be determined by following the process defined in DOE-STD-1189-2016 [2], the design team made preliminary assumptions about safety classification of structures, systems, and components (SSCs) to enable efficient design and cost estimating. The distinction between safety-significant and safety-class was not a large area of interest since it was an assumption that active safety systems would be avoided. With passive systems, the design was not anticipated to change significantly between safety-significant and safety-class equipment. The assumption was made that systems would generally be safety-class as a bounding scenario. With this framework, the following assumptions about safety classification were made:

1. ZPPR Cell Confinement – Safety class for leak tight boundary and structural integrity during and after NDC-3 hazards
2. Ventilation System – Safety class for passive filtration and isolation
3. Over/Under Pressure Protection – Safety class to protect structural integrity
4. Backup Batteries – Safety class for power

An exception to the passive system assumption is that provisions have been included in the pre-conceptual design to allow for some limited amount of safety-class power at 24V. This assumption was made to be able to support a limited amount of reactor monitoring in accident scenarios and/or take a very limited target action (e.g., operate a solenoid valve for a short period). The pre-conceptual design of this battery power system satisfies the design criteria for active safety-class systems.

2.1.2 Building Structure and Infrastructure

2.1.2.1 ZPPR Cell Structure

The existing ZPPR cell structure is a 50-foot inner diameter reinforced concrete cylinder with 16-inch walls. At the top of the cylinder is an integral 6-foot, 11-inch wide and 4-foot, 6-inch tall ring beam. There are two openings into the cylinder, one to the west from the normal access corridor and one to the northeast for the emergency egress tunnel. The concrete portion of the structure is approximately 32.5 feet tall measured from the floor level. A steel super structure sits on top of the ring beam. The steel structure is a 24-sided polygon approximating a circular structure which extends beyond the ring beam approximately an additional 4 feet. The steel structure is roughly 28 feet tall. An earthen mound (see Figure 2) surrounds the structure (covers the corridor, workroom, and vault) from grade up to a height 27.5 feet above the floor level, 5 feet above the top of the ring beam (5 feet of the steel structure is buried). Figures 3 and 4 provide an elevation view of the current structure and the extent of the mound.

Figure 2. Picture of ZPPR Cell Mound

A catenary cable system is supported from the ring beam. The low point of the catenary cable system is approximately 23.5 feet above the floor inside the cell. The catenary cable supports about 21 feet of gravel and sand layers that fill the steel structure.

The original design of the ZPPR cell limited the total load applied to the floor to 250 tons. This total load limit was anticipated to be challenged by the equipment and shielding structures of reactor demonstration projects (RDPs). A structural evaluation of the ZPPR foundation was performed in ECAR-5116 [3] and the total allowable load on the ZPPR floor was increased to a maximum of 607 tons. The total load from the new roof structure and the demonstration reactor equipment must be less than 2,889 tons.

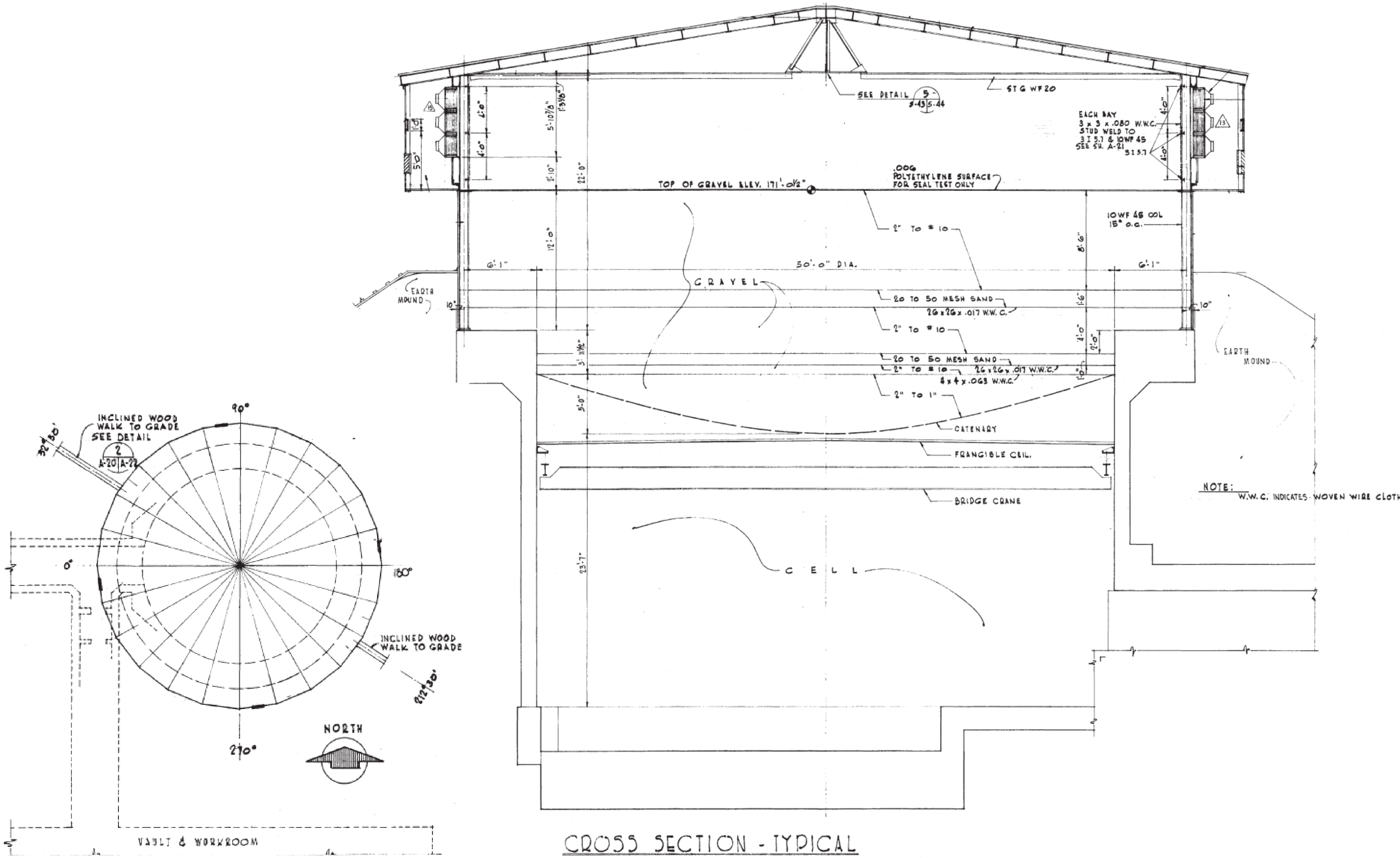

Figure 3. Existing Roof Structure

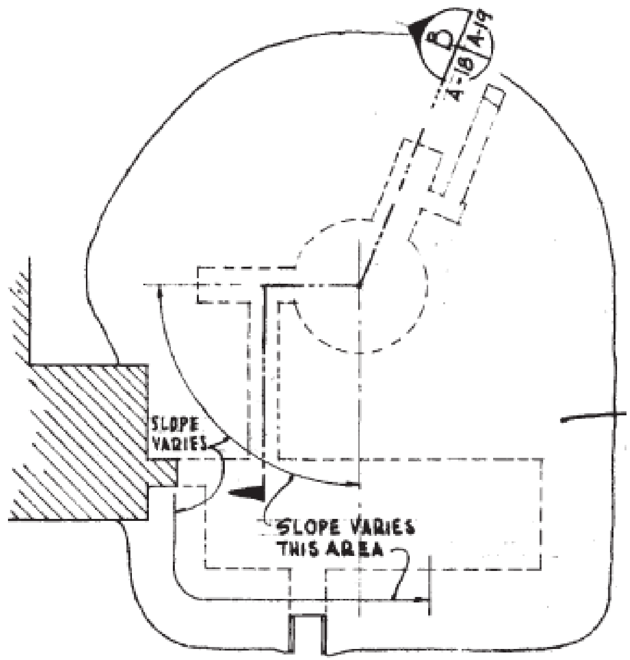

Figure 4. ZPPR Cell Layout and Relative Extent of Mound

In the existing facility configuration, all equipment entering the ZPPR cell must pass through the corridor. This limits the maximum size to less than 7 feet tall by 4 feet wide (door frame size with no clearance for handling).

2.1.3 Description of Modifications

To support the various systems identified in the pre-conceptual design and provide a method for placement of large/heavy objects into the ZPPR cell, a new roof structure was developed to replace the existing roof. The new roof structure has a 30-foot by 30-foot square hatch which will provide access to a large portion of the cell floor from an external crane.

As an alternative to using the roof to install reactor modules, an opening in the side of the facility was considered. This configuration would require modification to or possibly replacement of the steel superstructure to meet Seismic Design Category 3 (SDC-3) requirements. Additionally, a side entry configuration would further limit size of RDP modules. Additional investigations on the most cost-effective entry into the ZPPR cell should be performed at the discretion of the program.

Several major demolition activities are required to replace the roof. First, the mound will need to be lowered by at least 5 feet from its current maximum elevation to expose the entire steel super structure and the concrete ring beam. Second, the gravel/sand filling the top of the ZPPR cell structure will need to be excavated. Over 2,000 tons of gravel/sand is anticipated to exist in the top of the ZPPR cell structure. Third, the steel structure of the roof will need to be removed. Finally, the catenary cable system will need to be removed.

Each of these activities will present unique challenges due to the existing operational facilities adjacent to the ZPPR cell. However, the gravel/sand removal is anticipated to be the most challenging. In discussion with equipment vendors, vacuum excavators are ideally suited to this activity, and the duration of the activity is directly scalable by adding additional excavators. The vacuum excavators can utilize suction hoses longer than 200 feet in length and still accomplish the necessary excavation.

The new roof structure is currently designed as a 16-sided structure with a flat roof extending beyond the walls 5 to 10 feet (Figure 5). The current concept is that the walls and roof would be cast in place concrete using traditional forms. However, in the follow-on design phases, precast concrete and stay in place forms should be considered, to minimize the construction time for the roof.

2.1.3.1 Structural Analysis Scoping

A structural analysis model of the ZPPR cell was created to evaluate wind loads, seismic loads, pressure loads, and dead loads. As illustrated in Figure 5, the model includes both the proposed new structure and the existing cell structure. Three options for the proposed new structure were considered and one of the three was modeled and analyzed.

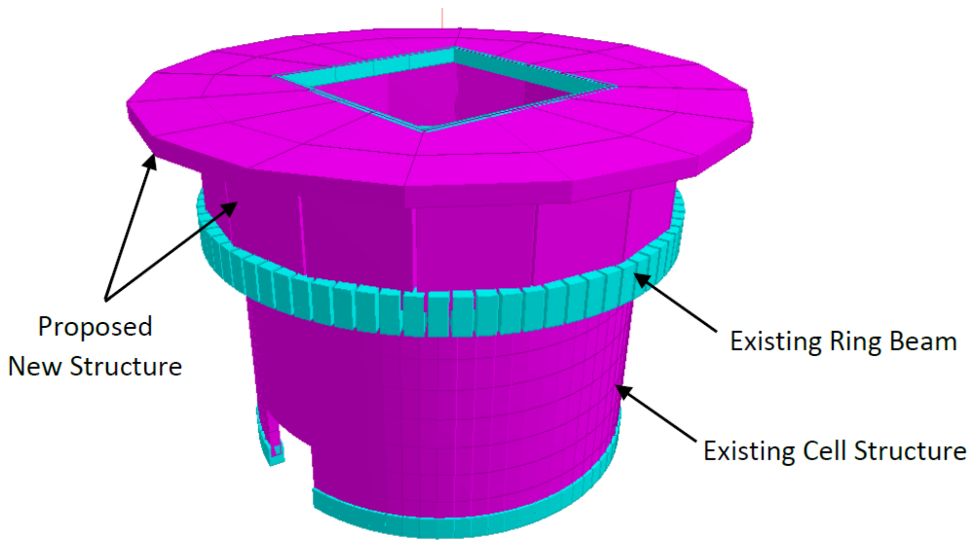

Figure 5. Model of New ZPPR Roof Structure

As stated in FOR-538 [1], the existing ZPPR cell roof above the ring beam, including the gravel/sand inside the cell structure, will be removed. The existing concrete structure of the cell, including the ring beam, will remain. The proposed new structure will be started at the top of existing ring beam and will be a reinforced concrete shear wall system similar to the existing cell structure below.

To meet the nuclear safety and physical security requirements, the major elements of the proposed new structure include a 2-foot thick roof slab and 2-foot thick by 15-foot high concrete exterior walls, see Figure 6. There is a proposed hatch (30-foot by 30-foot square) in the middle of the roof. The hatch area was modeled as an opening with perimeter beams. The loads from the hatch will be carried out by perimeter beams and then by roof slabs. The utility penetrations in the new structure were not included in the pre-conceptual design report due to lack of detailed information. However, those penetrations are small relative to the structure and anticipated to have minimal impact on the structural analysis results.

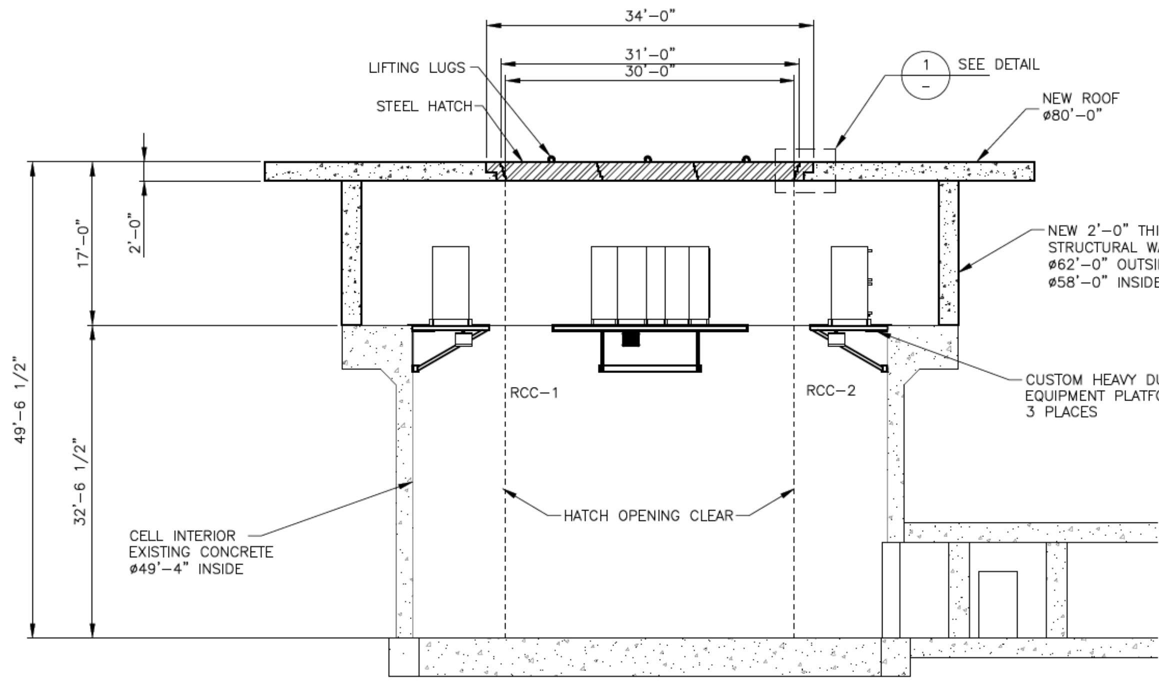

Figure 6. Elevation View of Cell, Existing Structure and Proposed New Structure

In accordance with ASCE 43 [5], both non-seismic demand and seismic demand were evaluated using linear equivalent static analysis for the pre-conceptual design. Several items were excluded from the model as a simplification: 1) soil-structure interaction, 2) any structures below cell floor, 3) any structures beyond/outside existing cell, 4) reinforcement detailing, 5) detailed analysis of the equipment supports, and 6) ductility of the structure. These items will need to be evaluated as the design progresses; however, during the pre-conceptual design these items were judged to be of low risk.

The design response spectra for an SDC-3 earthquake was taken from INL/EXT-05-00925 [4] (MFC rock spectra) and is shown in Figure 7 below.

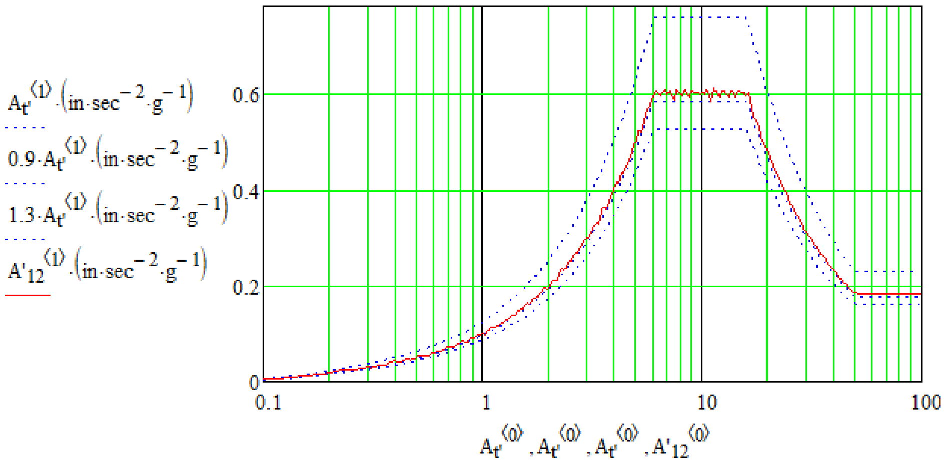

Figure 7. Design Response Spectra for SDC-3 Earthquake

Loads were assumed to act concurrently except wind and seismic loads. Loads applied to the model include (but are not limited to): 1) equipment loads of 72 kips total (for chillers and pump house), 2) hatch weight of 270 kips, 3) operational pressure (+/- 1.0 psi), 4) lateral earth pressure, 5) live and snow loads, 6) wind loads, and 7) seismic loads. Wind loads were applied to the structure in accordance with ASCE 7 [6] and evaluated in all directions.

All analyses were based on the applicable codes and stress design. The strengths for bending, in-plane shear, and out-of-plane shear, were evaluated for both the proposed new structure and the existing cell structure. A summary of the evaluation results is shown in Table 1 below.

Table 1. Summary of ZPPR Cell Modification Structural Integrity Analysis Results Summary.

	Proposed New Structure [fc' = 4000 psi]		Existing Cell Structure [fc' = 3000 psi]	
	Max. Values from Model	ACI Allowable	Max. Values from Model	ACI Allowable
Bending Moment, lb.-in/in	17,600	45,500	1,535	12,850
Shear Stress (out-of-plane), psi	16.10	94.87	5.72	82.16
Shear Stress (in-plane), psi	199	474	300	410

A selection of representative load cases from the analysis are shown in Figure 8 through Figure 13. These figures show the bending stresses, out-of-plane shear stresses, and in-plane shear stresses, respectively.

Based on the structural analysis using the simplified static model, the ZPPR cell confinement structure can handle the required loads with acceptable stresses. However, more in-depth analysis including dynamic seismic analysis with soil-structure interactions will be needed as the design progresses.

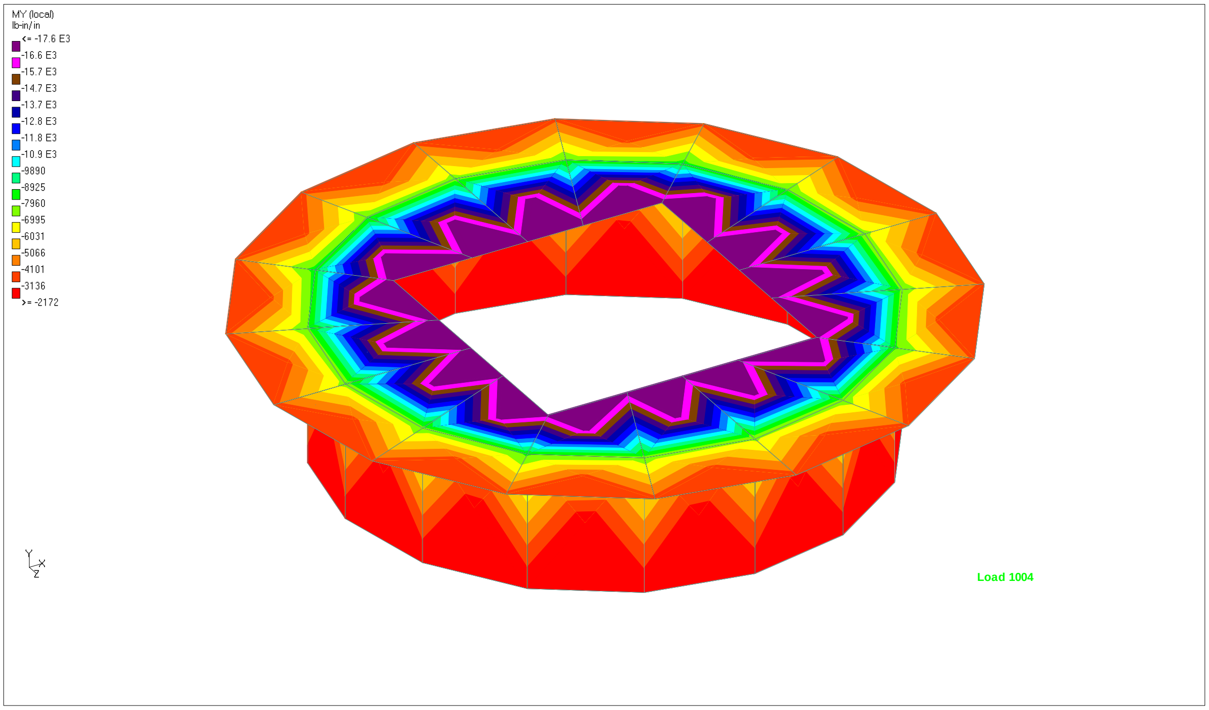

Figure 8. Bending Moment for Proposed New Structure

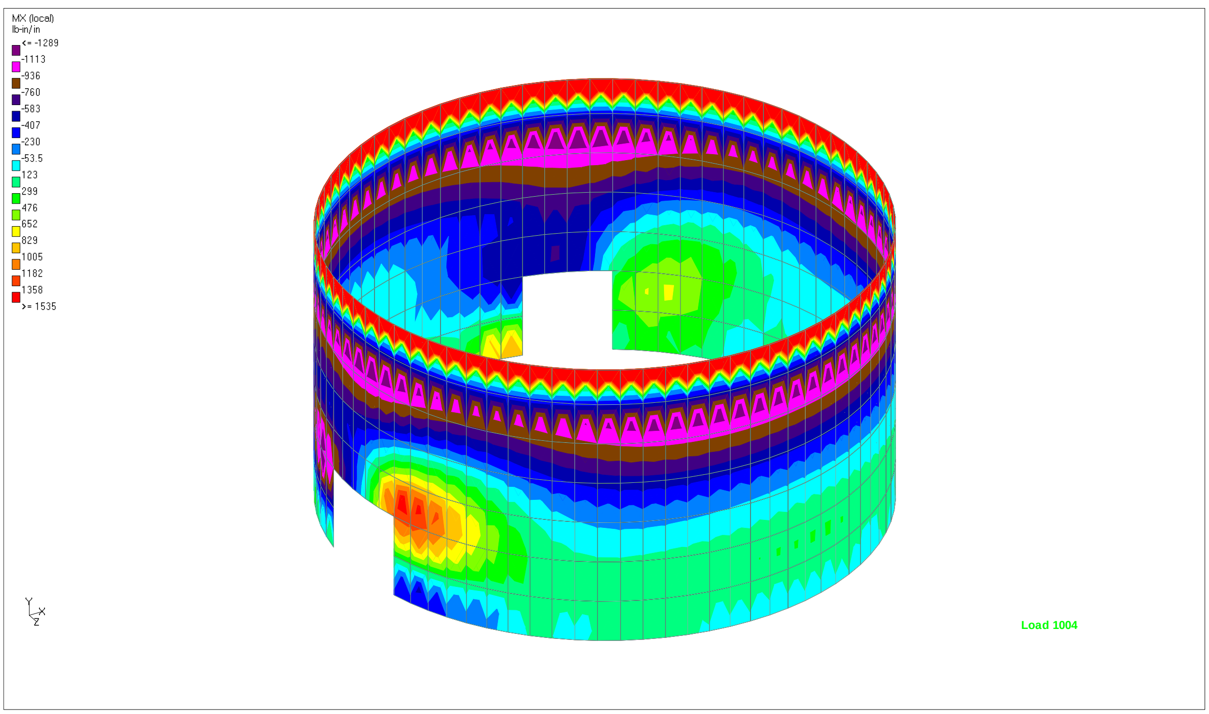

Figure 9. Bending Moment for Existing Cell Structure

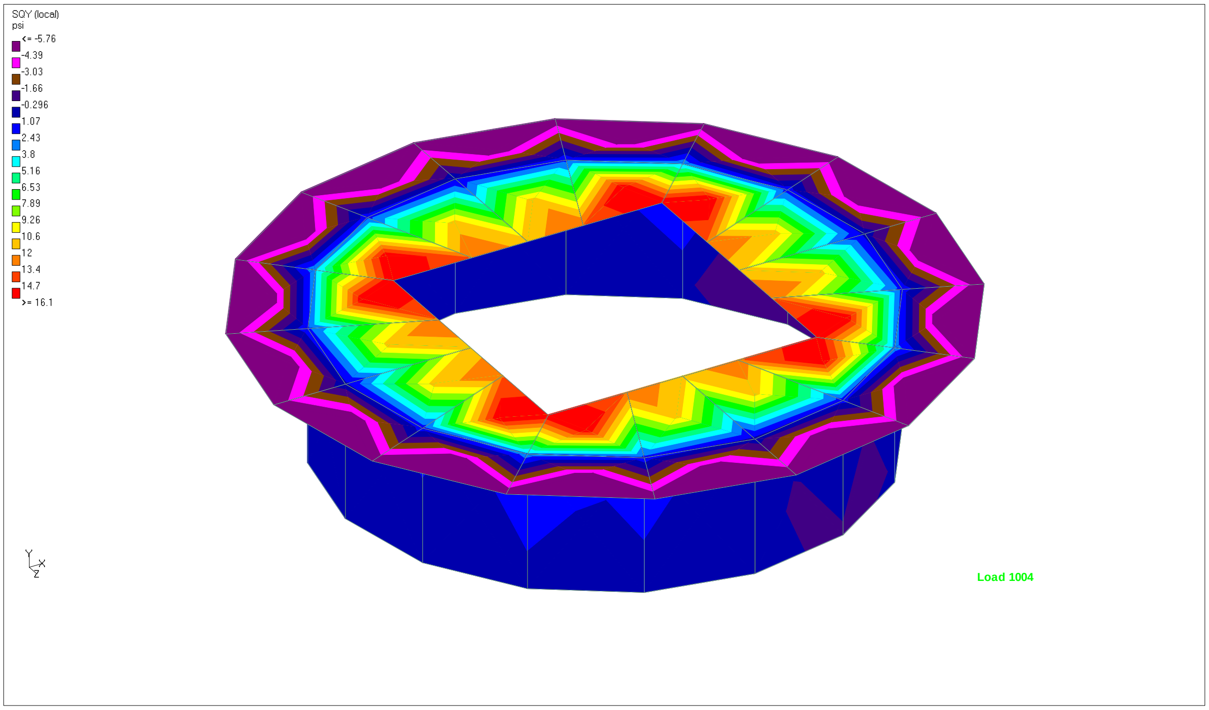

Figure 10. Shear Stress (out-of-plane) for Proposed New Structure

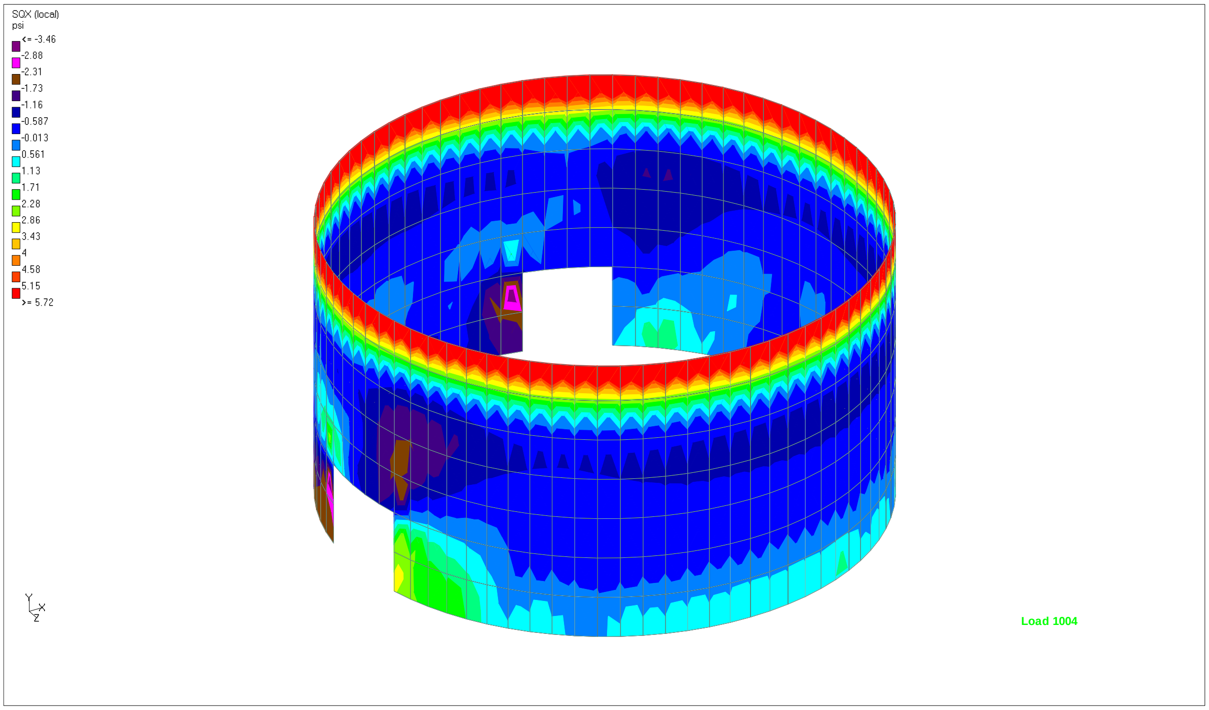

Figure 11. Shear Stress (out-of-plane) for Existing Cell Structure

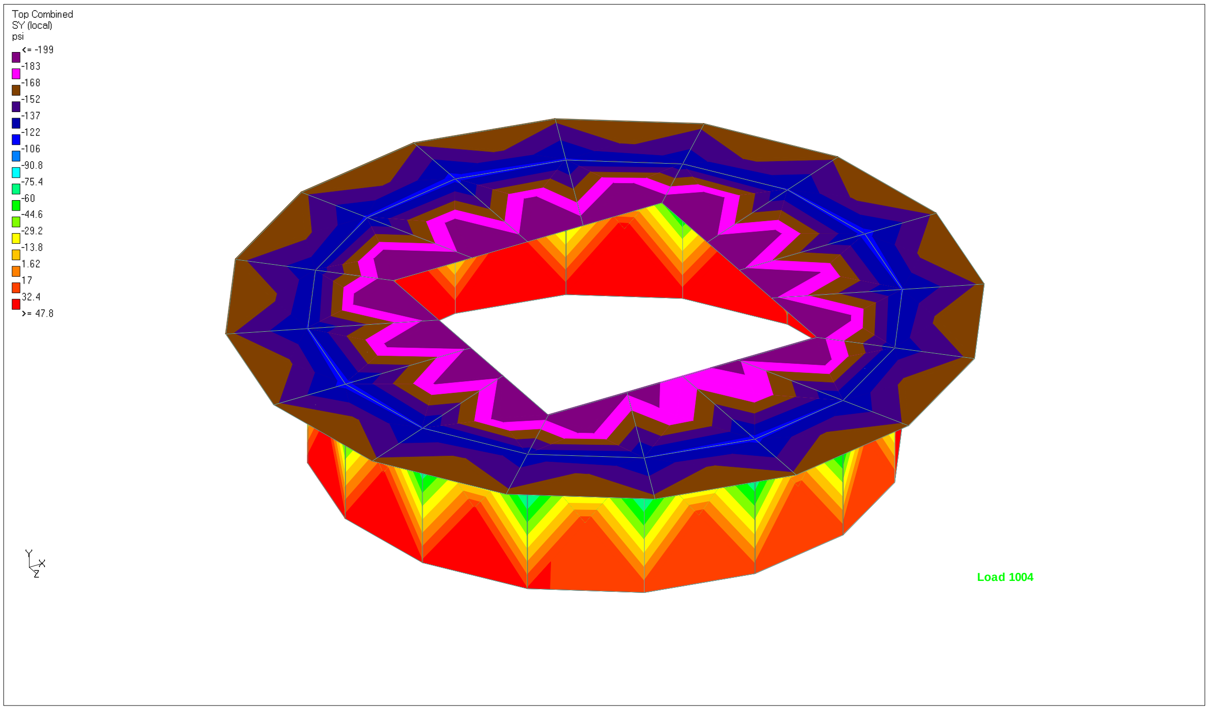

Figure 12. Shear Stress (in-plane) for Proposed New Structure

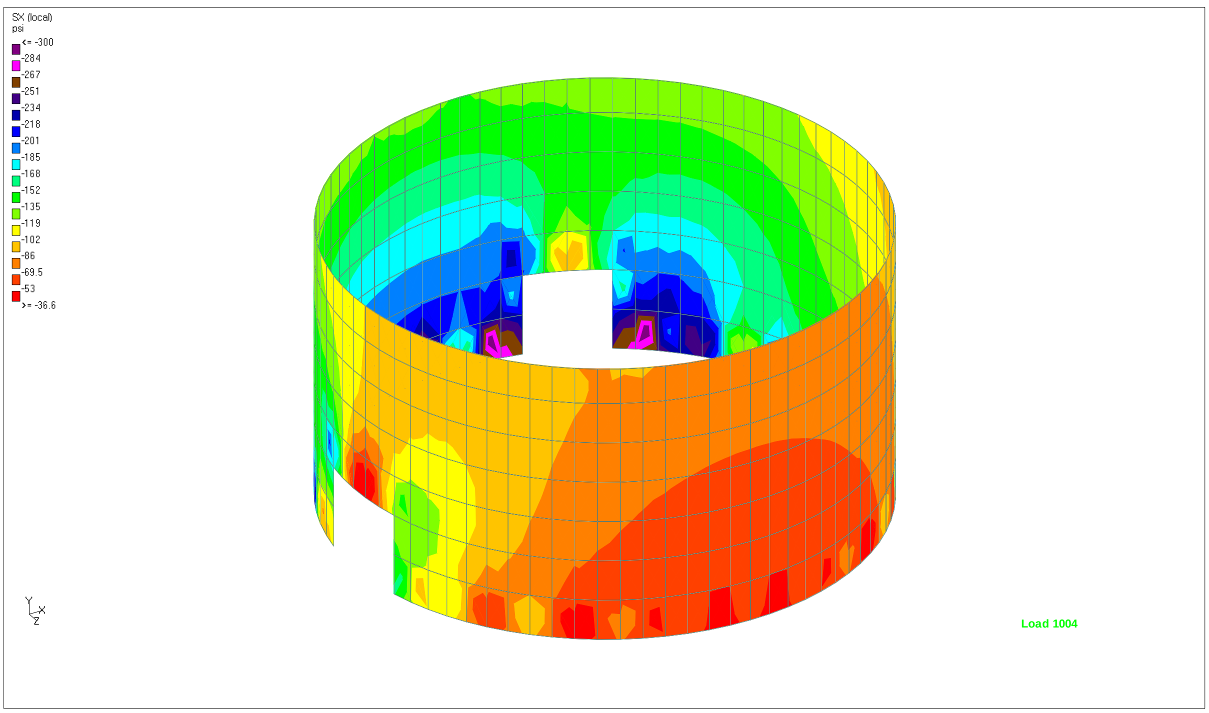

Figure 13. Shear Stress (in-plane) for Existing Cell Structure

As stated in FOR-538 [1], there must be instrumentation or other means to detect and record the occurrence and severity of seismic events. It is assumed that the existing seismic monitors at MFC/INL will be sufficient to meet this requirement. If seismic monitoring and reactor shutdown is necessary for the safety case of a given reactor, it is assumed that equipment will be provided by the RDP.

2.1.3.2 Exterior Layout

The exterior of the ZTB will consist of three main areas: 1) the top of the confinement roof, 2) open yard area east of ZPPR, and 3) new electrical equipment south of building MFC-774. These areas are shown in Figure 14 through Figure 16. The new cooling systems and associated equipment will be located on top of the confinement roof. Locating this equipment on the roof limits the pipe run distances. The yard area consists of a large equipment staging area (gravel/soil), a crane operations concrete pad, and a bulk gas equipment concrete pad (for future use, see Section 2.1.4.5.3).

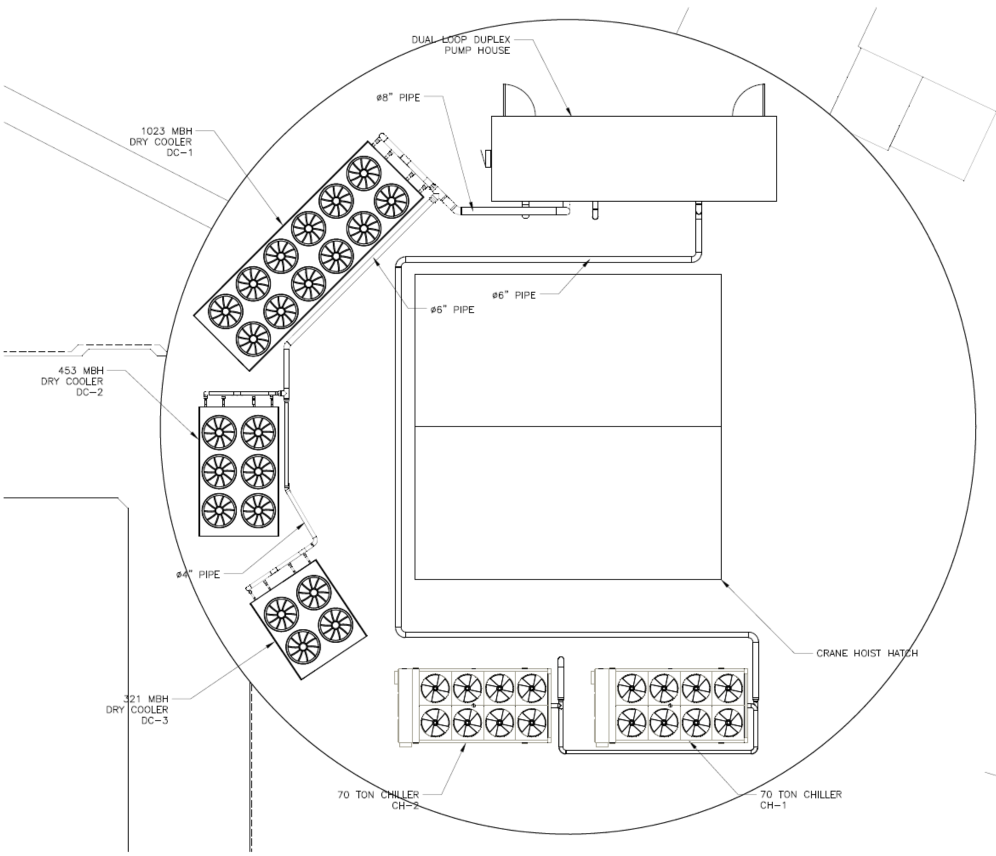

Figure 14. Roof Layout with Equipment

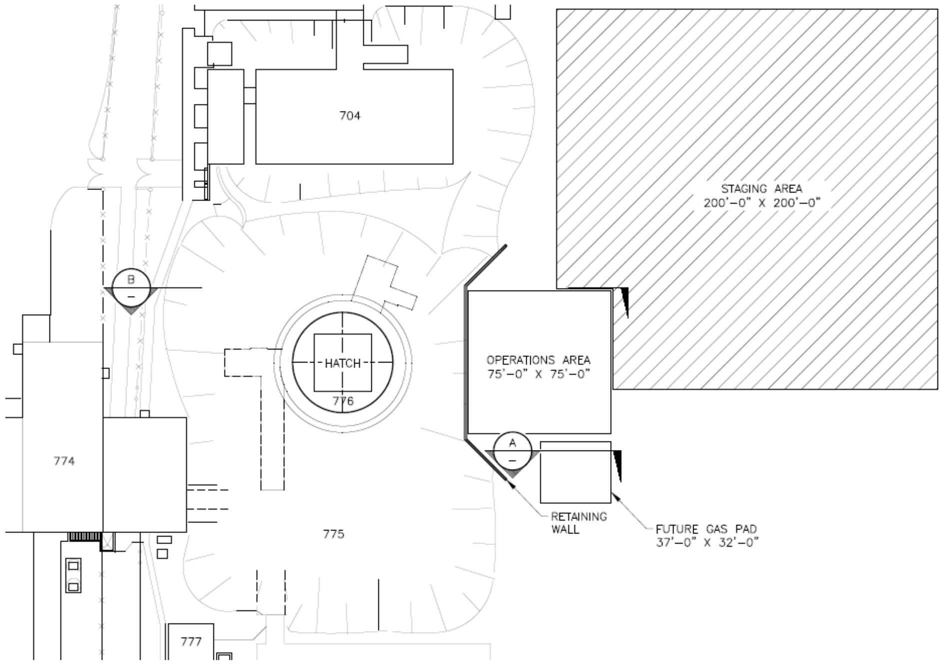

Figure 15. Yard Area Layout

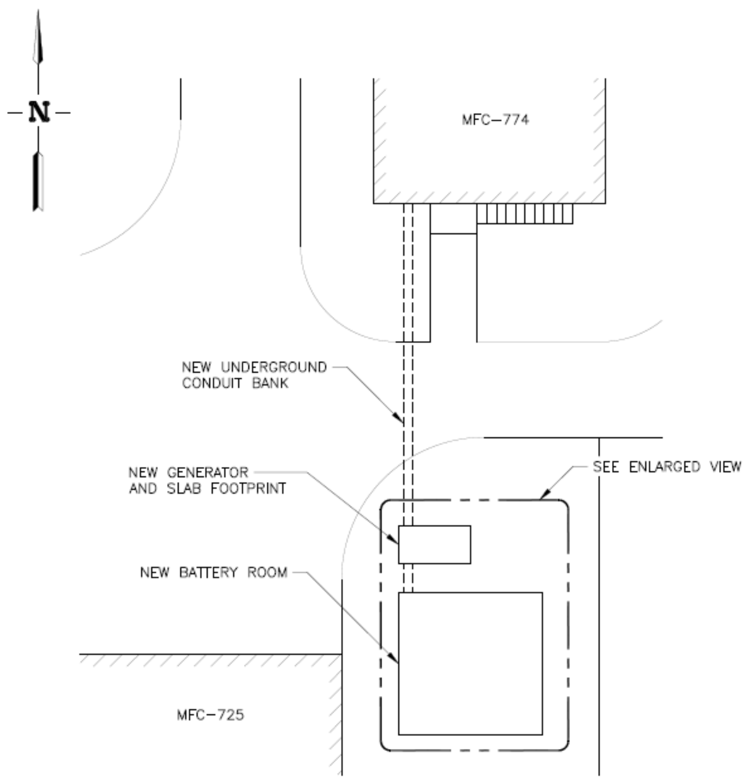

Figure 16. Electrical Equipment Area General Arrangement

The yard area consists of two concrete pads. One for the crane operations area to support reactor loading and removal, discussed in Section 2.1.3.3. The second concrete pad is for the bulk gas equipment. This pad is currently 2 feet thick based on 3,000 psi concrete and ground net bearing capacity of 2,500 psf and use of

ASCE 7 [6], ACI 318 [7], and ACI 360 [8]. The load on the pad is based on the assumed weight of major equipment. However, more detailed analysis in the future may allow for the use of thinner pads. The crane operations pad is discussed in more detail in Section 2.1.3.3.

Water management also needs to be considered during the implementation of ZTB. Two areas of specific consideration are drainage, and restoration of mound area membrane (waterproofing).

2.1.3.3 Reactor Loading/Removal

A mobile crane is planned for the major lifting and handling operations for placing a demonstration reactor and the associated equipment in cell. This option was chosen to avoid the large costs associated with installing and maintaining a permanent crane. The main factor considered for reactor loading was the maximum weight that could be lifted using a reasonably sized/priced crane. The reactor will not be the only item that is placed into the ZTB confinement. FOR-538 [1] requires shielding to be in place for reactor operations to limit the activation of permanent facility structures and radiation dose to personnel. Shielding materials (typically concrete and steel) tend to be heavy; therefore, providing a heavier lift capability will allow the shielding to be installed in fewer lifts. Based on discussions with potential demonstrators, a lifting capability of at least 50 tons was determined to be needed, with a greater capacity desired.

Given the current facility footprint and the location of the equipment hatch centered on the roof, the mobile crane may need to be positioned up to 120 feet away from the center of the hatch opening to the east as all other directions are obstructed by existing facilities. To place items as far west as possible (e.g., west side of the hatch) a reach of 135 feet may be needed. Finding readily available mobile cranes with the necessary load and reach capability proved to be a challenge.

To reduce the required crane reach, and consequently increase lift capacity for a given crane, the east side of the ZPPR mound should be excavated to remove approximately 20 feet of the mound and allow the crane operations pad to be closer to the center of the cell. This will reduce the required crane reach to approximately 100 feet. The excavation will require a retaining wall be placed on the west side of the crane operations pad to prevent soil collapse from the remaining ZPPR mound. Figure 17 and Figure 18 show the general layout for lifting operations.

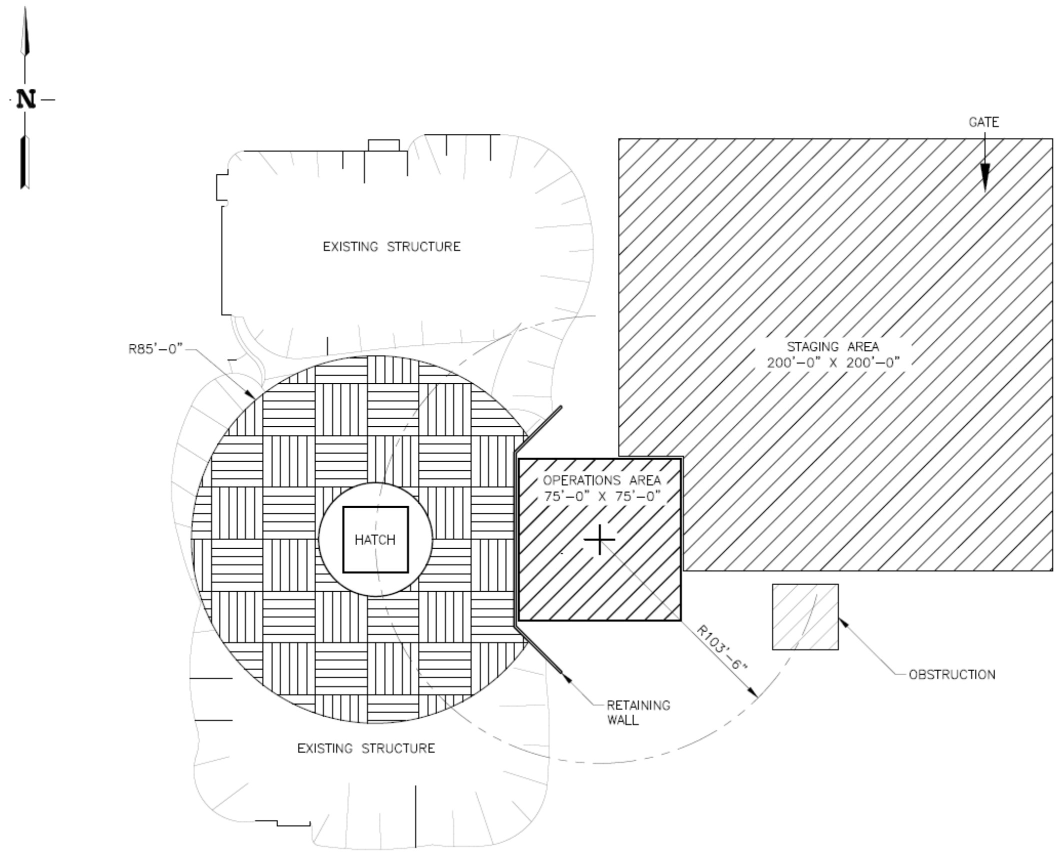

Figure 17. Site Lifting, Plan View

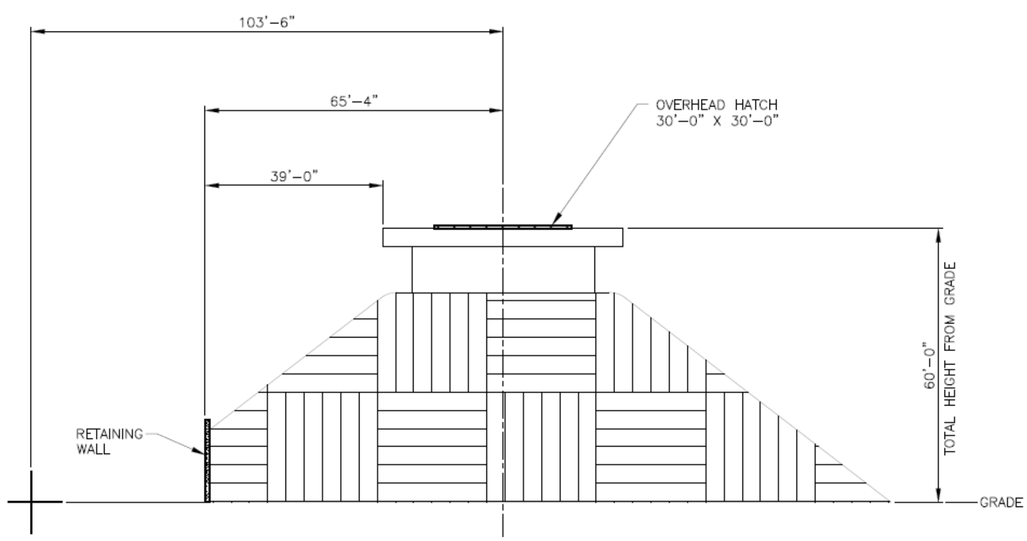

Figure 18. Site Lifting, Elevation View

The concrete pad for crane operations is a 2-foot thick pad. This pad is based on 3,000 psi concrete, a ground net bearing capacity of 2,500 psf, and use of ASCE7 [6], ACI 318 [7], and ACI 360 [8]. The retaining wall is also a 2-foot thick concrete slab with larger reinforcing bar. The retaining wall and the operations pad will be joined into a single structure to allow the wall to utilize the operations pad to avoid tipping. This will require a strong joint between the two structures. An example is shown in Figure 19 below.

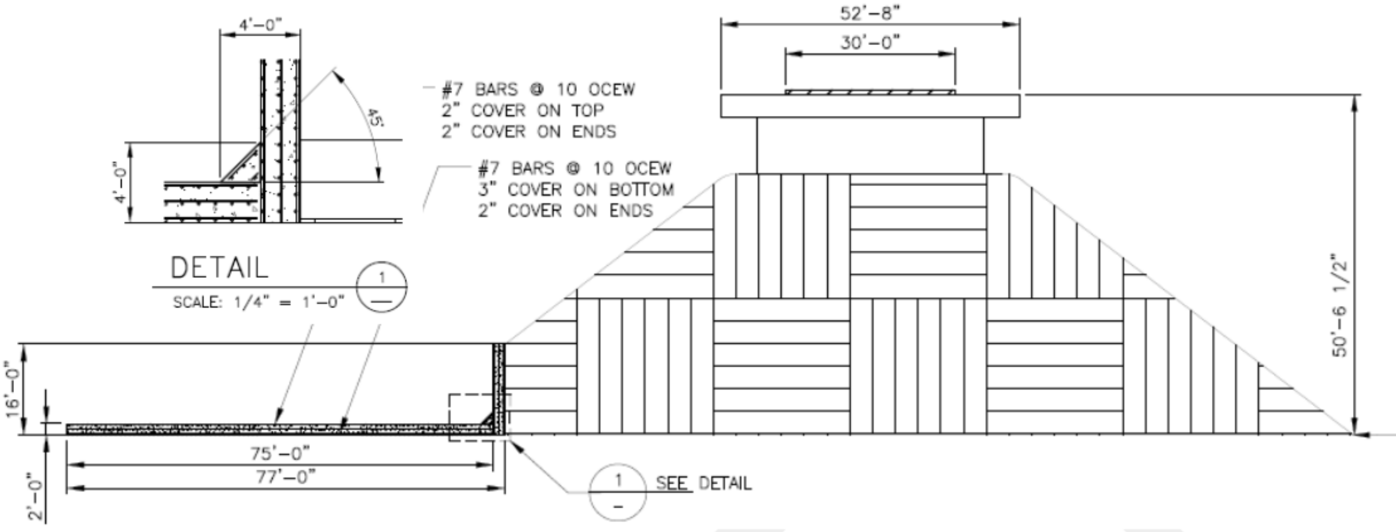

Figure 19. Joint Detail Between Retaining Wall and Operations Pad

Due to the large loads that will be applied by the crane outriggers (total crane weight plus the load weight is over 500 tons), load distribution supports will be required under the crane outriggers. The use of additional load distribution supports will allow the crane operations pad to be thinner than otherwise allowable. Localized areas of additional reinforcement or increased thickness were evaluated but would require the crane to be in a fixed location in all uses and would potentially require longer reach lifts.

To load a prefabricated RDP module into the ZTB, the hatch must be taken off. Based on the planned opening size and the required concrete thickness, a single piece hatch will weigh approximately 270,000 lb. At this size, the hatch will need to be split into three pieces to allow the exterior crane to lift the hatch, see Figure 20. It may be possible to design a structure that is lighter than solid concrete and would still provide a sufficiently resilient structure to meet security requirements. If this can be accomplished, it should be pursued since a single piece hatch will be easier to seal. The hatch is not anticipated to support any loads other than itself and Natural Phenomena Hazards (NPH) loads.

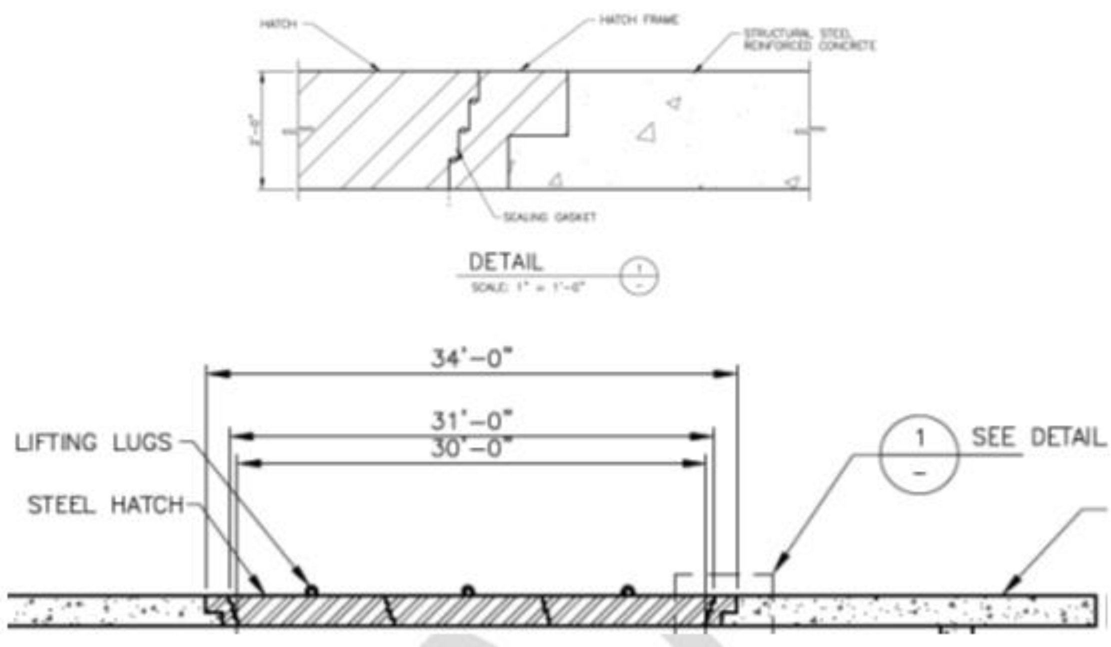

Figure 20. Split Hatch Concept

After operations of an RDP complete, the RDP modules will need to be removed. While the reactor will most likely be defueled prior to removal, it is still anticipated that the modules will be activated by neutrons from reactor operations. If necessary, a shielded container could be designed for placement on the roof with the ability to hoist a reactor vessel or highly activated equipment, into the container. In this scenario the shielding and equipment weight would have to be lower than the allowable crane lifting limit. However, this type of shielding system will be reactor specific and thus is outside the scope of the ZTB design efforts.

2.1.3.4 Lifting Inside Confinement

Major equipment placements and moves are anticipated to be performed by use of the crane exterior to the facility. However, some limited lifting and handling operations are likely to be necessary inside the ZPPR cell. For example, relocation of small equipment or maintenance on the demonstration reactor.

Currently, the ZPPR cell contains a 5-ton polar crane. This crane is planned for removal to allow for a larger hatch opening. The largest equipment hatch with the polar crane remaining in place would be approximately 12 feet by 12 feet square vs. the 30 feet by 30 feet square planned opening. In addition, the hatch would be off-center and prohibit access by the exterior crane to perform heavy lifts for a majority of the cell. This design choice, by default, would limit all in-cell equipment/modules which require relocation to weigh less than or equal to 5 tons.

To provide an allowance for the removal of the polar crane, FOR-538 [1] requires a 100 psf live load to be included in the roof design. This load was included in the structural scoping calculations. This load is anticipated to provide sufficient allowance for a new lifting system to be installed on the inside of the cell.

2.1.3.5 Platforms, Ladders, Walks

Ladders, platforms and cat-walks will be installed, if needed, to provide access to regularly accessed equipment mounted to the interior walls of the ZTB confinement (e.g., air handling units for the cell air cooling system), and on the outside roof of confinement (e.g., chillers).

2.1.4 Mechanical Systems

2.1.4.1 Decay Heat Removal

The ZTB cooling systems are not assumed to be required for decay heat removal of an RDP. This was a deliberate decision by the design team to avoid the necessity for a very large Safety-Class backup electrical system. As a result of this decision, analysis of the ZTB confinement to passively reject decay heat generated by an RDP was necessary.

Scoping studies to assess the ZTB confinement's ability to reject decay heat were performed as part of the pre-conceptual design. In total, nine cases were evaluated to determine if the structural temperature limits (100°C, see FOR-538 [1]) would be met during passive decay heat dissipation. The nine cases included several variations on the roof structure configuration, physical size of the reactor, confinement initial temperature, and ambient initial temperature. The variations on the new roof structure were necessary as the decay heat scoping was performed before the pre-conceptual design of the new roof was complete. The cell floor below the reactor was not evaluated since it is anticipated that shielding will be present between the reactor and the cell floor.

The general model set-up is shown in Figure 21 through Figure 24. The decay heat rejection simulation time was 72 hours. In all cases the temperature in the confinement reduced due to the reduction in decay heat being produced at the 72-hour period. From these results, the team judged that longer analysis time periods were not necessary.

The decay heat at shutdown for case one was set at 5% operating power with a linear reduction over the next 72 hours to 0.5% operating power. With the thermal power limit of the ZTB confinement set at 500kW, these values are 25kW and 2.5kW, respectively. These values are representative of a plutonium fueled reactor, per informal discussions with a potential RDP. For the remaining cases, the decay heat was doubled (50kW linearly decreasing to 5kW over 72 hours), which conservatively bounds the decay heat from a uranium fueled reactor.

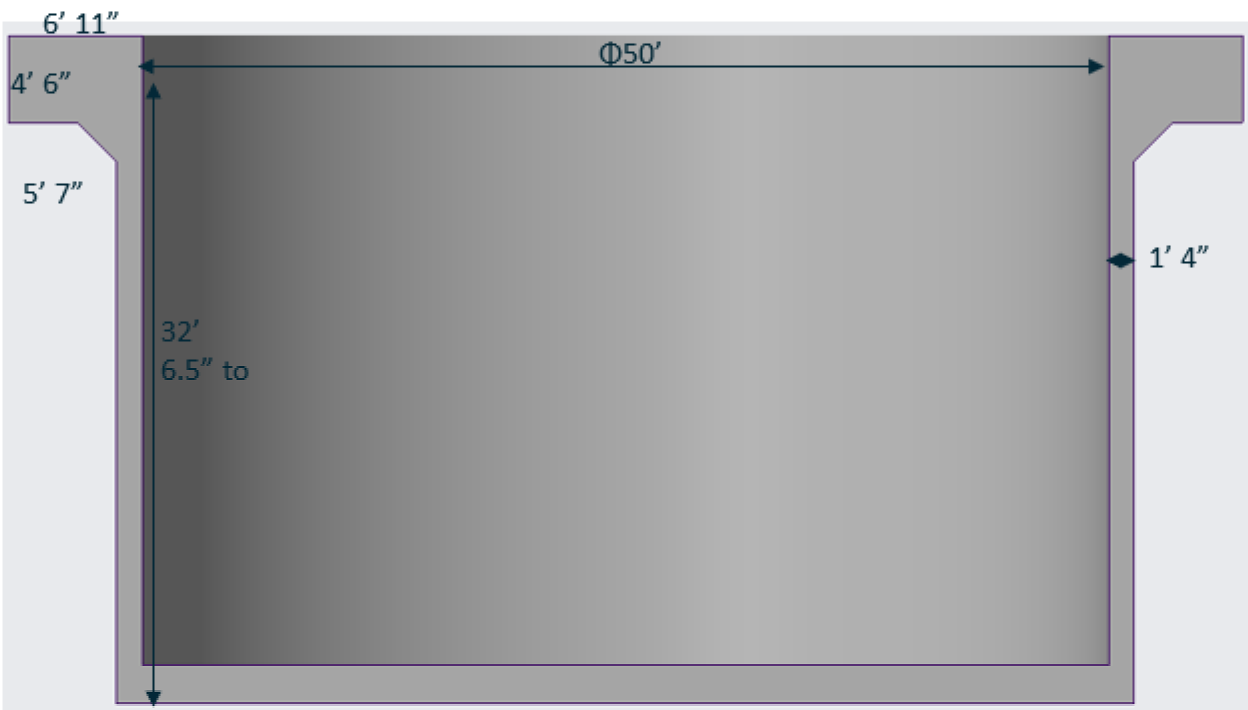

Figure 21. ZTB Base Confinement Structure as Modeled in Decay Heat Evaluations

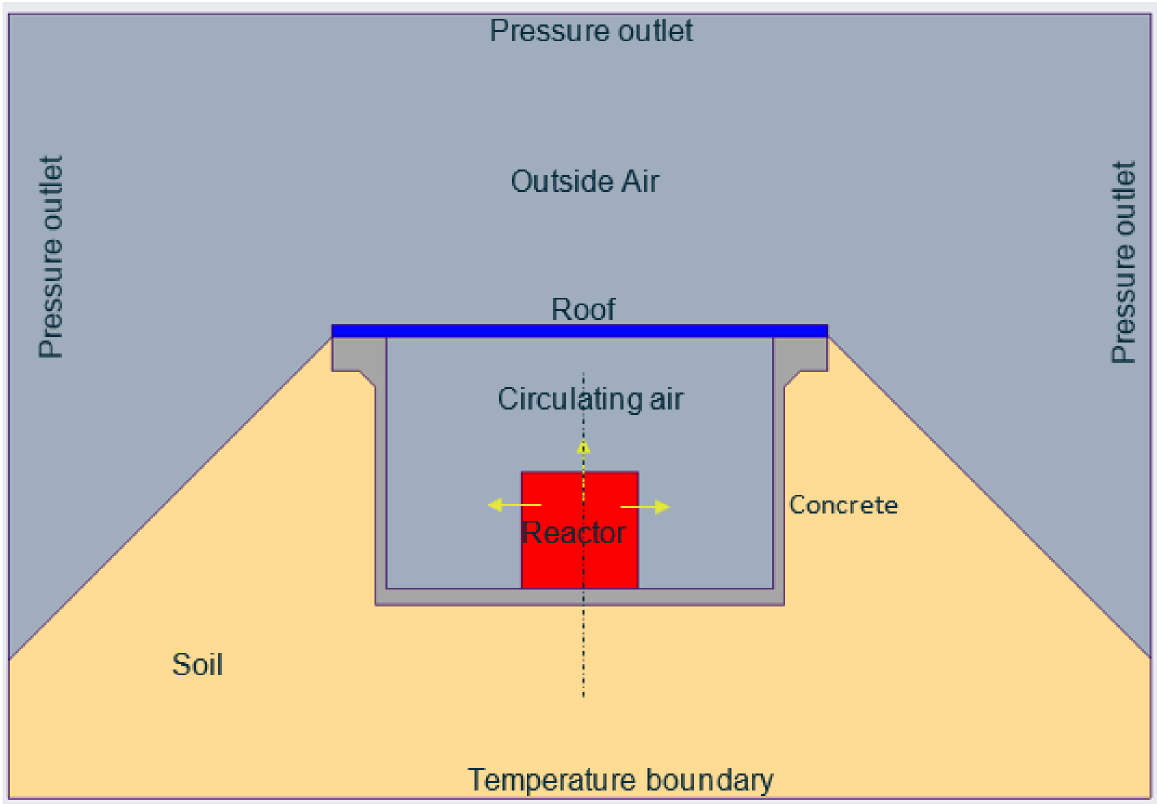

Figure 22. ZTB Decay Heat Analysis Simulation Domain with 18-inch Concrete Roof

Figure 23. ZTB Decay Heat Analysis Simulation Domain with 1-inch Steel Roof

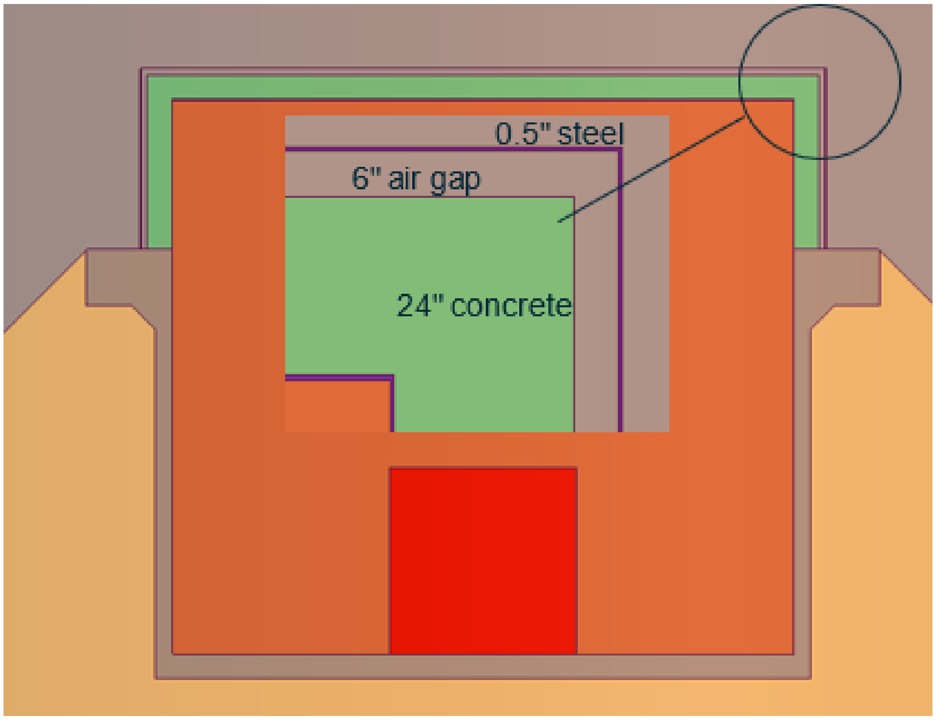

Figure 24. ZTB Decay Heat Analysis Simulation Domain with 24-inch Concrete Roof, Steel Liners on two sides and 6-inch Air Gap

The 24-inch thick concrete wall and roof is the most representative of the final preconceptual design. The additional steel plate and air gap were included to provide an allowance for possible modifications to the structure in later design phases. It should be noted that each of the potential roof structures analyzed had an internal volume smaller than the final roof geometry of the ZTB in the pre-conceptual design, which is conservative.

For all nine cases, a linear reduction of decay heat over time was used. This is a very conservative model since it is known that decay heat decreases exponentially. Even with this assumption, all nine cases maintained the ZTB structural temperatures below the allowable limit (100°C) over the 72-hour time frame evaluated.

A brief description of the analyzed cases is listed below:

- Case 1 – 18-inch concrete slab roof, 27°C initial inside temperature (air and concrete), 27°C outside temperature (constant as an average between the daytime and night time temp), reactor is 15-foot diameter right cylinder 15 feet tall
- Case 2 – Same as Case 1, but with decay heat doubled
- Case 3 – 1-inch steel roof, 27°C initial inside temperature, 27°C outside temperature, reactor is 15-foot diameter right cylinder 15 feet tall
- Case 4 – 18-inch concrete slab roof, 90°C initial inside temperature (air and concrete), 27°C outside temperature, reactor is 15-foot diameter right cylinder 15 feet tall
- Case 5 – 18-inch concrete slab roof, 27°C initial inside temperature (air and concrete), 27°C outside temperature, reactor is 1-meter diameter right cylinder 1 meter tall

- Case 6 – 24-inch concrete roof with steel liners and 6-inch air gap, 90°C initial inside temperature (air and concrete), 27°C outside temperature, reactor is 15-foot diameter right cylinder 15 feet tall
- Case 7 – 24-inch concrete roof with steel liners and 6-inch air gap, 27°C initial inside temperature (air and concrete), 27°C outside temperature, reactor is 1-meter diameter right cylinder 1 meter tall
- Case 8 – 24-inch concrete roof with steel liners and 6-inch air gap, 90°C initial inside temperature (air and concrete), 40.6°C outside temperature, reactor is 15-foot diameter right cylinder 15 feet tall
- Case 9 – 24-inch concrete roof with steel liners and 6-inch air gap, 27°C initial inside temperature (air and concrete), 40.6°C outside temperature, reactor is 1-meter diameter right cylinder 1 meter tall

Selected structure temperature plots are shown from the cases analyzed in Figure 25 through Figure 31.

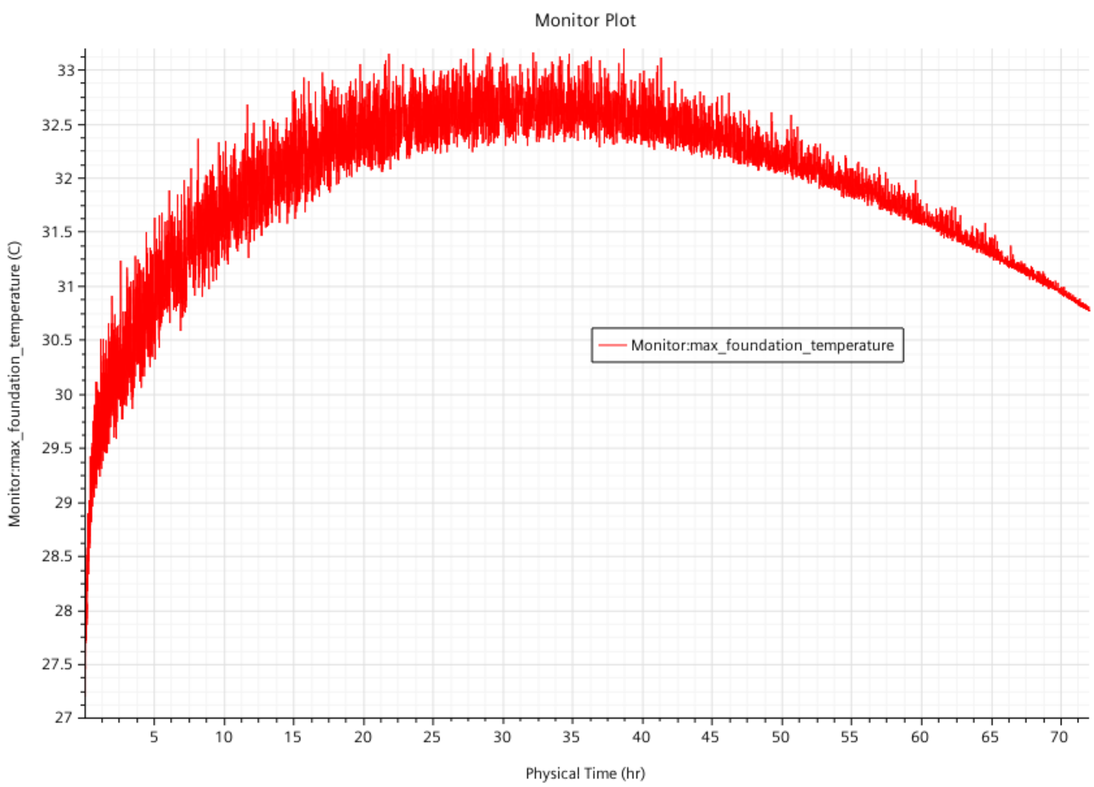

Figure 25. Case 1 Structure Temperatures

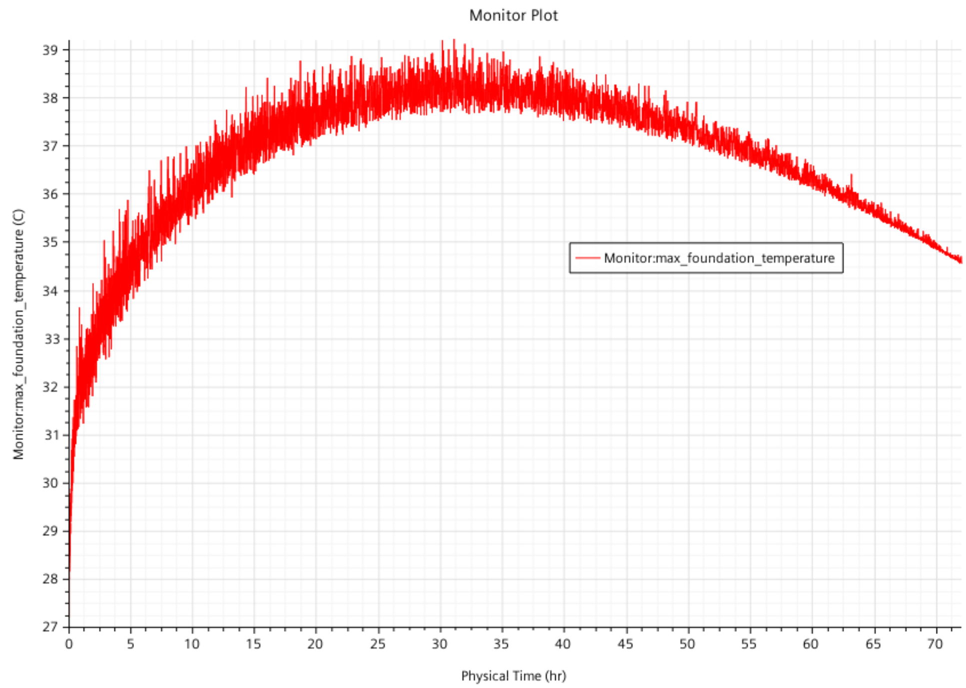

Figure 26. Case 2 Structure Temperatures

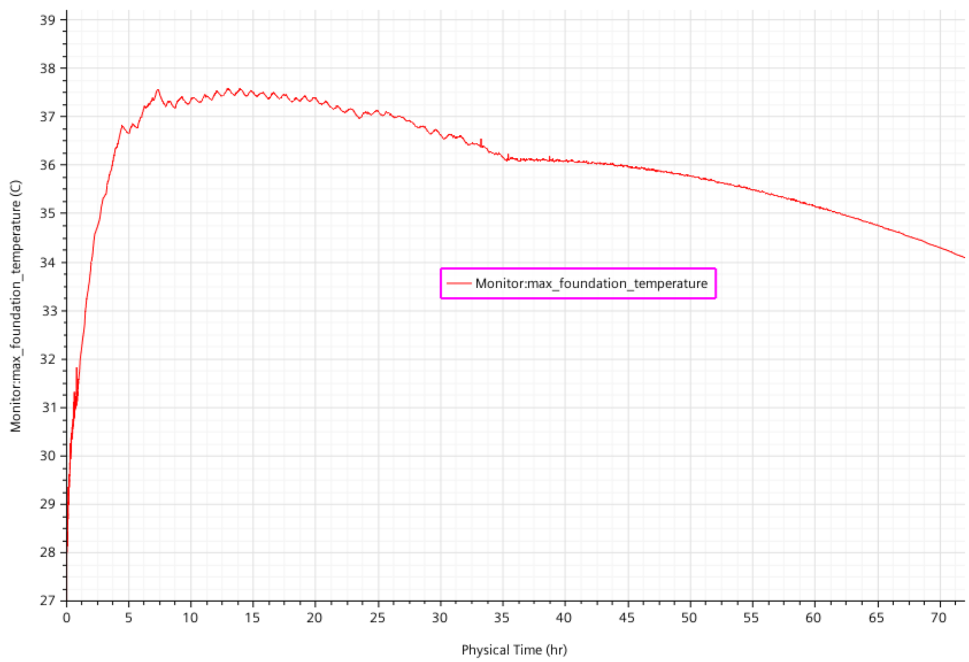

Figure 27. Case 3 Structure Temperatures

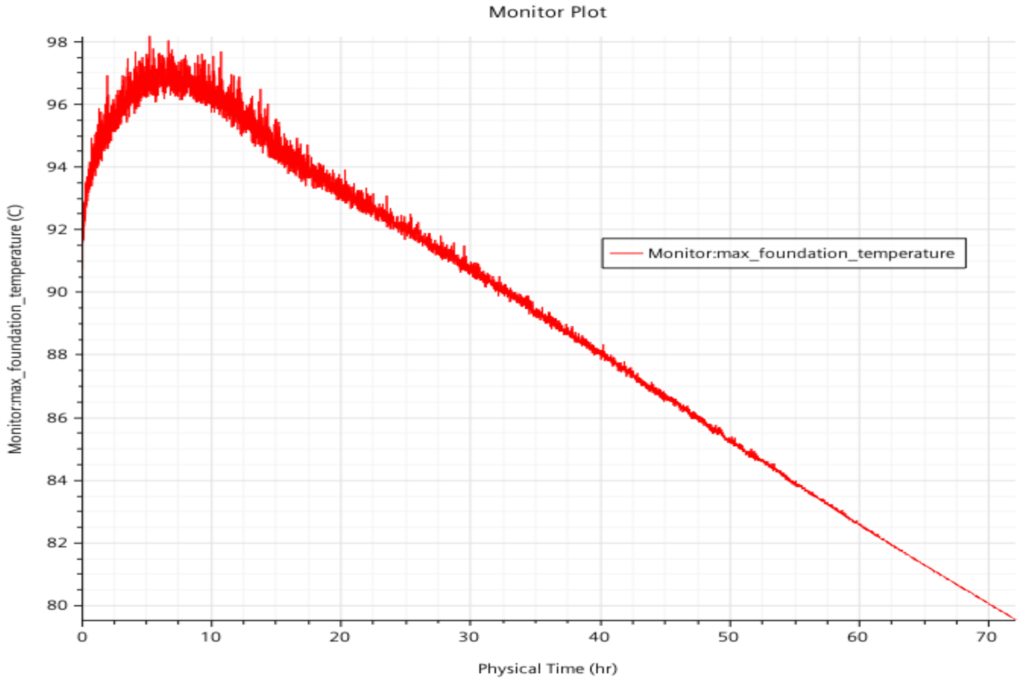

Figure 28. Case 4 Structure Temperatures

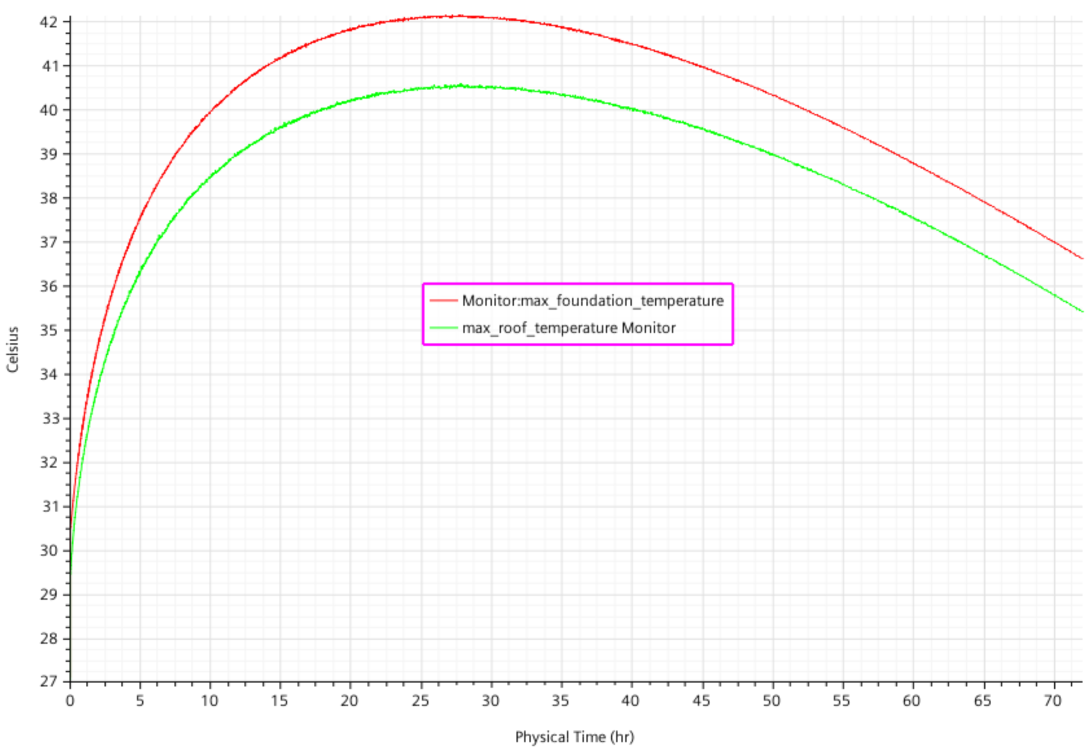

Figure 29. Case 5 Structure Temperatures

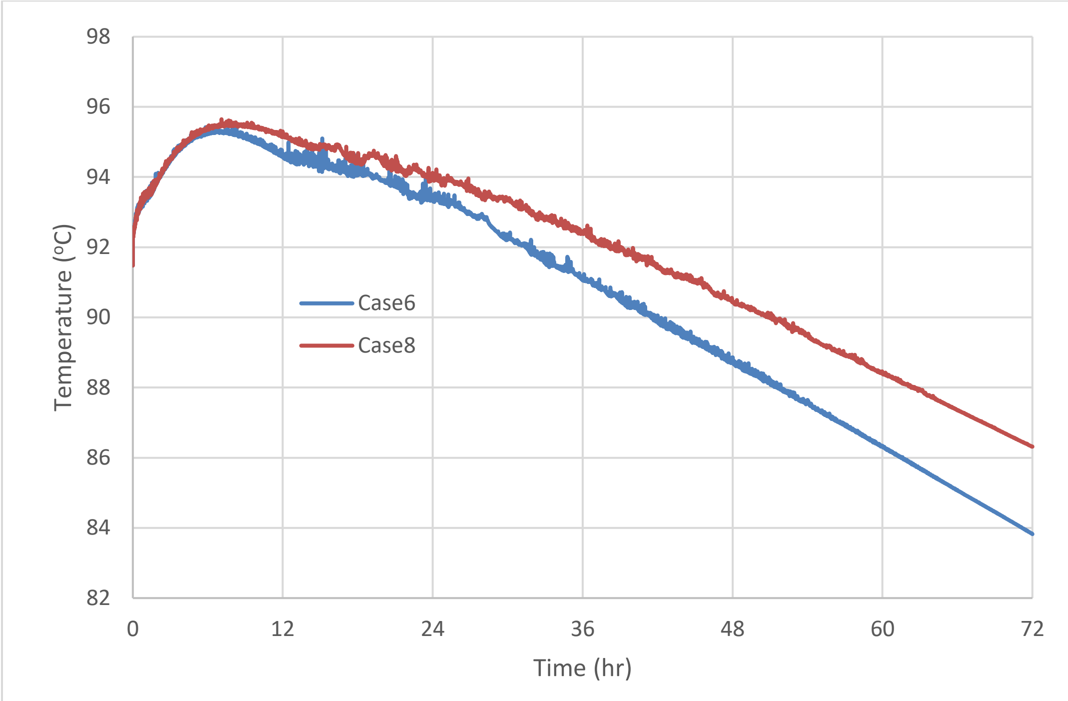

Figure 30. Cases 6 and 8 – Structure Temperatures

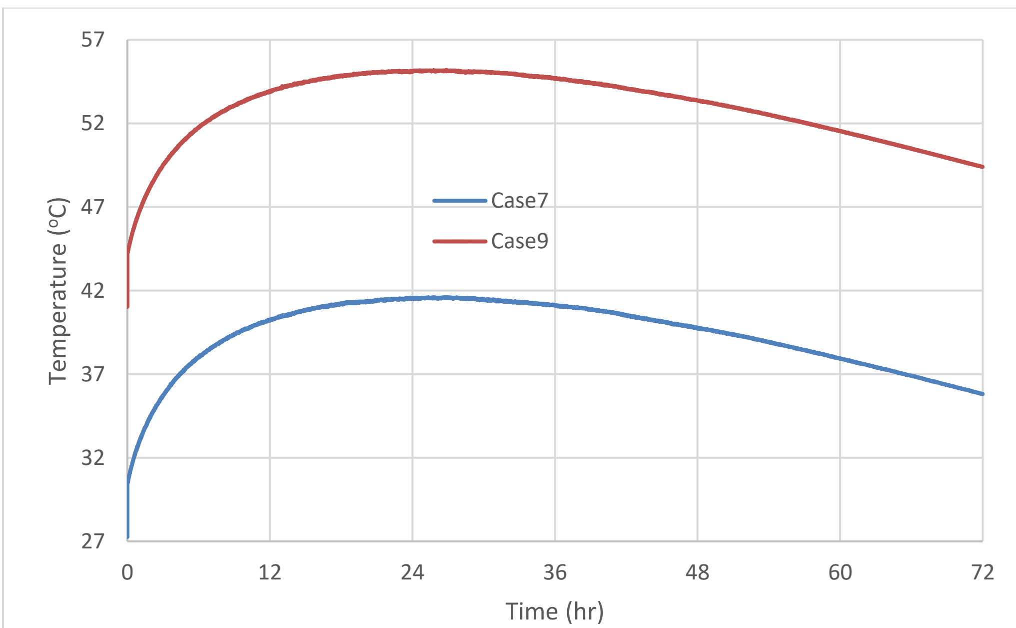

Figure 31. Cases 7 and 9 – Structure Temperatures

The decay heat scoping calculations are being formalized in accordance with INL engineering processes (ECAR-5228, to be released). It should be noted that while the ZTB confinement can handle the anticipated decay heat produced by a demonstration reactor, the calculation does not make any assessment of the reactor's ability to survive its own decay heat.

2.1.4.2 Cooling Systems

Several alternative cooling systems for the ZTB were evaluated as part of the pre-conceptual design. The initial system was a chilled water system that only provided cell air cooling. This system was not selected due to its lack of ability to provide a dynamic response to RDPs that need a fast-acting cooling system. A second round of evaluations were performed based on using chilled water to allow direct cooling of a demonstration reactor heat exchanger. Chilled water systems were determined to not have a high enough operating temperature to support potential RDP needs. The final round of evaluations considered two separate systems, a chilled water system for cooling cell air and a thermal fluid system (e.g., Dowtherm Q) for providing more direct reactor cooling capability. The cell air cooling system was kept in all variations because it was considered feasible that some demonstrators would have strictly air-cooled machines. Providing both the air-cooling system and a direct reactor cooling system within the ZTB delivers the greatest flexibility to support the widest variety of RDPs.

The final heat rejection/cooling system consists of a central plant comprised of two separate subsystems. A 492 kW (140 Tons) chilled water/glycol system will provide air cooling designed to maintain the cell space at a maximum temperature. This system will reject external heat released to the cell space from the operating reactor. A 500 kW direct reactor cooling system (notionally Dowtherm Q) will supply cooling fluid to reactor cooling coils designed and furnished by the RDP for direct reactor cooling. This system will supply cooling fluid at a specific flow rate and temperature to the demonstration reactor heat rejection equipment (e.g., heat exchangers). Figure 32 through Figure 35 provide the general layout and arrangement of the cooling systems.

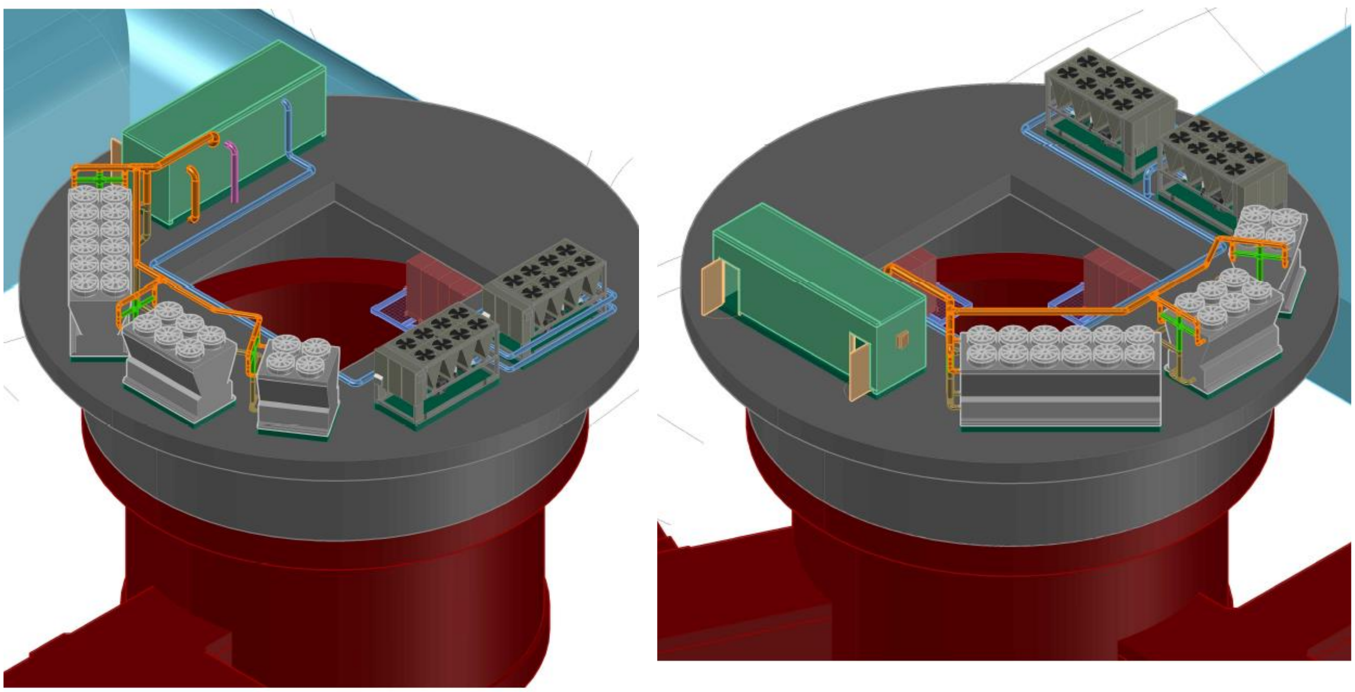

Figure 32. Cooling System Piping from Pump House to Chillers/Coolers

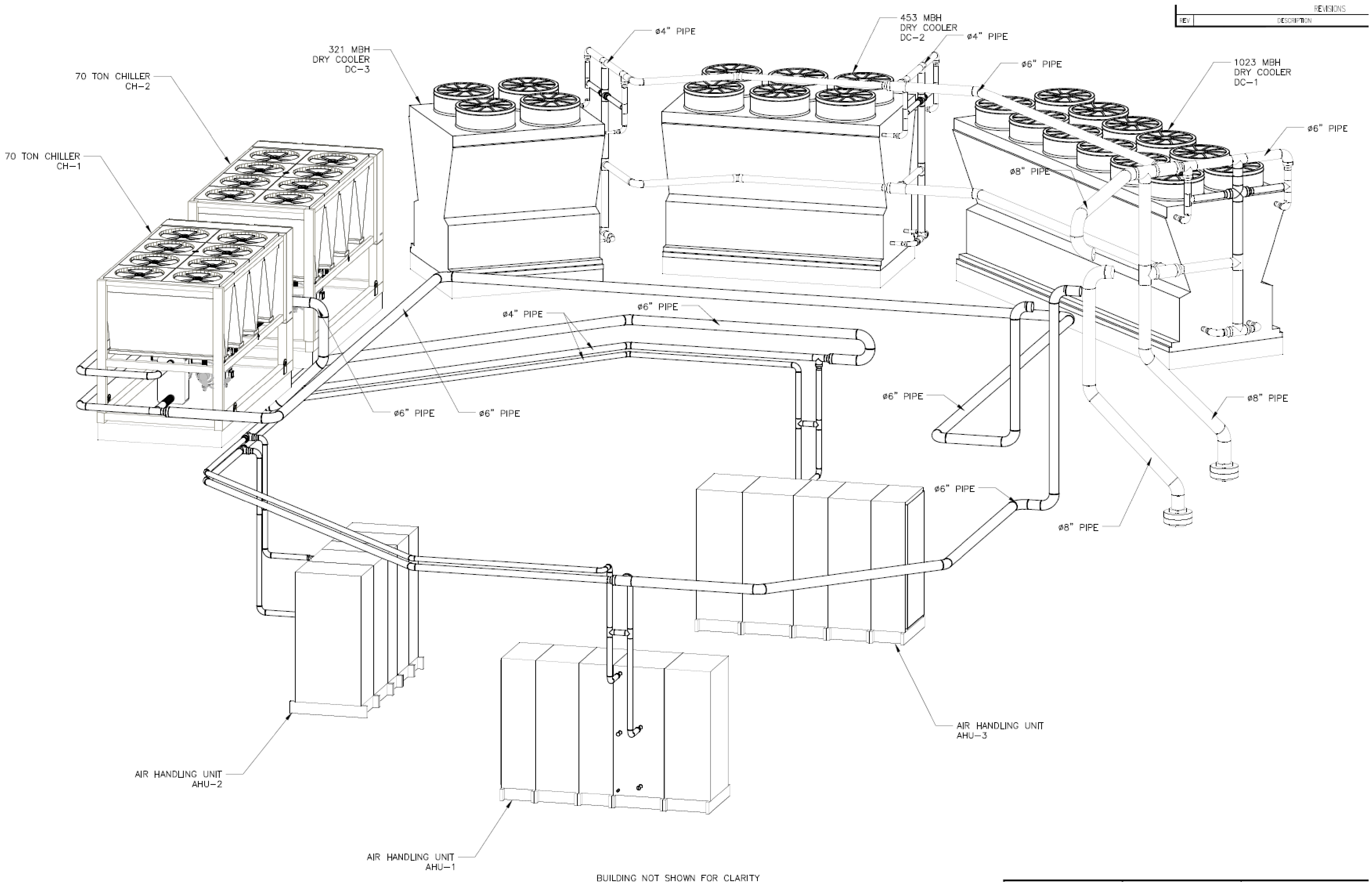

Figure 33. Isometric View of Cooling Systems Without Pump House

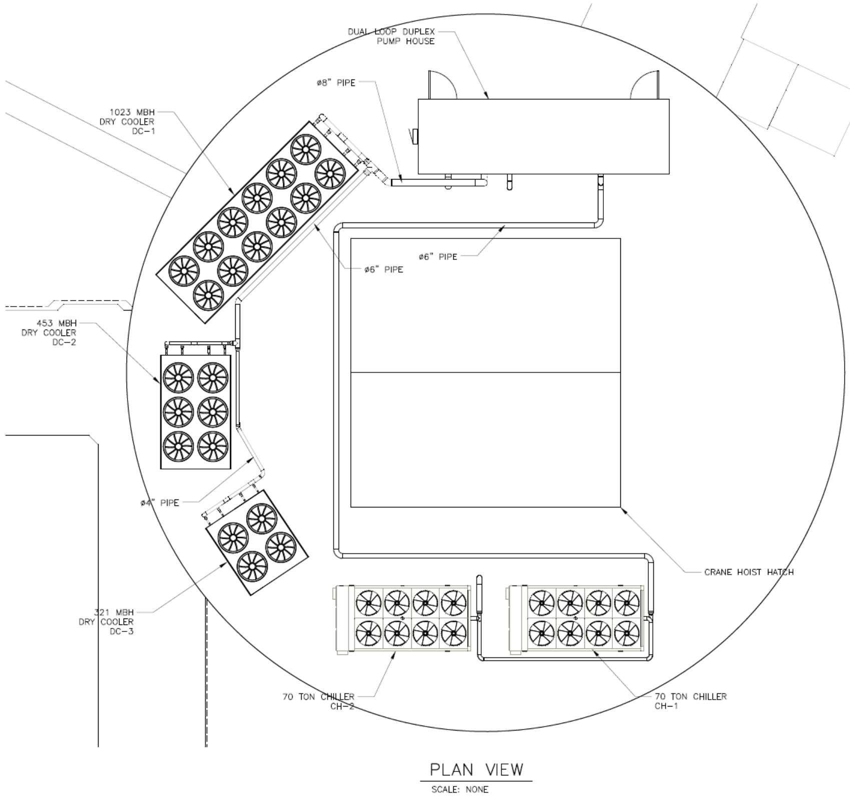

Figure 34. Plan View of Cooling System Outside Confinement

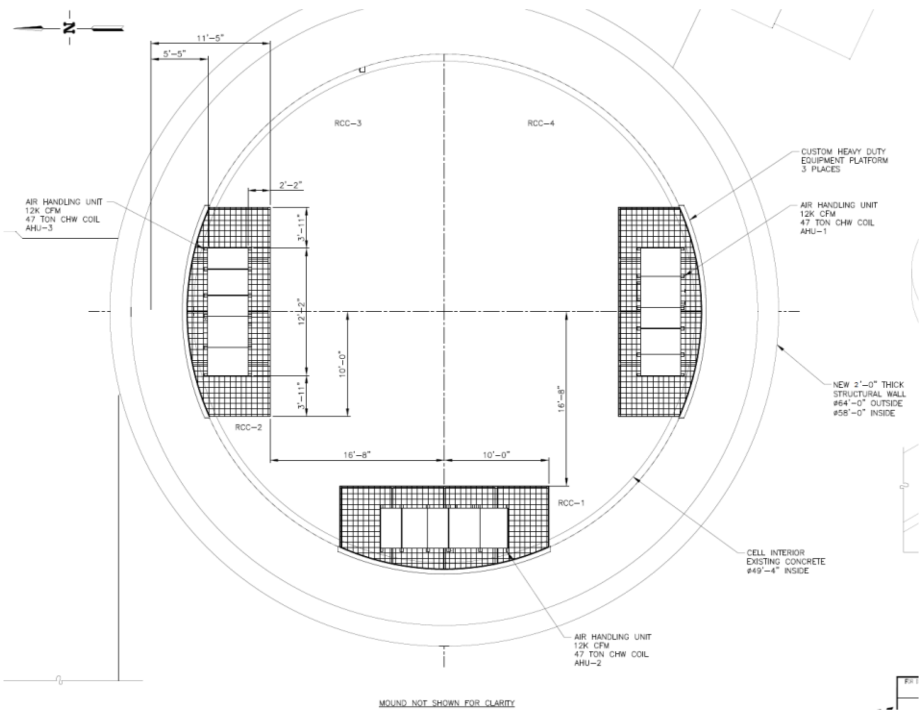

Figure 35. Plan View of Cooling System Inside Confinement

2.1.4.2.1 Confinement Air Cooling

This system consists of two 70-ton air-cooled chillers operating and piped in parallel with both chillers served by one variable speed pump to circulate chilled water/glycol in a primary-only piping loop. There are two pumps for both chillers. One pump is for stand-by service and the pumps will alternate operation in a lead/lag control configuration. The operating chilled water pump shall provide a constant flow of 380 gpm with 190 gpm flowing through each chiller to supply 40°F chilled water/glycol to three cooling coils contained within three 11,500 cfm air handling units with two supply fans each. Each of these air handling units shall supply 50°F supply air to the cell to maintain a maximum cell space temperature of 104°F. Supply air temperature control is provided by use of 3-way modulating control valves serving the cooling coils. It should be noted that the air-cooled chillers can operate down to an ambient temperature of -20°F. Below this ambient temperature the chillers will trip off during operation. They are not able to re-start at an ambient temperature of -10°F or below without having the free-cooling option. Follow-on design efforts are needed to evaluate the impact of the low operating temperature limitation. See Figure 36 for the system piping and instrumentation diagram (P&ID).

2.1.4.2.2 Reactor Cooling

This system consists of three dry coolers operating and piped in parallel with all dry coolers served by one variable speed pump to circulate a heat transfer fluid (e.g., Dowtherm Q) in a primary only piping loop. Three smaller dry coolers were selected instead of a single large cooler to provide more flexibility with power turndown scenarios. There are two pumps for all three dry coolers. One pump is for stand-by service and the pumps will alternate operation in a lead/lag control configuration. Each of the three dry coolers will be a different size. The system shall have one large cooler, one medium cooler, and one small cooler. Load capacity control for each dry cooler shall be provided by 3-way modulating control valves located at each dry cooler. The RDP heat rejection equipment/coils shall be supplied with a constant Dowtherm Q fluid temperature of 110°F at variable flow rates based on RDP heat rejection operating conditions. See Figure 36 for the system P&ID.

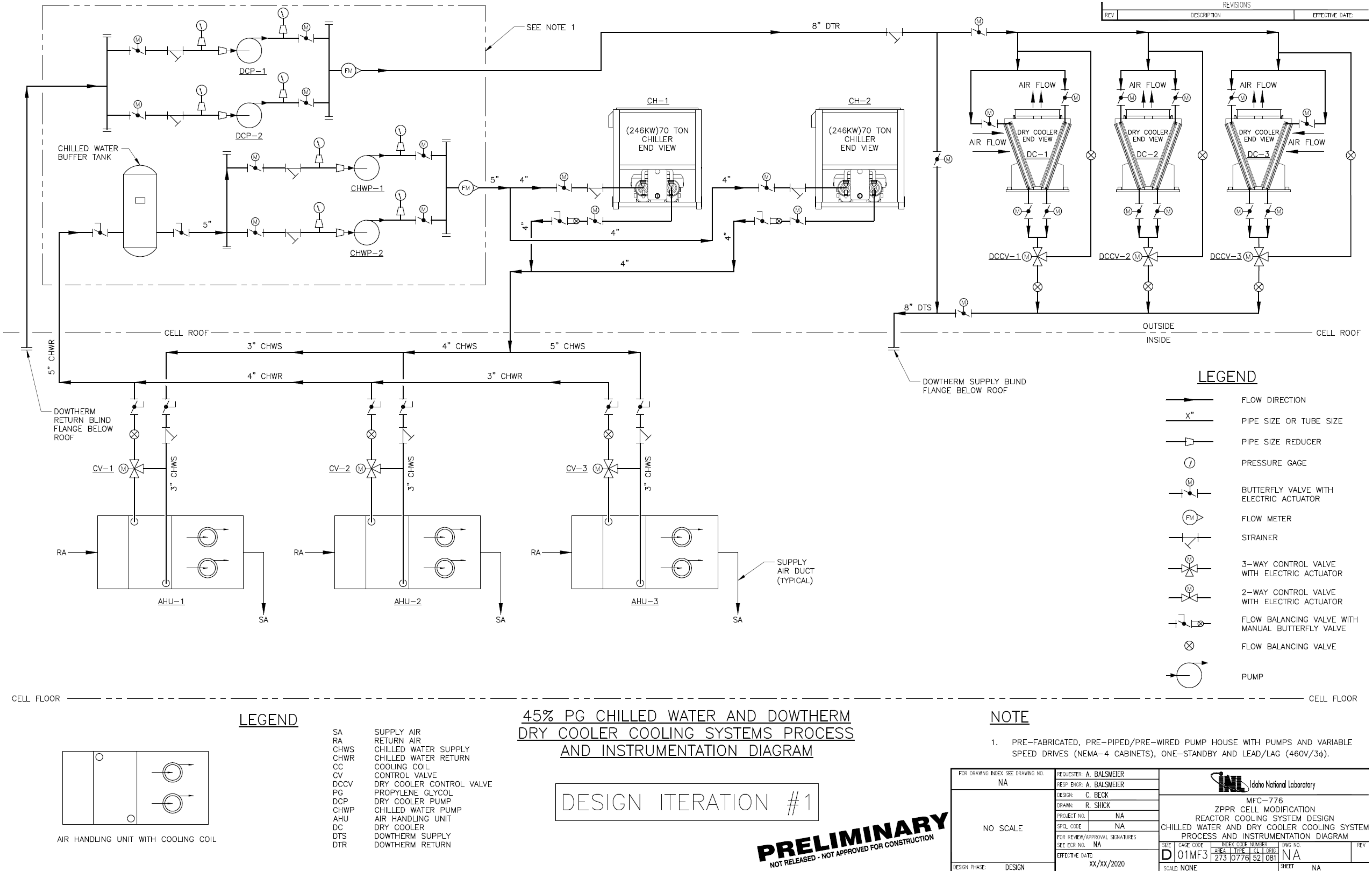

Figure 36. Cooling Systems P&ID

2.1.4.2.3 Pump House

The pump house is a modular prefabricated building comprised of one module enclosure and has overall dimensions of 29 feet long by 8 feet 6 inches wide by 10 feet 6 inches tall and contains the chilled water/glycol pumps and thermal fluid pumps. All pumps are piped and wired at the manufacturer with all necessary piping, valves, fittings, supports and hydronic specialties (major specialty is a 400-gallon buffer tank), and electrical power connections to variable speed drives and pump motor controls. Located on the outside wall external to the pump house module is one 480 Volt/3 Phase Electrical Power Panel, one 208 Volt/3 Phase electrical power panel, and one 480 Volt – 208 Volt transformer; all ready to accept single-point power connections. There is one chilled water fan coil unit with electric heater to provide a conditioned environment inside the pump house.

2.1.4.2.4 Heating

The heating of the ZPPR cell space will be provided by three 15 kWe unit heaters. Each heater will be mounted to the underside of the air handling unit structural support platforms. These unit heaters are sized and selected to maintain the ZPPR cell space at 60°F, minimum.

2.1.4.2.5 Turndown Capability

With the three installed Dowtherm Q coolers and the adjustability on fan and pump speed, it is anticipated that the system will be able to dynamically cool a heat source down to 5% of the total plant rated capacity or less.

2.1.4.3 Ventilation

2.1.4.3.1 Existing System

The ZPPR cell ventilation system is tied in with other facilities within the ZPPR mound including the workroom and vault. The ventilation is identified as a defense-in-depth system that mitigates hazards associated with certain fissionable material handling activities and accidents.

The ventilation system supplies air to the ZPPR mound area by one of two ventilation supply fans (located within the outside equipment room in building MFC-777). Air enters the mound area via filters and heating or cooling coils and is directed to the work room vault and cell. Approximately 4,000 to 5,000 cfm is provided to the mound. Approximately 200-1,000 cfm of air flows from the supply distribution header through ductwork down the cell access corridor entering the cell where it is distributed from ducting located around the periphery of the cell wall. The air then flows across the cell entering the exhaust duct in the alcove adjacent to the access corridor.

In the original configuration, when the cell supported the ZPPR, ventilation system dampers RIV-101 and RIV-101A on cell exhaust (DWG 785555 [9]), and RIV-102 and RIV-102A on cell supply (DWG 785554 [10]) acted as an isolation boundary between the cell and other mound area rooms. These valves were shut when the reactor was operating. In 2008, the ZPPR reactor was dismantled and removed from the facility eliminating the need for the isolation. In 2016, these dampers were locked open and the actuators were removed.

The ZPPR mound ventilation exhaust is divided into four zones, one of which exhausts air from the ZPPR cell and the workroom. The exhaust fans move air to a common exhaust header which then flows through the exhaust header and to the ZPPR stack.

The ZPPR stack is located outside of the mound on the south east corner and north of building MFC-777. The stack is 75 feet tall and made from 24-inch diameter schedule 10 pipe. The ZPPR mound main exhaust is connected to the base of the stack. Stack monitoring is not currently required for the ZPPR exhaust, but it does have an alpha monitor for radiation detection.

2.1.4.3.2 Modified System

The system will have to be flexible to support different evolutions and a variety of demonstration reactors. Upgrades will have to ensure that differential pressures within the facility and flow rates are sufficient for each evolution or mode within which the cell is operated. These modes are envisioned to include a standby mode, operation mode, and an isolation mode.

The isolation mode is required while a reactor is operating within the cell and may be initiated during design basis accidents. During this mode the cell will be isolated reducing the exhaust from the room to a small amount to maintain required differential pressure. The exhaust will also have to control any direct emissions from the reactor.

The operation mode occurs when work is being performed within the cell (not including reactor operation), and is required during installation, maintenance, and decommissioning of reactors within the cell. This mode is to allow personnel in the ZPPR cell as well as allow for the cell to be opened to receive or remove a reactor through the cell hatch. In this mode, operations are anticipated in the cell that may use bottled gasses or might have the potential to increase the creation of fumes and other airborne contaminates. These operations will increase the amount of outside air required for the cell. The exact increase in airflow required for a particular operation is a function of several factors and will be determined by the Industrial Hygienist based on analysis of the operation. The system needs to provide sufficient ventilation for a variety of operations.

The standby mode would occur when the cell is not in use and could potentially require less ventilation.

To allow for the cell to be isolated during operation of reactors, upgrades to the ventilation system will be required. In the original configuration ventilation dampers acted as an isolation boundary between the cell and other mound area rooms. These dampers are no longer in service and need to be refurbished/replaced. As part of the confinement boundary, these isolations are anticipated to be safety-class SSC. In the corridor, the cell supply and exhaust ducts utilize 12-inch and 14-inch diameter pipes.

When supply is isolated from the cell, the ventilation system needs to accommodate for the change in flow. A study needs to be performed to verify that the existing variable frequency drives (VFDs), fans, and ducting can maintain required differential pressures during operations. The cell exhaust will have to accommodate low flow exhaust capabilities to handle potential exhaust from demonstration reactors/equipment.

Currently the exhaust ventilation is provided with single stage HEPA filtration. A second stage should be installed within the cell. This will help reduce any potential contamination from the cell entering the exhaust header that is shared with other rooms in the mound. Flanders G series filters can easily be installed in the exhaust duct, if required. In addition, fire dampers will need to be installed in the exhaust and supply ducts to isolate the cell from other areas within the mound.

2.1.4.3.3 Stack and Monitor

The use of the ZPPR cell as a demonstration reactor test bed increases the potential to emit radionuclides into the environment. Due to this possibility, a stack monitoring system will be required. The monitoring would be required during reactor operation (isolation mode), and during maintenance (operation mode). In the current system all exhaust from the ZPPR cell is combined with other exhaust from the mound in the common exhaust header and is then is routed to the stack.

It is uncertain if the existing stack can be qualified in accordance with the required American National Standards Institute (ANSI) standards. For the pre-conceptual design, it is assumed that a new stack will be required.

A stack monitoring system will be required. A system similar to those in use at MFC facilities Fuel Manufacturing Facility (FMF) and the Irradiated Materials Characterization Laboratory (IMCL), will be the basis for the design of the stack monitor. There is sufficient room within MFC-777 (directly south of the stack) for the stack monitoring equipment.

2.1.4.3.4 Over/Under Pressure Protection

The ZTB provides a confinement to enclose the demonstration reactor and associated systems. The purpose of the confinement is to ensure any potential release from a demonstration reactor is filtered using the ZTB ventilation system. The confinement volume will be kept at a negative gauge pressure in normal operation to enable the leak tightness of the secondary confinement building to be monitored. A filtered ventilation system is provided to maintain a negative gauge pressure during operation. However, the ventilation system installed in the ZPPR mound is not designed to provide over/under pressure control during a design basis accident (DBA). These DBAs will vary for each test reactor and will have to be verified with the capabilities of the ZTB confinement.

Confinement over-pressurization is a postulated event in which the pressure loads applied to the confinement boundary during a severe accident eventually exceed the boundary’s ultimate strength at its most vulnerable point(s). This event has been hypothesized as a means of confinement failure through one or more of several potential physical mechanisms. The extent of pressurization, its timing, and the pressurization rate all depend on several factors, including the accident sequence characteristics involved, the confinement geometric configuration, etc. Ultimately the difference between the confinement’s pressure retaining capability and the induced pressure the confinement will undergo during severe accidents must be compensated for with an over/under pressure protection system.

Originally the ZPPR cell over/under pressure protection was provided by the design of the ZPPR roof structure. The roof of the cell contained a gravel-sand roof that provided filtering and ventilation, as well as a secondary structure above the ZPPR roof that provided filtration. The secondary structure housed 285 high-efficiency filters that were nominally rated at 1,000 cfm each (285,000 cfm total). The original ZPPR gravel-sand roof could accommodate steady cell overpressures up to 12.5 psig without disturbing the roof or altering its confinement characteristics. The removal of the gravel and existing roof structure will eliminate the original over/under pressure protection.

The planned modifications for the ZTB include removing the gravel-sand roof and replacing the roof with steel/concrete structure and an access hatch. Pre-conceptual design analysis has shown that the new ZTB roof and structure can withstand at least a pressure of +/- 1 psig. Additional analysis needs to be performed to evaluate the confinement's upper pressure limits during DBA. It should be noted that the roof hatch with the current anticipated weight will be unseated at a pressure slightly over 2 psig unless additional hold down measures are taken (not currently planned). For any given demonstration reactor, engineering solutions must be implemented to ensure that the DBA for that reactor does not violate the ZTB confinement's pressure retaining ability.

Seal pots have successfully been used to provide over/under protection in hot cells at MFC. Seal pots can be made in a variety of sizes and flow rates and can be connected to HEPA filters to provide filtered exhaust. The oil level provides a bi-directional pressure seal to allow an overpressure exhaust or an under-pressure intake of air and can be set to provide protection below the design pressure of the confinement. A seal pot sized for 3,000 cfm of flow would provide sufficient cell exhaust due to temperature and pressure increase caused by decay heat of a 500 kWth test reactor.

The existing ventilation and exhaust system have been evaluated for support of demonstration reactors and was originally thought to be the most cost-effective solution. However, given that a new stack is needed, the over pressure protection system will likely be required to install ducting to the roof with filters, and installing safety-class SSC in the existing system indicate that evaluation of a separate system dedicated to the ZTB cell should be done. It is unclear if a separate system would be significantly more expensive than the required modification and would allow the ZTB to operate more as an independent facility from the other portions of the ZPPR mound.

2.1.4.4 Confinement Sealing and Testing

2.1.4.4.1 Doors

There are two seal doors in the corridor to the ZTB cell. Until a few years ago, these seals were maintained as part of the preventive maintenance program. The seal doors will have to be returned to service and re-furbished to perform their original function.

At the location of each of the seal doors, there are bulkheads with utility penetrations. The seals at these bulkheads will need to be re-furbished to restore their sealing function either by repair, replacement, or removal of various utilities, as applicable.

2.1.4.4.2 Leak Test/Pressure Test Accommodations

Testing of the ZTB confinement will be performed by drawing a suction on and pressurizing the ZTB cell with the exhaust and supply fans and measuring the flow rate. This will require accurate flow measurement capability in the exhaust and supply ducting.

The initial leak rate requirement for the ZTB cell identified in FOR-538 [1] is 5% of cell volume per day. Given the anticipated size of the cell after modification, this will result in an allowable leak rate of approximately 3-4 cfm. Given the facility construction, size of the hatch, and doors in the corridor to the cell, it may be challenging to achieve this level of leak tightness.

2.1.4.5 Gas Supplies

2.1.4.5.1 Compressed Air

Compressed air is already available for use in the ZPPR cell. No action is needed to provide compressed air as a utility to the ZTB, unless it is needed in very large quantities. Initial discussions with demonstrators do not currently indicate a large demand for compressed air.

2.1.4.5.2 Compressed Argon

Compressed argon from a bulk cryogenic tank is available in the ZPPR work room. A connection to this system will be provided to the ZTB. However, this system has a relatively limited capacity (less than 25 scfm, based on vaporizer limitations). Approaching the limit of the system capacity could be viable for short periods. However, prolonged use at or near the system flow limit will likely not be practical since the system is currently shared between three facilities.

2.1.4.5.3 Other (Future Use)

It is anticipated that over the life of the ZTB, demonstrators may have a need for other bulk compressed gases such as nitrogen or increased argon flow. Provisions have been made for additional bulk gas use as part of the ZTB. The provisions include penetrations in the roof and a concrete pad in the yard area that is 32 feet by 37 feet. This pad is over twice as large as a recently installed pad at MFC for a 6,000 gallon cryogenic argon tank and vaporizers.

Based on discussions with the anticipated initial demonstrators, there is no demand for the ZTB to have additional bulk compressed gas at this time. Bulk gas storage will not be installed as part of the initial construction of the ZTB. Small quantities of other compressed gasses can be provided with the use of gas bottles or small portable dewars.

2.1.5 Electrical and I&C Systems

2.1.5.1 Normal Power

The two major loads that will require power in the ZTB are the reactor and the new cooling systems. The new cooling systems are anticipated to require a 600A 480V service. The power supply to the reactor is anticipated to require a 400A 480V service. Together these two services will require approximately 500 kW of power. The ZPPR substation has approximately 800 kW of capacity remaining. The substation also has available breaker positions. A one-line diagram is shown in Figure 37.

Routing of the normal power from the substation can be accomplished by installing conduit to the cable routing room. From the cable routing room, there are penetrations into the ZPPR cell with multiple 4-inch conduits. There is an existing 4-inch conduit run directly to the desired location for the reactor power panel, which is sufficient for the planned 400A service. The 600A service will leave the building from the cable routing room and conduit will be run along the outside of the mound to the roof for connections to the cooling system equipment.

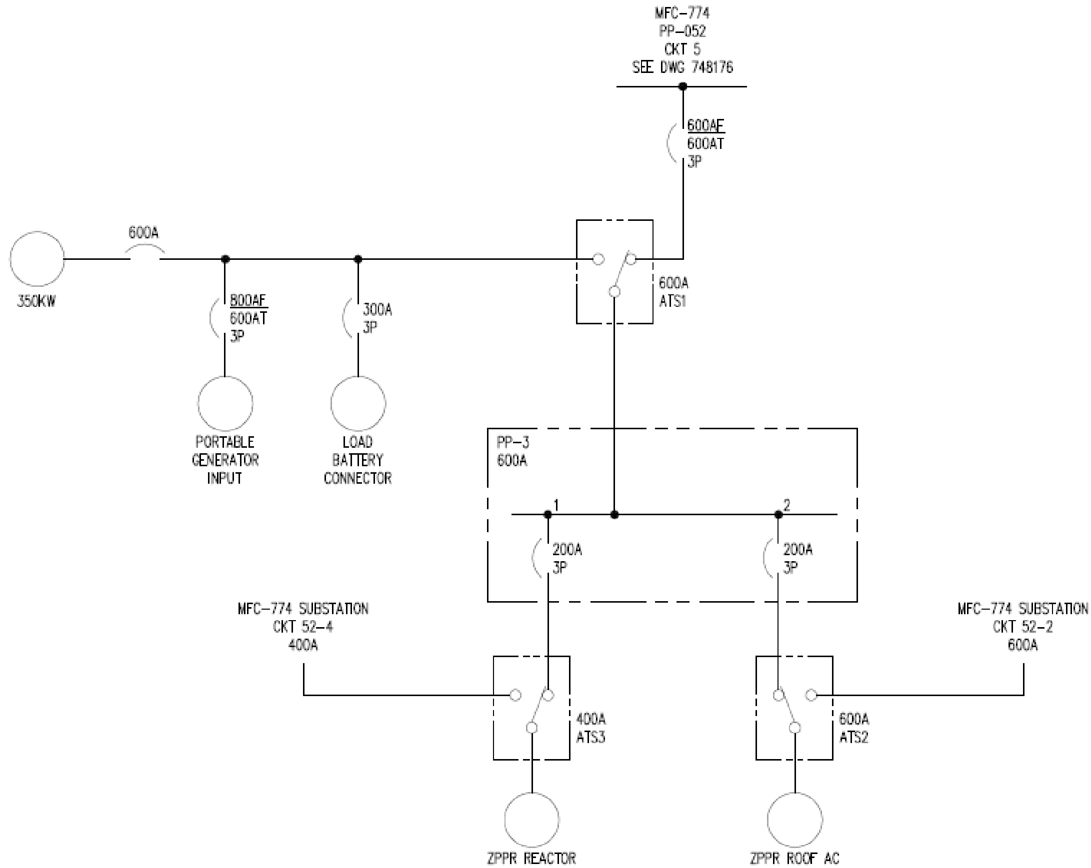

Figure 37. One-line Diagram for the ZTB Electrical Systems

Reactor control cables will also have to pass through seal boxes. There is the possibility that the power lines (400A service) could interfere with the signals. Shielding is planned for the power lines, but the worst-case scenario is the electrical power would have to be routed to the ZPPR cell without use of the penetrations from the cable routing room. In this case the 400A service would follow the same route as the 600A service to the roof, but would then have to penetrate the roof and be routed down the cell wall to the desired location of the reactor electrical panel.

2.1.5.2 Non-Safety Backup Power

Conversations with demonstrators interested in use of the ZTB indicate that non-safety backup power would be advantageous due to the liquid metal reactor designs being considered. In the event of a loss of off-site power, a generator that could run heaters and keep the reactor molten would prevent potential damage to equipment and lost time on re-starting the reactor.

The existing diesel generator available for ZPPR use is original equipment from initial construction and does not have sufficient excess capacity to supply the anticipated reactor loads. A new diesel generator will be installed south of building MFC-774 and adjacent to building MFC-725. A generator sized in the range of 350 kW would be able to replace the existing facility demands and supply the anticipated power required for demonstration reactors.

To support the new generator location, about 100 feet of duct bank will have to be installed to connect the diesel generator to the basement of building MFC-774.

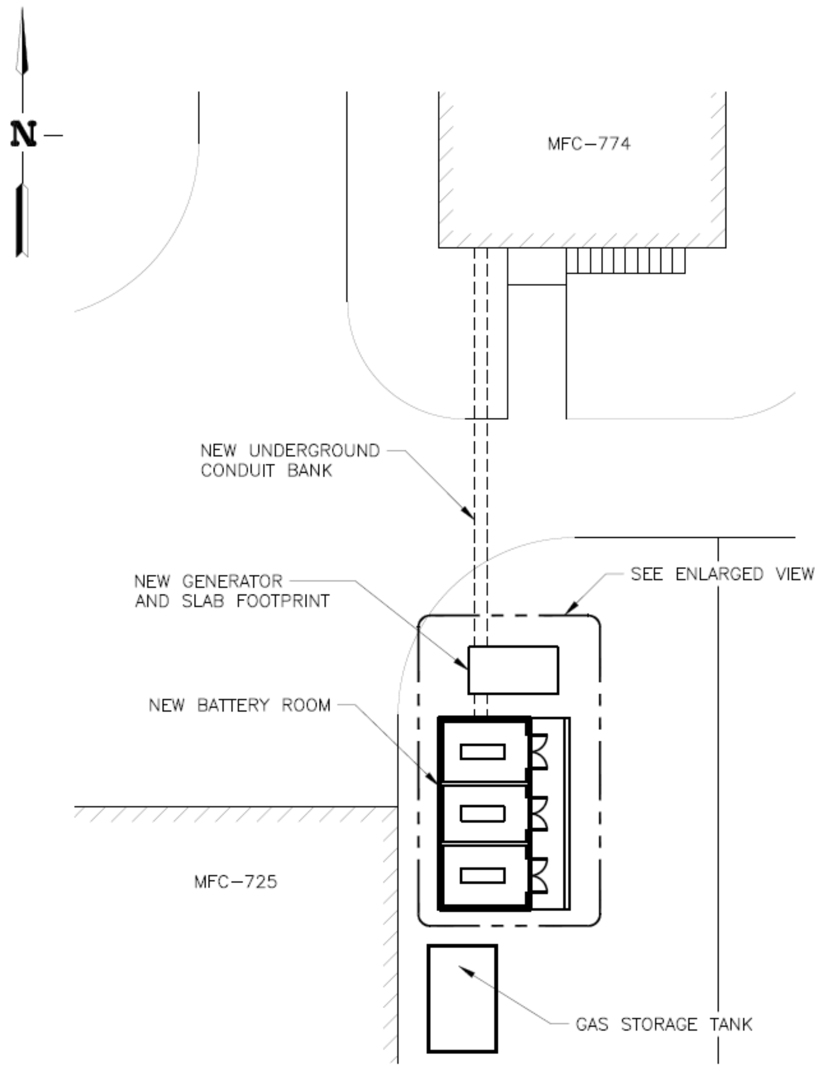

Figure 38. Diesel Generator Install and Battery Room Location

In addition to the diesel generator being installed, a connection should be made available to allow additional power generation to be connected to the facility.

2.1.5.3 Safety Backup Power

It is anticipated that a limited safety-class electrical power supply will be needed/required for reactor operations. As a safety-class power system, there must be three divisions of equipment. Each division must be separate and independent from other divisions and from non-safety equipment.

The system is nominally 24VDC at 50A with a capacity to support up to 10 instruments (or equivalent) for up to 72 hours. Each division needs a capacity of 3,600 A · h. A 72 hour operation span was judged to be sufficient time for any one of several actions to happen: restore off-site power, connect alternate power supply (portable or otherwise) to feed battery chargers, or verify reactor is in a safe, stable, shutdown configuration with no risk of re-criticality. Battery sizing will need to be further refined as the design progresses.

The batteries will require support systems to ensure the environmental requirements for battery operation are maintained. The batteries must be maintained at 25 °C ± 3°C to achieve the rated capacities. The environmental controls are envisioned to be a simple mini-split heating/cooling unit on the roof for each division with a simple temperature feedback.

The major equipment required for this system is listed below and a one-line diagram of one division of the batteries is shown in Figure 39.

1. Battery – 12 plus 1 spare for each division (39 total cells)
2. Battery disconnects – 1 for each division (3 total)
3. Battery chargers – 1 for each division plus 1 spare (4 total)
4. Voltage regulators – 1 for each division (3 total)
5. Transformers – 1 for each division plus 1 spare (4 total)
6. Isolation breakers – 2 for each division (6 total)
7. Distribution panels and associate breakers – 1 for each division (3 total).

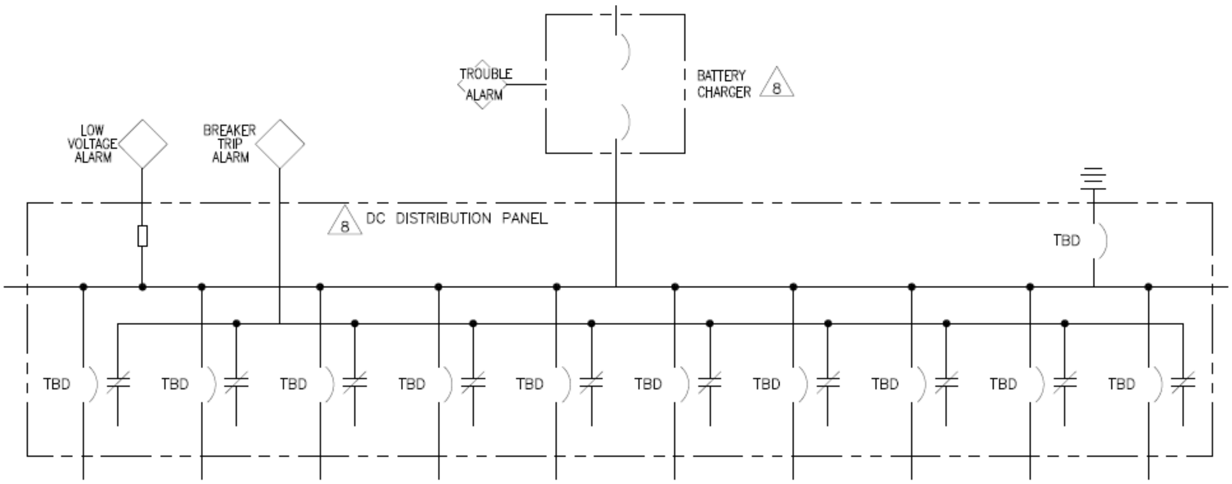

Figure 39. Single Division of Safety-Class Batteries

The current plan is to provide a new battery enclosure. The proposed battery building is a simple concrete block building on slab with a concrete roof. Power would have to be provide to the building for charging the batteries, lighting in the building, and environmental controls. The plan is to locate the battery building next to the new diesel generator. This would allow the battery building to utilize the duct bank being installed for the diesel generator connections to the facility. An evaluation will have to be performed for building MFC-774 to demonstrate its ability to house safety-class SSC without damage during an SDC-3 event. If the building is not structurally capable of withstanding an SDC-3 event, alternate routing of the battery connections will be required. The proposed general location of the battery building is shown in Figure 38. A detailed view of the battery building is shown in Figure 40 and Figure 41.

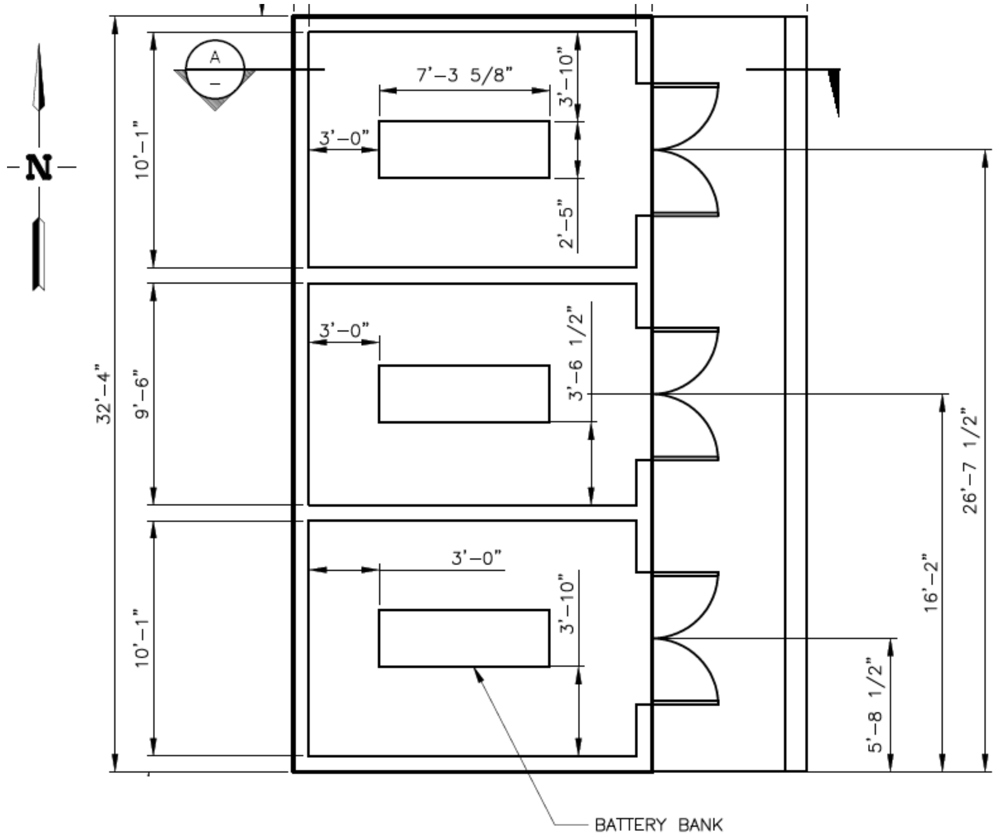

Figure 40. Proposed Battery Building Layout

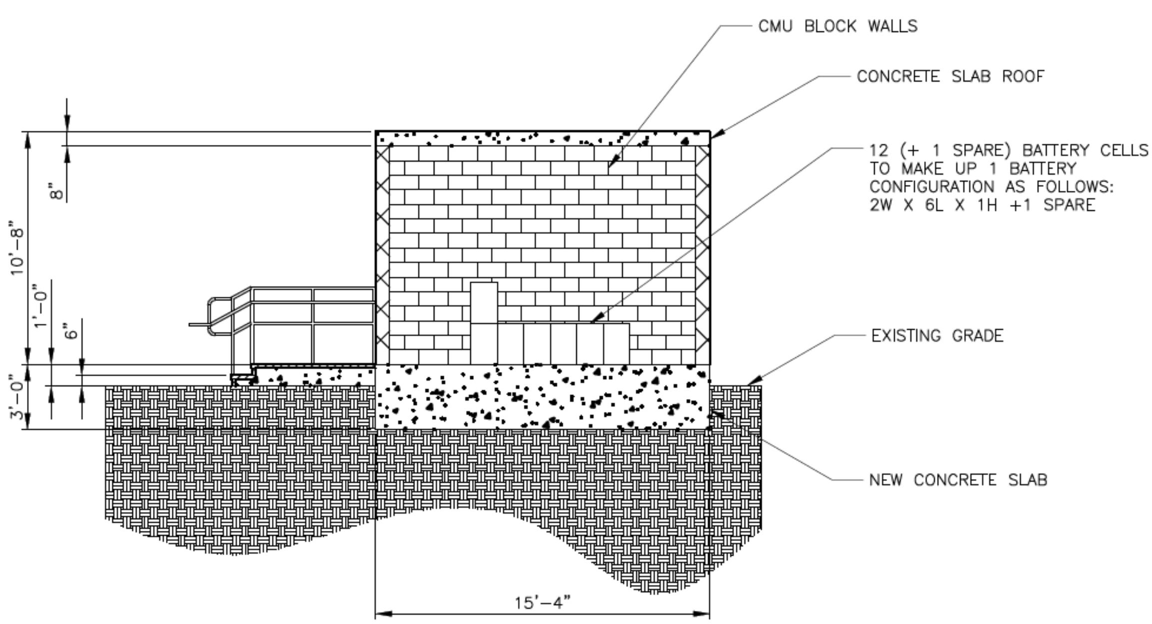

Figure 41. Battery Building Elevation View

2.1.5.4 Control Room and I&C

Basic ZTB control room equipment for controlling cooling systems, ventilation systems, etc. is not a Safety SSC. Any necessary reactor control and monitoring equipment, Safety SSC or otherwise, will be provided by the demonstrator with data integration to the ZTB control equipment and/or the MFC private facility control network (PFCN). The ZTB control room will include a Programmable Logic Controller (PLC) that will provide operator interfaces and control functions of the reactor cooling system and confinement cooling and ventilation systems. The confinement oxygen monitoring system will also be connected either using the same PLC or as a stand-alone PLC using the MFC-PFCN.

The pre-conceptual design locates the control room in building MFC-774 just outside the entrance to the ZPPR mound, see Figure 42. Figure 43 illustrates the location within building MFC-774. This location is the ZPPR control room, which formerly housed the control equipment for the original ZPPR reactor. The ZPPR control room is primarily used by ZPPR operations personnel as general workspace.

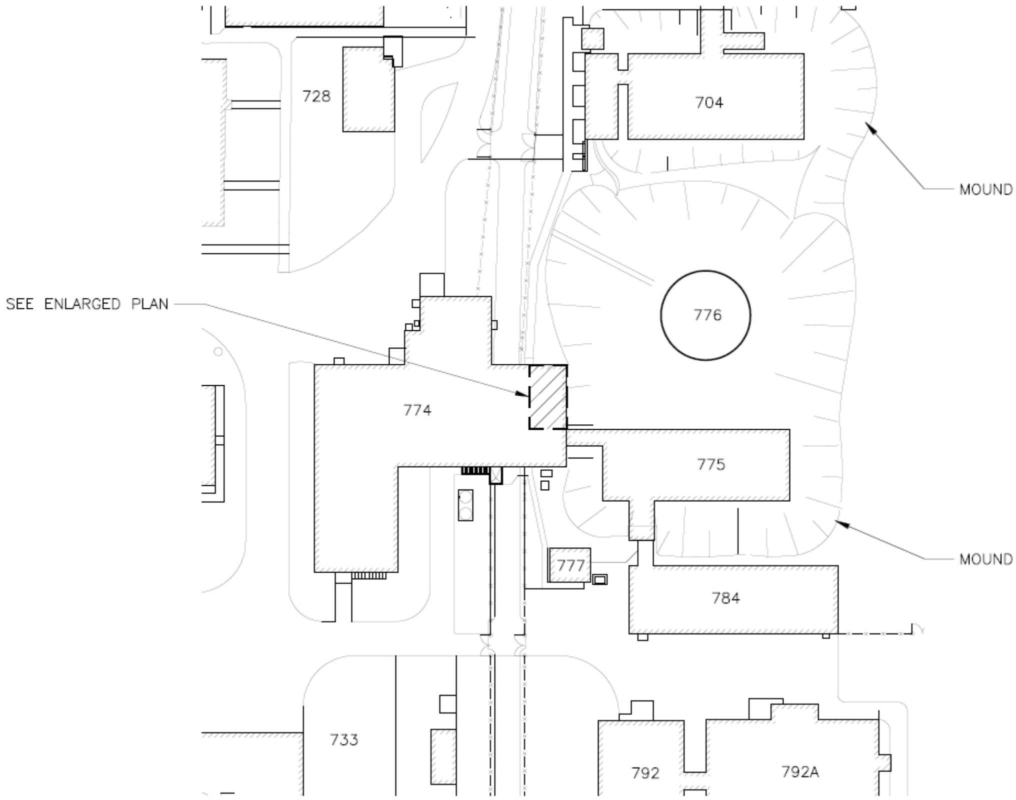

Figure 42. General Location of Control Room at MFC

To renovate this space into a control room, several actions will be necessary and are listed below:

1. Frame new walls
2. Restore conduits from the control room to the cable routing room
3. Route conduit and fiber optic cable from the control room to the existing PFCN in the basement of the Electron Microscopy Laboratory (EML)
4. Provide general telecommunications connections to the room (i.e., phone, and INL Intranet)
5. Install operator workstations (computers separate from the control system)
6. Install furniture (e.g., operating consoles, monitor mounts, tables, chairs, etc.)
7. Install a service window to allow communications with the control room personnel without entering.

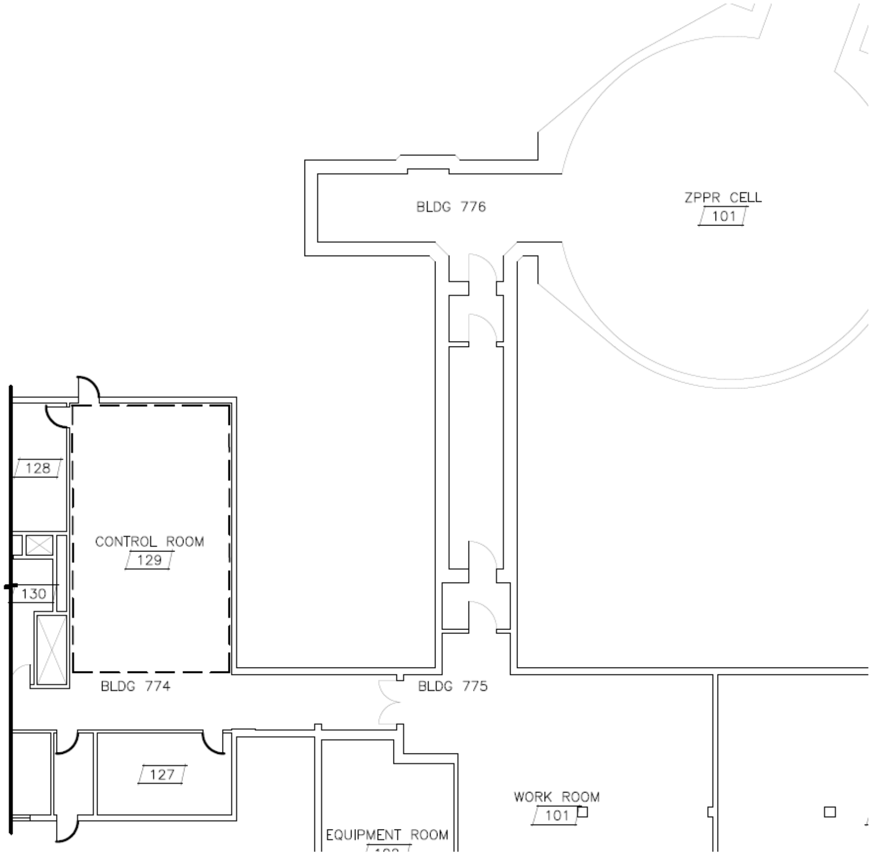

Figure 43. Control Room Location in Building MFC-774

In all conceptualized operating scenarios, the reactor operators are outside of the ZTB confinement and will be available for reactor monitoring since the safety-class confinement is anticipated to protect the operators and control room from the anticipated accidents. If the applicable data is being sent over and stored on the MFC-PFCN, it can be sent to any desired location at MFC or the INL, including to the emergency control center (ECC).

It is assumed that any data transmission outside of the control room would not require Safety SSC, that is, the MFC-PFCN will not be a Safety SSC.

2.1.5.5 Network

MFC has a PFCN that can be used as a secure backbone for transmitting data internal to INL and has provisions for transmitting data through multiple firewalls and DMZ to outside entities. It is envisioned that data transmission from MFC to an offsite demonstrator will be necessary, but that all control functions will be limited to the control room for the ZTB.

The system architecture to accomplish the anticipated connection and data transmission are shown in Figure 44 and Figure 45 and a network schematic for the NRIC connection to the MFC-PFCN is shown in Figure 46.

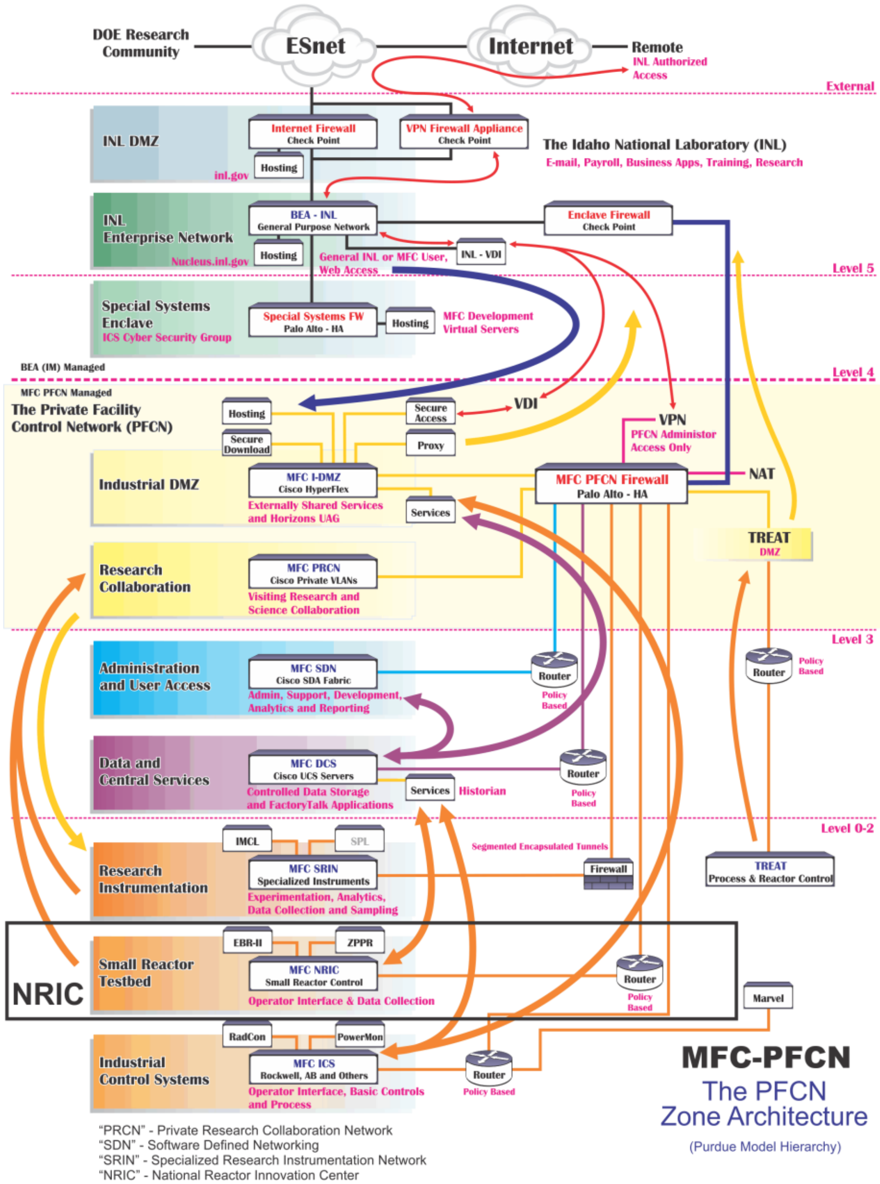

Figure 44. MFC-PFCN Zone Architecture

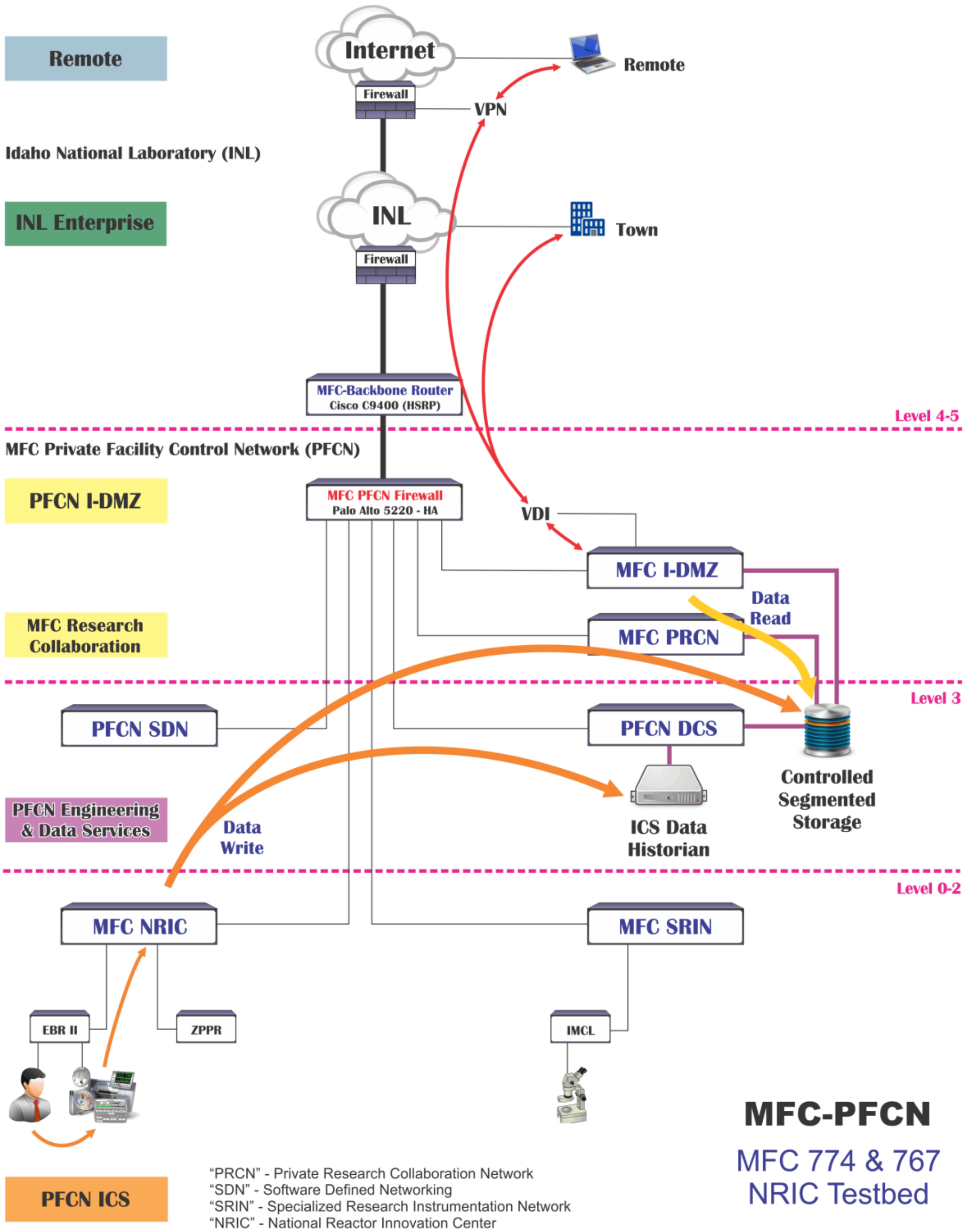

Figure 45. NRIC Testbed PFCN Architecture

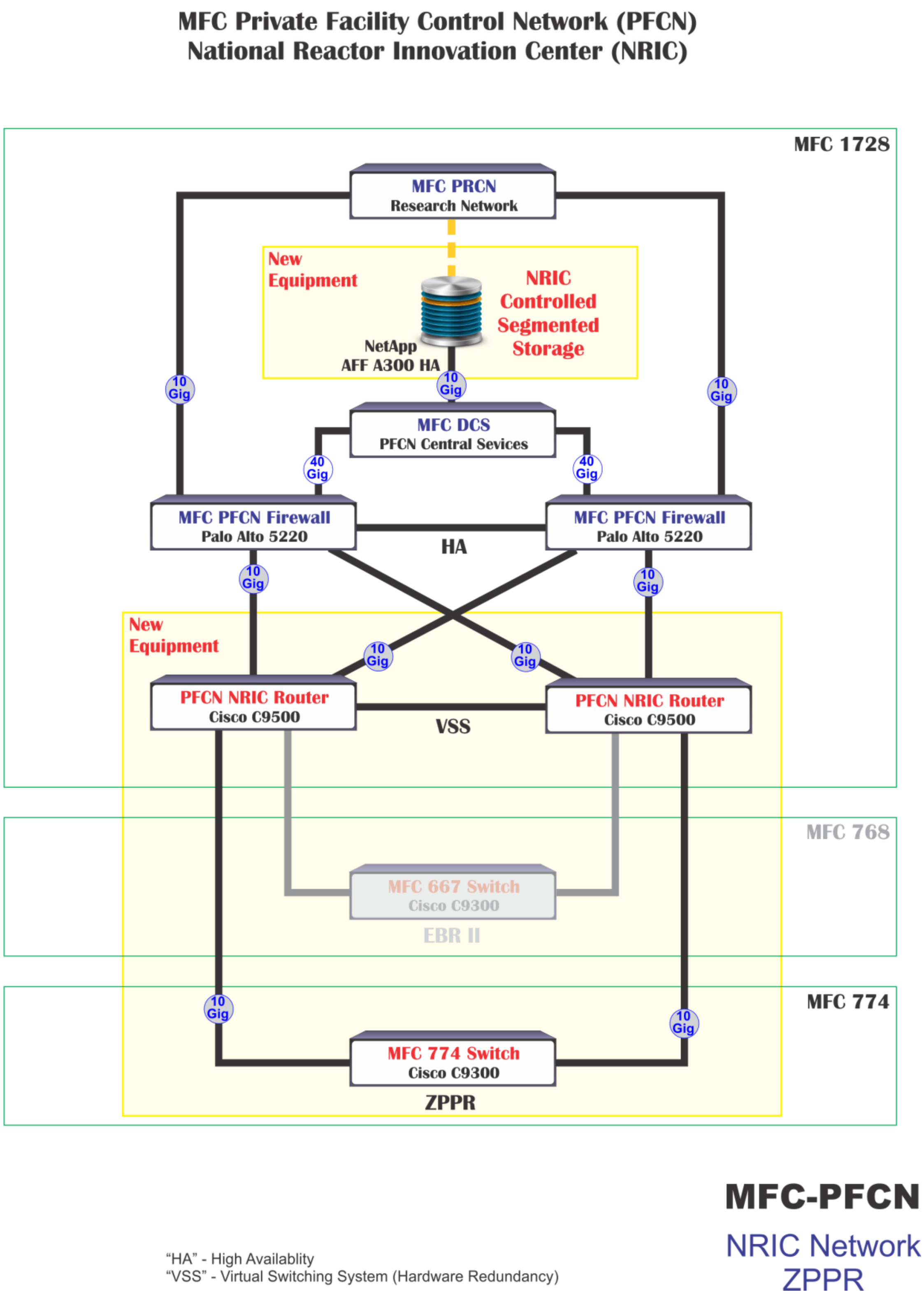

Figure 46. NRIC ZTB Network

To accomplish the connection to the MFC-PFCN and data transmission beyond the PFCN, a network cabinet will be required in the ZTB control room. In addition, a high-availability, controlled storage segment for NRIC and two high availability routers will be required in building MFC-1728 (dial room). It should be noted that once the NRIC equipment is placed in the dial room, it can support multiple test beds (i.e., ETB) without duplication of the equipment in the dial room. A draft of the network cabinet needed in the ZTB control room is shown in Figure 47.

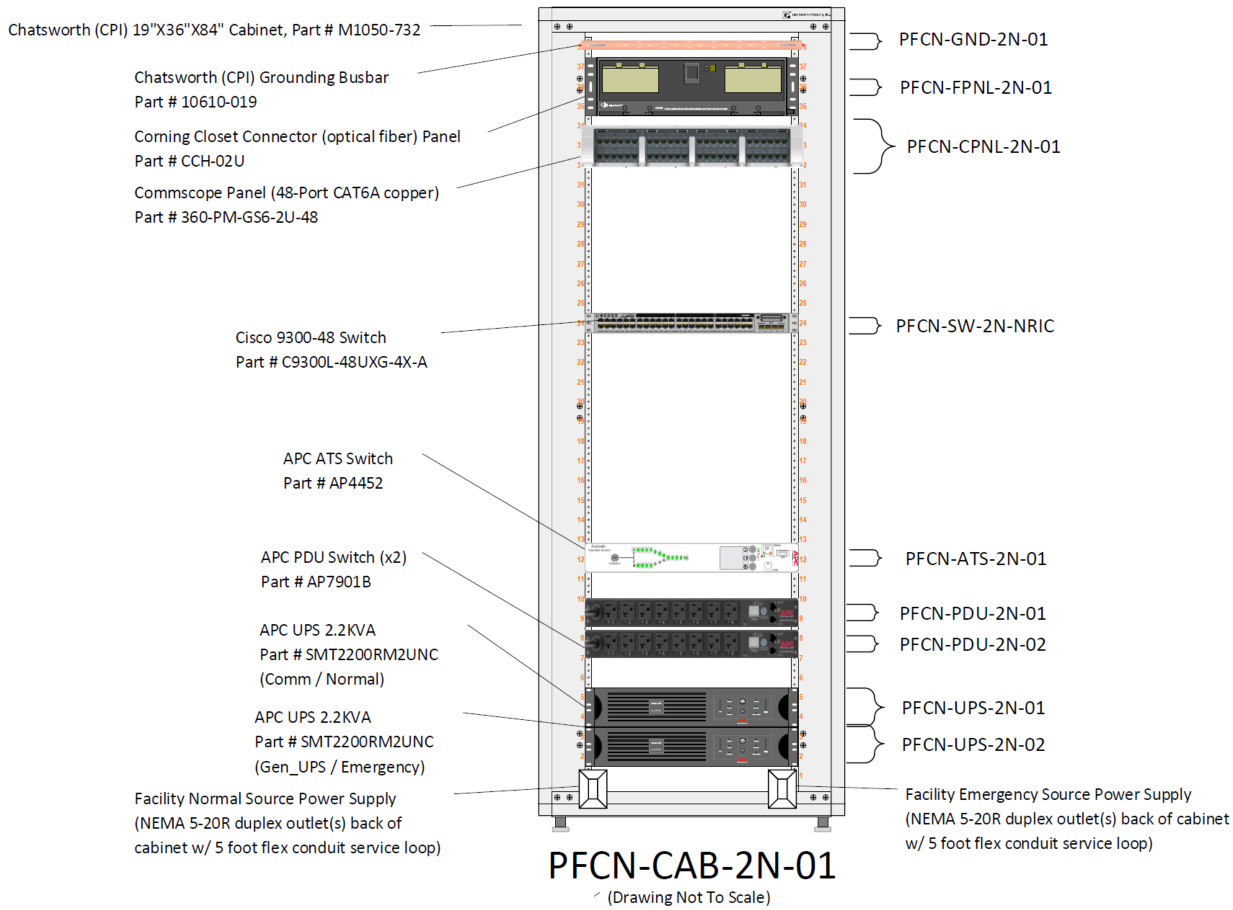

Figure 47. ZTB Network Cabinet

With this network in place, any ZTB equipment that utilizes ethernet (e.g., PLCs), can be connected to the NRIC network and controlled in the control room and the associated data can be sent to the control storage segment and shared appropriately with the necessary parties both internally or externally.

2.1.6 Life Safety

2.1.6.1 Fire Protection

The ideal strategy for dealing with fire hazards is an active fire suppression system in accordance with DOE orders. If this type of system is infeasible, ineffective, or hazardous, other equivalent means of mitigating risk may be pursued. Exemptions from the applicable requirements would have to be sought prior to using “equivalent” means. Several types active fire suppression systems were considered as part of the ZTB pre-conceptual design. Each of the systems types is listed below with a brief description of the potential challenges the system poses.

1. Water Suppression – These systems create a fire hazard where reactive materials are in use. In addition, water systems may pose a criticality hazard depending on the reactor type, configuration, and accident scenario.

2. Mist System – These systems rely on water and pose some of the same hazards water suppression.

3. Clean Agents (Novec 1230, Halon, Stat-X) – Based on evaluations to date, these systems are ineffective on Class D fires, e.g., uranium or sodium.

4. Inerting Systems (CO_2/N_2) – These systems are hazardous to personnel and require approval from DOE to implement. Due to the personnel hazards involved, these systems should not be used for occupied areas.

The ZTB is planned to support a wide variety of advanced reactor concepts some of which may include reactive materials (e.g., sodium) as a main aspect of the design. The potential for reactive materials likely eliminates options 1-3, above. The ZTB confinement is not currently intended to be occupied during reactor operation, but will have to be occupied for equipment maintenance, reactor installation, and reactor removal for non-trivial periods of time. The need to occupy the ZTB confinement would eliminate option 4 above.

MFC fire protection engineering is continuing to evaluate various fire suppression systems. If an effective option can be identified, it will be pursued. It should be noted that various reactors at MFC have existed in the past that did not have active fire suppression systems for the same reasons discussed here.

If an active fire suppression system is determined to be infeasible, hazardous, or ineffective, an evaluation justifying the position will be completed and submitted for approval by the INL Fire Marshal and DOE. In this situation a fire detection system would be pursued as the next most effective strategy for mitigating fire hazards. These types of systems provide early detection and allow response while the fire is in the incipient stages. Along with other controls such as non-combustible facility construction, fire barriers, and combustible loading program, fire suppression systems help provide an equivalent means of protection. Examples of fire detection systems are: smoke detection, heat detection, a very early smoke detection apparatus (VESDA), and flame detectors. Each of the detection systems is a viable option and has positive features and limitations that would be further evaluated in the fire system analysis if an effective suppression system cannot be implemented.

2.1.6.2 Oxygen Monitoring

Based on the possible presence of non-trivial quantities of inert gases used in support of demonstration reactors, an oxygen monitoring system must be installed for personnel protection. Oxygen monitoring systems are in widespread use at MFC and a general design exists that is tailored to the needs of a given facility. A representative example of what would be require for the ZTB confinement is that of building MFC-784, shown in INL DWG 815131 [11].

For the ZTB, a PLC controlled system with four oxygen area monitors is envisioned. The monitors will be equipped with strobe lights and audible alarms and will be positioned roughly equally around the perimeter of the confinement with one at the personnel entrance to the confinement near ground level. The PLC is envisioned to be located in the control room with the wires from each monitor passing through an existing conduit back to the control room for termination in the PLC.

2.1.7 Security

Anticipated demonstration reactors for the ZTB include plutonium fuels and/or highly enriched uranium. This will require the ZTB to be a safeguards category 1 facility; the current facility is also a safeguards category 1 facility. One challenge presented by this is that the security posture of the existing facility must be maintained during removal of the old roof and construction of the new roof since there is currently not a security barrier between the ZPPR cell and the remainder of ZPPR facility in the mound. This difficulty would exist when the hatch is removed for equipment installation, as well.

To help alleviate security issues a security door should be placed in the corridor to the ZTB cell prior to initiated any activities that would breach the existing facility boundary. The suggested location of the new security door is shown in Figure 48. In this location, those portions of the ZPPR facility requiring the highest levels of security could be isolated from the construction/installation activities and workers could enter through the north tunnel. While the new door does not remove all concerns with physical security during construction, it is anticipated to reduce the compensatory measures required.

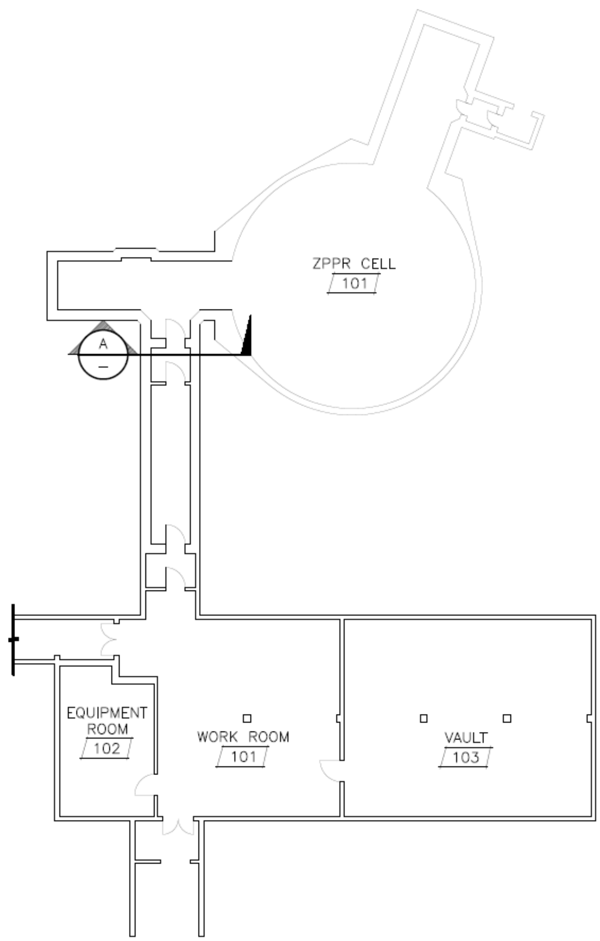

Figure 48. Security Door Location

For this strategy to be successful, the north tunnel must be accessible so the new security door in the corridor can remain closed throughout the duration of the construction and installation activities. It is known that the north tunnel currently has structural issues that may prevent it from becoming the regular access method for the cell during construction. These issues are assumed to be resolved by others prior to initiating the ZTB construction project.

3. SYSTEMS ENGINEERING

Since the realization of the ZTB requires the design, installation, and integration of several unique systems the implementation of the ZTB will utilize a systems engineering (SE) approach. SE is an interdisciplinary approach and means to enable the realization of successful systems and facilities. The initial focus is defining customer needs and required functionality early in the development lifecycle and then proceeding with design synthesis while balancing operations, cost, schedule, and performance. This approach integrates all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to operations and eventually, disposal. Model-based systems engineering (MBSE) further extends the use of systems engineering methodologies by relying on models and a database as the primary means of information exchange between engineers, rather than traditional document-based environments. The benefits of this approach include enhanced communications between team members, real-time collaboration, and a single source of truth for up-to-date project information.

The fundamental principle to the MBSE approach employed for the ZTB is that there are three architectures: a requirements architecture (traditional requirements management), a functional architecture (defining what the facility must accomplish), and a physical architecture (system development and design). Within each architecture there is also a hierarchy of information divided into the facility level, the system level, and the component level. The process moves from eliciting facility-level stakeholder requirements, to analyzing the full scope of functionalities required of the final project, and finally to developing systems and components that can meet the needs of the functional architecture. The relationships between information is captured at each phase so that decisions made at lower levels of the design can be traced all the way back to initial stakeholder input, facilitating faster impact analysis. During the design iteration, project action items and risks are also identified and captured in the database.

Figure 49 shows the completed data architecture of the MBSE process.

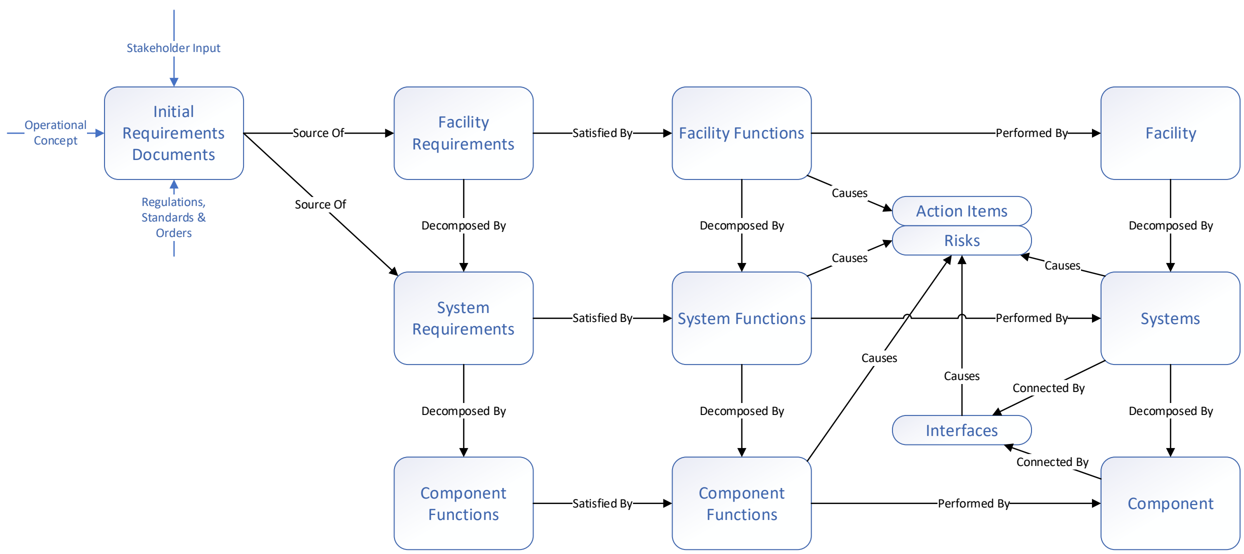

Figure 49. Completed Data Architecture of the MBSE Process

Throughout the pre-conceptual design process, requirements, risks, design issues, test bed functions, system definitions, and other SE data were entered and managed through an online MBSE tool called Innoslate. This tool serves as the “source of truth” for working knowledge and information related to the ZTB. Periodically, data are output from the tool and saved as formal documents within INL’s document management system to serve as project snapshots.

3.1 ZTB Functional Architecture

As discussed in Section 3, a primary component of implementing an SE approach to the ZTB is defining the functional architecture. Through this process, the actions the ZTB is to perform are identified and then decomposed into step-by-step processes. Nine top-level actions were identified:

1. ZTB.1, “Accept and Store Reactor Demonstration Project (RDP) Modules”
2. ZTB.2, “Install and Prepare RDP”
3. ZTB.3, “Provide Industrial Utilities for Operations”
4. ZTB.4, “Provide Availability to RDP During Planned-Use Timeframes”
5. ZTB.5, “Maintain Confinement Boundary”
6. ZTB.6, “Provide Safeguards & Security”
7. ZTB.7, “Provide Human Life Safety”
8. ZTB.8, “Monitor and Control Facility and Systems”
9. ZTB.9, “Remove RDP”

Figure 50 provides an example of an action diagram located within ZTB.1, to accept and store RDP modules.

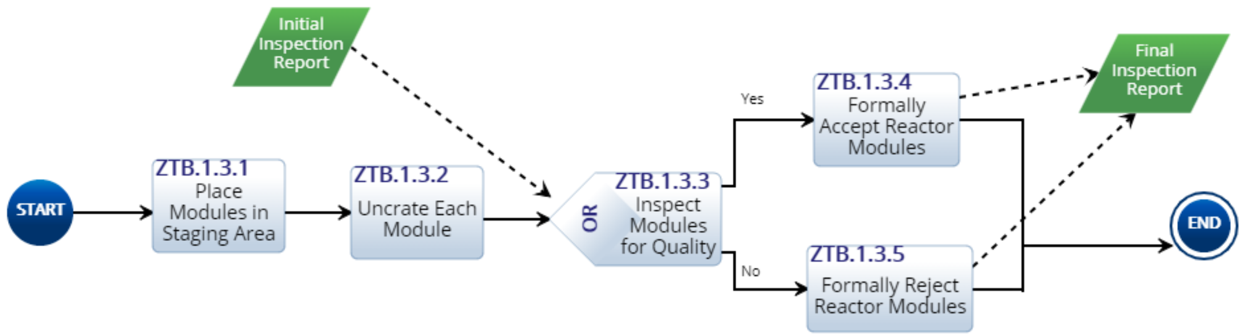

Figure 50. Decomposed Action Diagram of ZTB Function 1.3, “Accept Delivery to Site.”

3.2 ZTB System Architecture

As the ZTB utilizes a currently functional facility, a system breakdown structure (SBS) could not be created considering only the ZTB. Therefore, existing systems that will neither be modified nor installed throughout the implementation of the ZTB are included in the SBS. The “R” notation within the system’s number denotes an addition to the current Master Equipment and Activities List (MEAAL) [12]. The SBS for the ZTB is included in Appendix D.

4. COST ESTIMATE TO RENOVATE ZPPR

A level 5 cost estimate has been completed to identify expected costs for the renovation of the ZPPR cell to create a test bed for advanced reactor demonstrations. The estimate is based on the pre-conceptual design outlined in this report. The final estimate is provided to DOE under separate cover.

To aid in the development of the cost estimate the detailed work breakdown structure (WBS) has been used. The WBS separates the project into major systems to allow the organization of project performance data by system rather than phase. The cost estimate uses the WBS to identify costs of the major systems and this strategy will be used for all future work on the project. The detailed WBS can be found in Appendix B.

5. RISKS AND DESIGN ISSUES FOR IMPLEMENTING THE ZPPR TEST BED PROGRAM

Appropriately managing risk is paramount to the success of implementing the ZTB within defined project thresholds. Risk can simply be defined as anything that impacts the ability of the project to meet its objectives. Risks themselves are known while their possibility of occurring is only supposed. DOE Order 413.3b [13] defines risk as a “factor, element, constraint or course of action that introduces an uncertainty of outcome, either positively or negatively that could impact project objectives.”

The identification and documentation of risks begins early in the project lifecycle and is an iterative process. Risks are then managed through identified response strategies such as to accept, mitigate, or transfer. These strategies integrate with and become part of the overall project execution strategy.

As they relate to an engineering design project, design issues signify details of project activities not yet performed. In contrast to a risk, an issue represents a standard (known) component of the engineering design process. Design issues are confronted and addressed throughout project design phases. Some of the design issues may represent obtaining a simple communication with a stakeholder while others may indicate a need for an analysis of design alternatives. While the resolutions of these issues may cause changes to the project’s deliverables, the impact of those changes is minimized as the design progresses towards finalization.

Both risks and design issues were identified and documented during the ZTB pre-conceptual design phase. Further design phases (e.g., conceptual, preliminary) will address these elements through detailed project planning.

5.1 Risks

Thirty-four individual risks were identified and analyzed during the ZTB pre-conceptual design risk analysis. Commensurate with the maturity of the ZTB’s design, only preliminary probability and consequence values have been assigned to the risks. Risk identification, analysis, planning, and responses will iteratively continue throughout the process of implementing the ZTB.

Project risks were analyzed using five categories for each consequence and probability. Definitions of those categories are provided in Table 2 (Consequence) and Table 3 (Probability).

Table 2. Consequence Category Definitions

Consequence Category	Technical Definition	Schedule Definition
Negligible	Minimal or no impact	Schedule delays that do not affect milestones or critical path
Marginal	Small change needed to design or path forward	Schedule delays that may affect external milestones or threaten a slip along the critical path
Significant	Moderate change needed to design or path forward	Schedule delays that will slip the critical path <6 months
Critical	Major change needed to design or path forward with an available workaround	Schedule delays that will slip the critical path ≥6 months but < 1 year
Crisis	Major change needed to design or path forward with no available workaround	Schedule delays that will slip the critical path ≥1 year

Table 3. Probability Category Definitions

Probability Category	Definition
Very Unlikely	< 20% of occurring during the ZTB implementation
Unlikely	≥ 20% and < 40% of occurring during the ZTB implementation
Somewhat Likely	≥ 40% and < 60% of occurring during the ZTB implementation
Likely	≥ 60% and ≤ 80% of occurring during the ZTB implementation
Very Likely	> 80% chance of occurring during the ZTB implementation

The initial risk identification and analysis yielded no high risks. Three medium-high risks were identified, one of which is an opportunity; these risks are described below:

1. **ZTB-RISK-026, "Digital Controls" (Opportunity)**

   Risk Description: Implementation of digital controls allow for modularity of control console and simplicity of cable runs

2. **ZTB-RISK-032, "Long Lead Items"**

   Risk Description: Long lead items cannot be ordered early enough in the project to meet expected project end date

3. **ZTB-RISK-034, "Subcontracting Delays"**

Risk Description: Issuing subcontracts requires more schedule time than planned.

A significant number of medium risks were identified. The combination of several medium risks occurring can quickly lead to unsatisfactory project-level results. Adequate risk management strategies should be applied to appropriately minimize the impact of these risks, where possible.

The risk diagram provided by the MBSE tool, Innoslate (Figure 51) illustrates the overall project risk profile. The risk register in Appendix A includes all the risks identified to implement the ZTB. Note that, all risk identifiers correspond to their numbering within Innoslate.

	Negligible	Marginal	Significant	Critical	Crisis
Very Likely > 80%			• ZTB-RISK-026 Opportunity - Digital controls • ZTB-RISK-034 Subcontracting Delays		
Likely 60% - 80%		• ZTB-RISK-027 Inadequate staff for key technical areas - Subcontractor(s)	• ZTB-RISK-006 Permit to Construct • ZTB-RISK-014 Changing Design Inputs • ZTB-RISK-029 Inclement Weather	• ZTB-RISK-032 Long Lead Items	
Somewhat Likely 40% - 60%		• ZTB-RISK-011 Utility Supply • ZTB-RISK-022 System Inspection Schedule • ZTB-RISK-030 Undocumented/Missed • ZTB-RISK-031 RDP Interface Assumptions	• ZTB-RISK-016 Cost overrun on test bed system(s) • ZTB-RISK-019 Installed systems do not meet • ZTB-RISK-021 Sole-source suppliers		
Unlikely 20% - 40%		• ZTB-RISK-008 Class 1E Backup Power Scope • ZTB-RISK-010 Roof Radiation Dose • ZTB-RISK-015 Inadequate staff for key technical areas - • ZTB-RISK-017 Emergent issues affect design documents	• ZTB-RISK-001 Cell Leak Rate • ZTB-RISK-007 Fire Protection System • ZTB-RISK-009 Electrical Penetrations • ZTB-RISK-020 Readiness Assessments • ZTB-RISK-028 Contractor unable to meet contractual requirements	• ZTB-RISK-018 Selected components unavailable at necessary quality levels	• ZTB-RISK-024 Funding lapse or delay • ZTB-RISK-033 National Environmental Protection Act (NEPA)
Very Unlikely < 20%			• ZTB-RISK-003 Lifting Capability / Area / Approach • ZTB-RISK-012 Code Compliance • ZTB-RISK-013 Crucial component supply chain	• ZTB-RISK-002 Seismic Design • ZTB-RISK-004 Reactor Removal • ZTB-RISK-005 Emissions Limits • ZTB-RISK-023 Accident at facility during system • ZTB-RISK-025 DOE does not approve the updated ZTB Documented Safety Analysis	

Figure 51. ZTB Risk Diagram

5.2 Design Issues

Numerous design issues were identified during the ZTB pre-conceptual design. Some design issues were resolved during the pre-conceptual design phase and are now incorporated into the engineered solutions provided in this report. Efforts to resolve the remaining issues will be undertaken in later design phases. As such, several of the design issues entail suggestions for specific design and analysis-related activities in those phases.

Some of the significant, outstanding issues are detailed below. A complete list of outstanding design issues is listed in Appendix C. Note that all design issue identifiers correspond to their numbering within Innoslate.

1. **ZTB-AI-005, "Heaviest Demonstration Reactor Component"**

   ZTB-AI-005 relates to the flow-down of system requirements due to the single heaviest component that supports an RDP. The ZTB Concept of Operations [14] describes a mobile crane that will be used to lift reactor components and place them in the ZPPR cell through an opening in the roof, typically covered by a large hatch. Through brief discussions with crane vendors, the pre-conceptual design team concluded that a larger crane than anticipated would be required to lift the roof hatch. In addition, the crane would need to be placed closer to the lift point as a crane's lifting capacity diminishes significantly as the boom is extended away from the crane's base. The pre-conceptual design proposes solving this challenge by removing a portion of the ZPPR mound to allow the crane to be placed as close as possible to the roof opening. The heaviest demonstration reactor component informs the crane's size, thus directly relating to the amount of the mound that must be removed from the existing ZPPR mound. Under-sizing this space could yield significant cost and capability issues for an RDP.

2. **ZTB-AI-026, "Sampling During Operations"**

   An originating requirement for the ZTB [15] involves implementing the capability to move radioactive samples from the ZPPR cell to an appropriate co-located examination facility. A concept for enabling this capability has yet to be determined. Most likely the concept would require some level of remote handling capability; however, that conclusion is highly dependent upon the RDP's goals and design.

3. **ZTB-AI-027, "Required I&C Signals"**

   This design issue specifically addresses which instrumentation and controls (I&C) signals will be passed from the demonstration reactor to the test bed supporting systems (e.g., cooling and ventilation isolation). This issue also represents a broader group of design issues which rely upon input from reactor demonstrators to be successful. Obtaining this input can be quite challenging since many demonstration reactor design projects are in early stages of design.

4. **ZTB-AI-030, "Compatibility and Rigor of I&C Signals"**

   Integrating I&C systems between projects often leads to a conclusion of incompatibility. The instrumentation and control scheme in the pre-conceptual design assumes a basic communication protocol is used between the reactor control system (provided by demonstrator) and the standard industrial controls system used in by the ZTB (provided by INL). If a more complex or robust communication protocol is needed or required, a substantial amount of engineering effort and/or additional hardware may be necessary. This issue also relies on reactor demonstrator input to be successful.

5. ZTB-AI-031, “Structural Integrity of ZPPR Control Room (MFC-774)”

Since safety-class electrical equipment will be inside of or routed through building MFC-774, it needs to be analyzed to NDC-3 criteria. If the structure cannot meet the criteria, then an alternate location for the batteries must be determined.

6. ZTB-AI-032, “Overpressure Protection Capability”

It is possible that pressure within the cell could increase due to a reactor accident. The current design of the ZTB includes overpressure protection equipment. Some accident scenarios will be analyzed within the general ZTB safety analyses showing that the overpressure protection equipment performs satisfactorily. However, each RDP will analyze their own reactor-specific events. The capability of the ZTB overpressure protection may not satisfy those specific reactor events which may require additional pressure relief. The maximum capabilities of the design shall be calculated and communicated to RDPs.

7. ZTB-AI-033, “Stand-alone Cell Ventilation”

The current design of the ZTB assumes the new ventilation system will replace the existing ventilation system. Due to the competing requirements for the ventilation system originating from the multiple facilities using it, it may be more cost-effective to construct a stand-alone ventilation system for the cell. This option should be investigated in later stages of the ZTB design.

6. SUMMARY

The engineered design solutions discussed throughout this report provide a feasible approach to implementing the ZTB concept described in the current Concept of Operations document [14]. While the depth of design detail varies between systems, the pre-conceptual design effort yielded a design package and cost estimate that delivers significant value to later design phases and project activities.

Commensurate with a pre-conceptual design effort, detailed system designs were not completed. However, the design team cataloged technical design issues that captured areas requiring further evaluation, design, and/or analyses. The MBSE software Innoslate contains the list of design issues, which are presented and discussed in this report. The design team recommends the continued use of Innoslate to ensure appropriate management of requirements, interfaces, issues, and individual risks. Furthermore, the success of these efforts was aided by the involvement of a reactor developer interested in using the ZTB to demonstrate their technology. The collaboration allowed each team to consider otherwise imperceptible aspects of interfaces and requirements. The design team further recommends close, continued collaboration with reactor developers to provide the highest quality product.

7. REFERENCES

1. FOR-538, "Functional and Operational Requirements - ZPPR Modifications to Support Demonstration Reactors," Revision 0, June 30, 2020.
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10. INL Drawing No. 785554, "MFC-775, MFC-776 and MFC-777 ZPPR Complex Building Air Supply Process and Instrument Diagram," Revision 1, June 2, 2016.
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14. PLN-6067, "ZPPR Demonstration Reactor Test Bed – Concept of Operations," Revision 0, May 28, 2020.
15. NRIC-20-PRG-0001, "Zero Power Physics Reactor Test Bed (ZTB) – Originating Requirements," Revision 0, August 25, 2020.

8. APPENDICES

Appendix A, Risk Register
Appendix B, ZTB Work Breakdown Structure
Appendix C, Design Issues
Appendix D, ZTB System Breakdown Structure
Attachment 1, ZTB Functional and Operational Requirements
Attachment 2, Pre-Conceptual Drawings

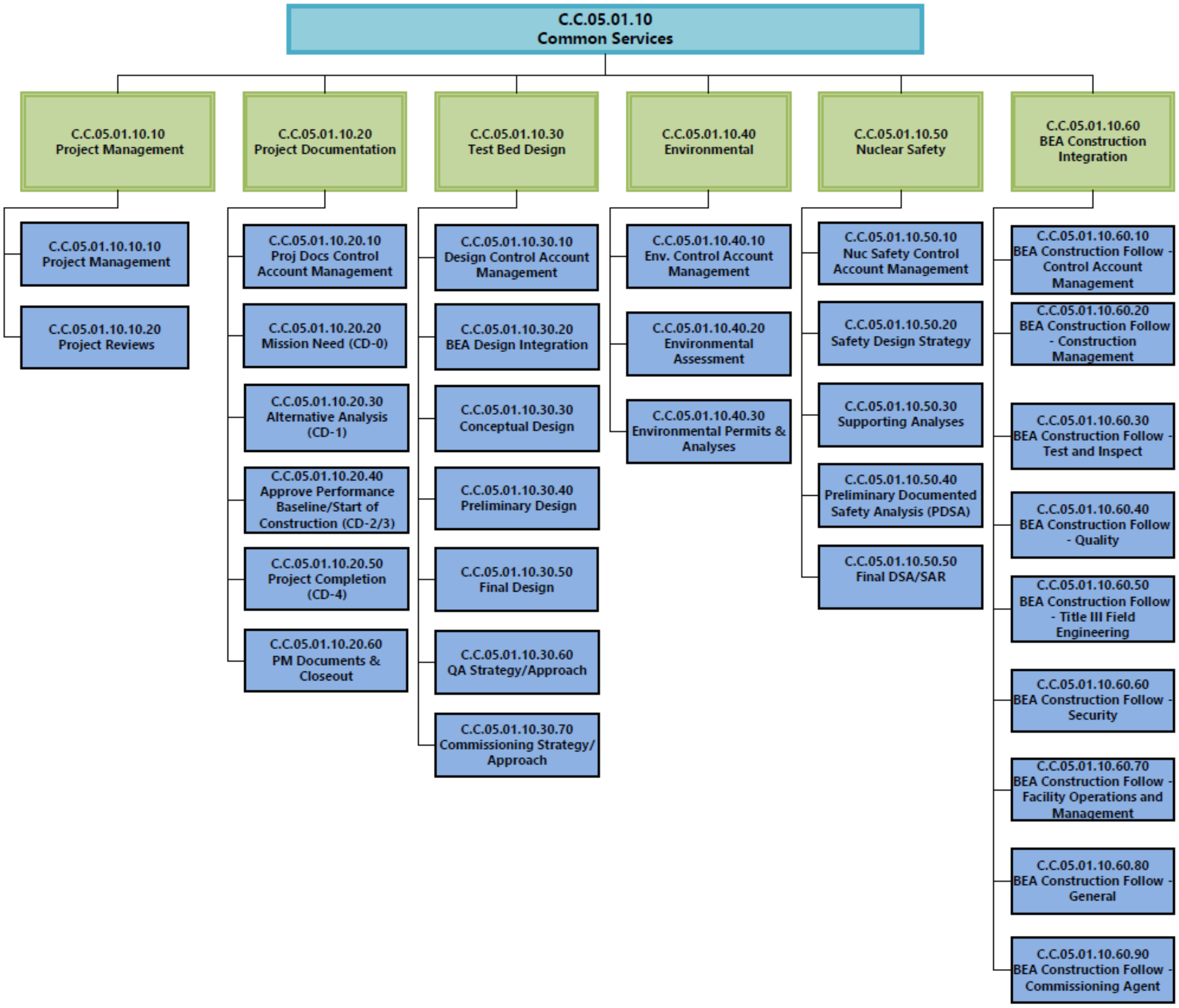
Appendix A
Risk Register

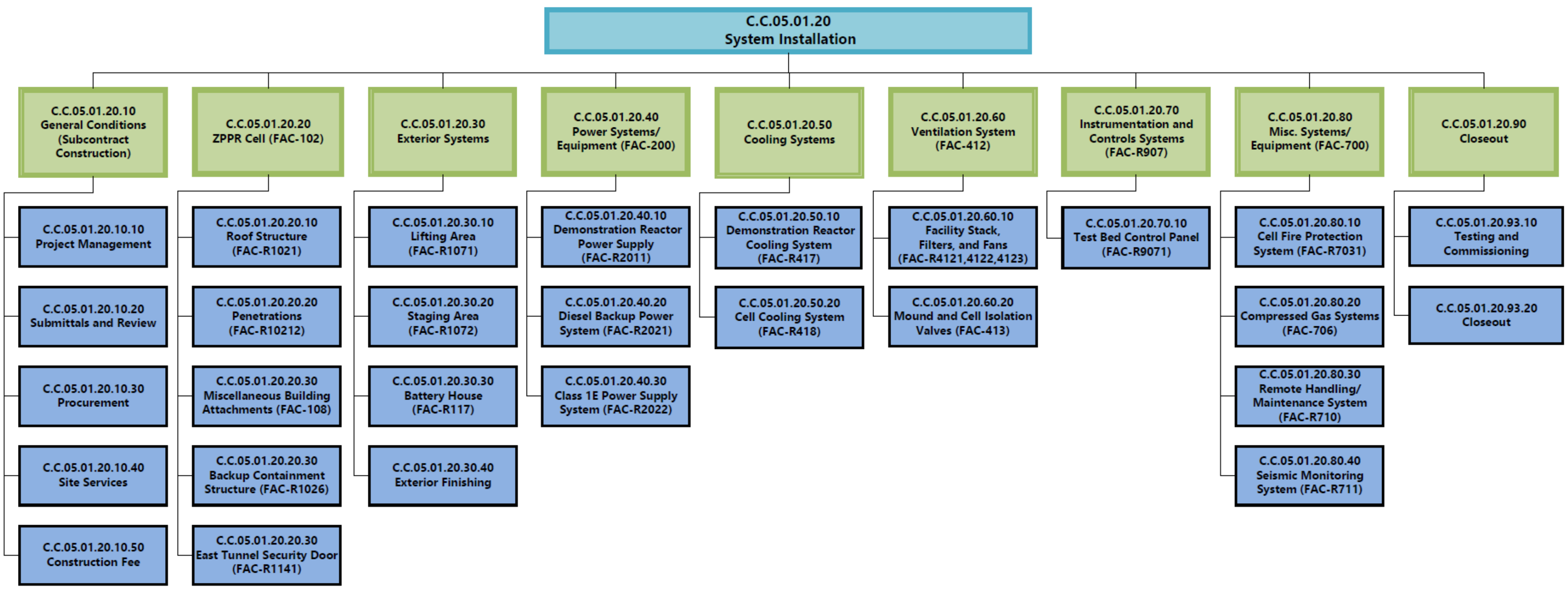
ZTB RISK REGISTER									
Number	**Name**	**Description**	**Risk Type**	**Identified Trigger Event**	**Probability**	**Consequence**	**Original Risk Level**	**Strategy Method**	**Risk Owner**
ZTB-RISK-001	Cell Leak Rate	The leak rate of the cell might not meet the criteria established in requirement 3.4.2.2 in FOR-538. This could be due to: seal doors, roof structure/penetrations/hatch, ventilation dampers, the existing structure, etc.	Technical	Initial testing of ZTB (w/o reactor) does not meet the specified leak rate	Unlikely	Significant	Low-Medium	Mitigate	Installation Project Team
ZTB-RISK-002	Seismic Design	The structure might not meet Seismic Design Category (SDC)-3 as required by 3.4.6.1 in FOR-538.	Technical	Structural analyses conclude the cell structure does not meet SDC-3	Very Unlikely	Critical	Low-Medium	Mitigate	Engineering Design Project Team
ZTB-RISK-003	Lifting Capability / Area / Approach	Crane and staging area capabilities cannot support RDP demands	Technical	An RDP designs a module that exceeds the weight/lifting limitations of the crane and/or staging area	Very Unlikely	Significant	Low	Avoid	INL Technical Leadership
ZTB-RISK-004	Reactor Removal	Test bed design/layout does not support demonstrator's plan to remove reactor	Technical	RDP communicates specific requirements of reactor removal strategy that require significant design changes	Very Unlikely	Critical	Low-Medium	Mitigate	INL Technical Leadership
ZTB-RISK-005	Emissions Limits	Emissions (radionuclide) from the ZTB stack might not meet 40 CFR part 61 requirements for radionuclide emissions.	Technical	Calculations from an RDP state that the as-designed/built ZTB systems will not effectively mitigate its release of radionuclides	Very Unlikely	Critical	Low-Medium	Transfer	INL Technical Leadership
ZTB-RISK-006	Permit to Construct	A permit to construct might be required if expected radionuclide emissions exceed certain standards.	Technical	Preliminary work with potential RDPs yields the expectation that a permit to construct will be required	Likely	Significant	Medium	Accept	INL Technical Leadership
ZTB-RISK-007	Fire Protection System	The fire protection system might cost more than anticipated if an exemption is not obtained.	Technical	DOE does not grant a renewal of ZPPR's existing fire protection system exemption	Unlikely	Significant	Low-Medium	Accept	INL Technical Leadership
ZTB-RISK-008	Class 1E Backup Power Scope	There is no Class 1E diesel available, only batteries. The system is only sized for instrumentation and some equipment but depending on what safe shutdown parameters are defined by a reactor demonstration project, the electrical supply demand could expand	Technical	An RDP expresses a need for additional Class 1E backup power	Unlikely	Marginal	Low	Transfer	INL Technical Leadership
ZTB-RISK-009	Electrical Penetrations	The existing electrical penetrations into the ZTB cell might not be sufficient for reactor demonstrations.	Technical	An RDP expresses a need for additional space for electrical feedthroughs	Unlikely	Significant	Low-Medium	Mitigate	INL Technical Leadership
ZTB-RISK-010	Roof Radiation Dose	Even with supplemental shielding, the dose rates on the roof may be too high during reactor ops. Roof's design will vary as structural and security requirements are validated and integrated. The design will directly impact the radiation field on top of the roof.	Technical	Radiation source assumption used by Engineering Design Project Team is invalidated	Unlikely	Marginal	Low	Mitigate	INL Technical Leadership
ZTB-RISK-011	Utility Supply	The RDP's demand on compressed gases and/or any other ZTB utilities might be greater than the supply available through the existing MFC distribution system.	Technical	An RDP expresses a need for additional utility capacity (gas, electrical power, etc.)	Somewhat Likely	Marginal	Low-Medium	Transfer	INL Technical Leadership
ZTB-RISK-012	Code Compliance	Codes of Record (CoR) chosen for design and installation are updated. DOE or AHJ does not allow grandfathering of the ZTB systems within the older version of the code	Business	AHJ determines CoR is invalid after design activities have begun	Very Unlikely	Significant	Low	Accept	INL Technical Leadership

ZTB RISK REGISTER									
Number	**Name**	**Description**	**Risk Type**	**Identified Trigger Event**	**Probability**	**Consequence**	**Original Risk Level**	**Strategy Method**	**Risk Owner**
ZTB-RISK-013	Crucial component supply chain	Crucial components are unavailable for procurement without supply chain development	Technical	Crucial component is identified with no alternatives, as unavailable without supply chain development	Very Unlikely	Significant	Low	Mitigate	INL Technical Leadership
ZTB-RISK-014	Changing Design Inputs	Postulated user requirements change which require functionality changes and require redesign	Programmatic	Potential system user provides new testing requirements beyond designed capability at a late stage of design	Likely	Significant	Medium	Mitigate	INL Technical Leadership
ZTB-RISK-015	Inadequate staff for key technical areas - INL	Lack of available technical resources creates schedule delay	Programmatic	Resources unavailable to support project schedule	Unlikely	Marginal	Low	Mitigate	INL Project Management
ZTB-RISK-016	Cost overrun on test bed system(s)	Rework is required or inaccurate cost estimates were provided for loop components	Programmatic	Vendor submits contract change request due to fabrication difficulties, etc.	Somewhat Likely	Significant	Medium	Mitigate	INL Project Management
ZTB-RISK-017	Emergent issues affect design documents	Rework is required on design documents (revisions, etc.) due to unexpected and required design changes	Technical	New requirement to be incorporated into design identified	Unlikely	Marginal	Low	Accept	INL Technical Leadership
ZTB-RISK-018	Selected components unavailable at necessary quality levels	The project cannot procure, fabricate, or validate components to NQA-1 standards	Technical	Supplier of component cannot meet NQA-1 requirements	Unlikely	Critical	Medium	Mitigate	INL Project Management
ZTB-RISK-019	Installed systems do not meet specifications	Schedule delays and possibly cost overruns occur due to difficulty in installing and testing components	Technical	Supplied part fails acceptance/receipt inspection	Somewhat Likely	Significant	Medium	Mitigate	Installation Project Team
ZTB-RISK-020	Readiness Assessments	Scope, cost, or schedule of readiness assessments increases beyond baseline plan	Programmatic	Negative SPI/CPI trend on work package or scope add	Unlikely	Significant	Low-Medium	Mitigate	INL Project Management
ZTB-RISK-021	Sole-source suppliers	Specific components may only be available through one supplier	Business	Equipment trade studies yield only one vendor for a specific component/system	Somewhat Likely	Significant	Medium	Mitigate	Engineering Design Project Team
ZTB-RISK-022	System Inspection Schedule	Problems encountered during initial system inspections require additional schedule time to complete test bed startup	Technical	System inspections yield unsatisfactory results	Somewhat Likely	Marginal	Low-Medium	Accept	Installation Project Team
ZTB-RISK-023	Accident at facility during system installation	Schedule delays incurred due to accident during system installation	Business	Accident occurs at facility	Very Unlikely	Critical	Low-Medium	Mitigate	INL Project Management
ZTB-RISK-024	Funding lapse or delay	DOE Programs supporting the implementation of ZTB lose/reduce funding to the ZTB program	Business	NRIC National Technical Director informs project of expected funding lapse	Unlikely	Crisis	Medium	Accept	INL Project Management
ZTB-RISK-025	DOE does not approve the updated ZTB Documented Safety Analysis	This review could yield to negative outcomes pertaining to the project	Technical	DOE rejects ZTB documented safety analysis	Very Unlikely	Critical	Low-Medium	Accept	INL Technical Leadership
ZTB-RISK-026	Opportunity - Digital controls	Implementation of digital controls allow for modularity of control console and simplicity of cable runs	Technical	Readily available electronic components are identified for use in control console/panel	Very Likely	Significant	Medium-High	Exploit	INL Technical Leadership
ZTB-RISK-027	Inadequate staff for key technical areas - Subcontractor(s)	Lack of available technical resources creates schedule delay	Programmatic	Resources unavailable to support project schedule	Likely	Marginal	Medium	Mitigate	INL Project Management
ZTB-RISK-028	Contractor unable to meet contractual requirements	Schedule delays and possibly cost overruns occur due to challenges with contractors meeting technical requirements included in contracts	Programmatic	Supplier initiates contract change request	Unlikely	Significant	Low-Medium	Transfer	INL Project Management
ZTB-RISK-029	Inclement Weather	Inclement weather (wind/rain/cold, etc.) delays system installation schedule (e.g., replacing ZPPR's roof will require the cell to be open to the exterior environment).	Business	Anticipated weather conditions do not meet required installation/construction environmental conditions	Likely	Significant	Medium	Mitigate	INL Project Management

ZTB RISK REGISTER									
Number	**Name**	**Description**	**Risk Type**	**Identified Trigger Event**	**Probability**	**Consequence**	**Original Risk Level**	**Strategy Method**	**Risk Owner**
ZTB-RISK-030	Undocumented/Missed Requirements	Requirements not identified during design phase (e.g., following DOE O 420.1C provides a wide breadth of requirements contained within referenced documents [numerous orders, guides, etc.]). Because the requirements are provided in this manner, the design process may not capture all requirements specified by DOE O 420.1C.	Technical	Requirement identified that requires additional project scope to be completed	Somewhat Likely	Marginal	Low-Medium	Mitigate	INL Technical Leadership
ZTB-RISK-031	RDP Interface Assumptions	RDPs are being designed in parallel with ZTB. Interfaces, physical or otherwise, between the ZTB and an RDP may not be adequately captured during the design phase.	Technical	Initial RDP encounters interface issues with ZTB	Somewhat Likely	Marginal	Low-Medium	Mitigate	INL Technical Leadership
ZTB-RISK-032	Long Lead Items	Long lead items cannot be ordered early enough in the project to meet expected project end date	Technical	Quote/input from vendor identifies inability to meet project schedule	Likely	Critical	Medium-High	Mitigate	INL Project Management
ZTB-RISK-033	National Environmental Protection Act (NEPA)	NEPA may require an Environmental Assessment (EA) or Environmental Impact Statement (EIS) to complete test bed modifications	Business	The Environmental Compliance Permits (ECPs) cannot be issued due to regulations.	Somewhat Likely	Crisis	Medium	Accept	INL Project Management
ZTB-RISK-034	Subcontracting Delays	Issuing subcontracts requires more schedule time than planned	Programmatic	Expected issuance date of critical contracts slips by one or more weeks	Very Likely	Significant	Medium-High	Mitigate	INL Project Management

Appendix B
ZTB Work Breakdown Structure

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(Subcontract
Construction)
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Project Management
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Submittals and Review
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Procurement
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Site Services
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Construction Fee
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ZPPR Cell (FAC-102)
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Roof Structure
(FAC-R1021)
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Penetrations
(FAC-R10212)
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Miscellaneous Building
Attachments (FAC-108)
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Backup Containment
Structure (FAC-R1026)
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East Tunnel Security Door
(FAC-R1141)
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Exterior Systems
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Lifting Area
(FAC-R1071)
C.C.05.01.20.30.20
Staging Area
(FAC-R1072)
C.C.05.01.20.30.30
Battery House
(FAC-R117)
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Exterior Finishing
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Power Systems/
Equipment (FAC-200)
C.C.05.01.20.40.10
Demonstration Reactor
Power Supply
(FAC-R2011)
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Diesel Backup Power
System (FAC-R2021)
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Class 1E Power Supply
System (FAC-R2022)
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Cooling Systems
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(FAC-R417)
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Filters, and Fans
(FAC-R4121,4122,4123)
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Mound and Cell Isolation
Valves (FAC-413)
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Instrumentation and
Controls Systems
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Test Bed Control Panel
(FAC-R9071)
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Misc. Systems/
Equipment (FAC-700)
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Cell Fire Protection
System (FAC-R7031)
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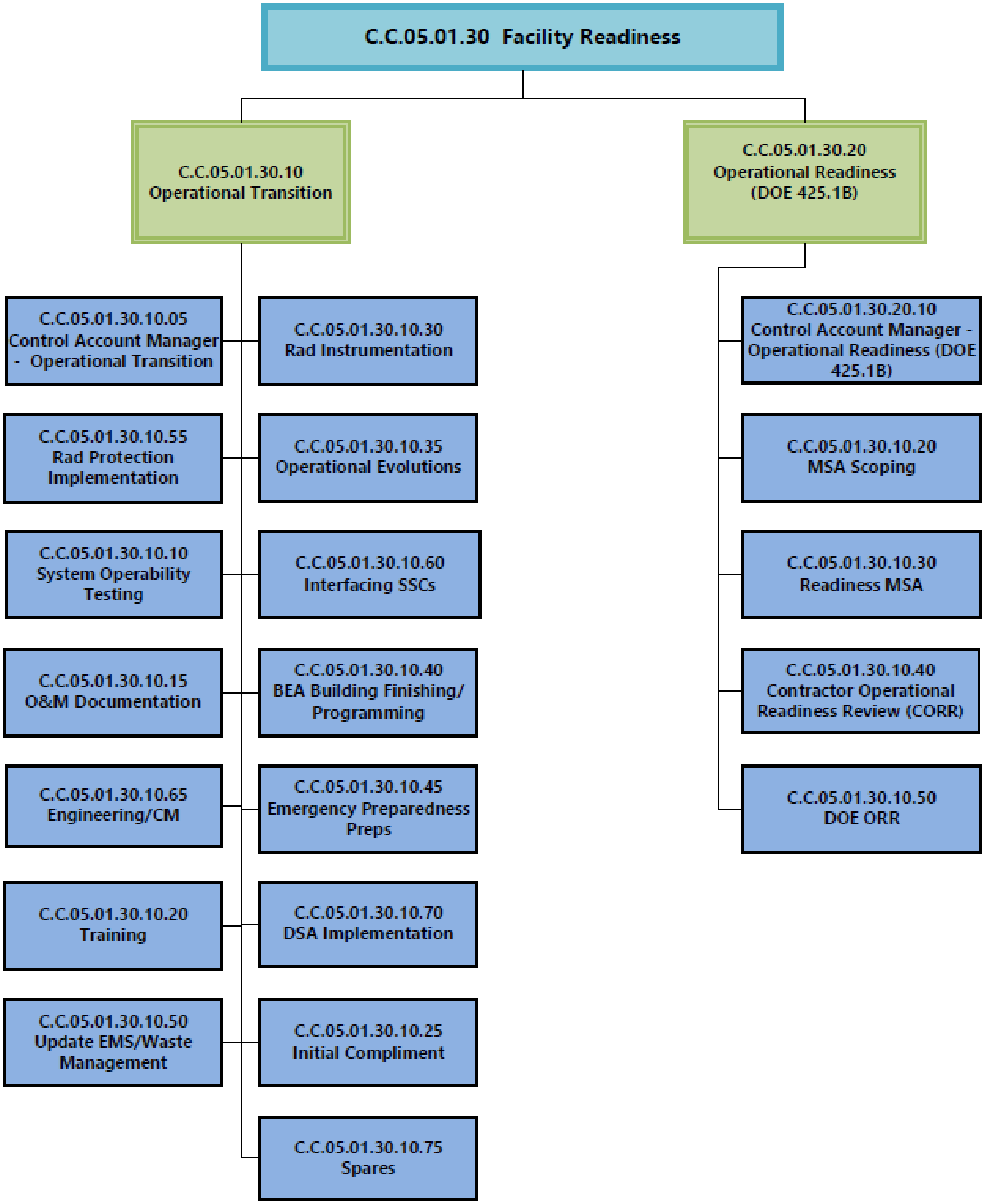
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C.C.05.01.30.10.15 O&M Documentation
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C.C.05.01.30.10.25 Initial Compliment
C.C.05.01.30.10.75 Spares
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C.C.05.01.30.10.20 MSA Scoping
C.C.05.01.30.10.30 Readiness MSA
C.C.05.01.30.10.40 Contractor Operational Readiness Review (CORR)
C.C.05.01.30.10.50 DOE ORR

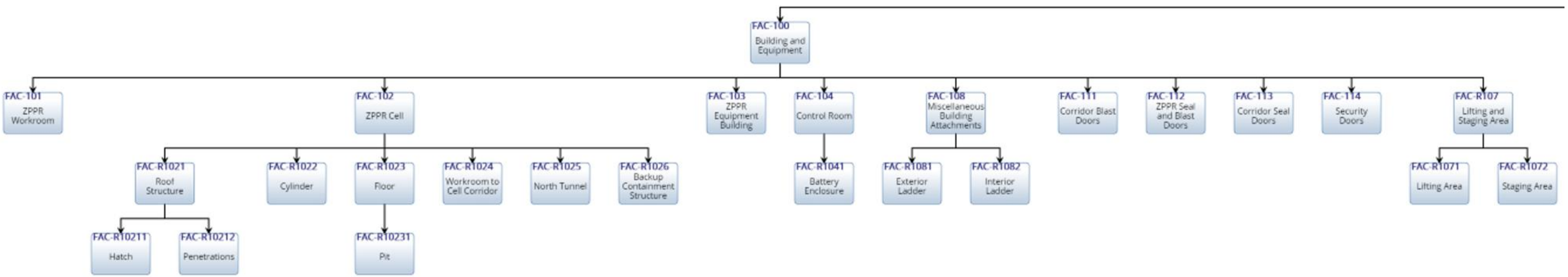
Appendix C
Design Issues

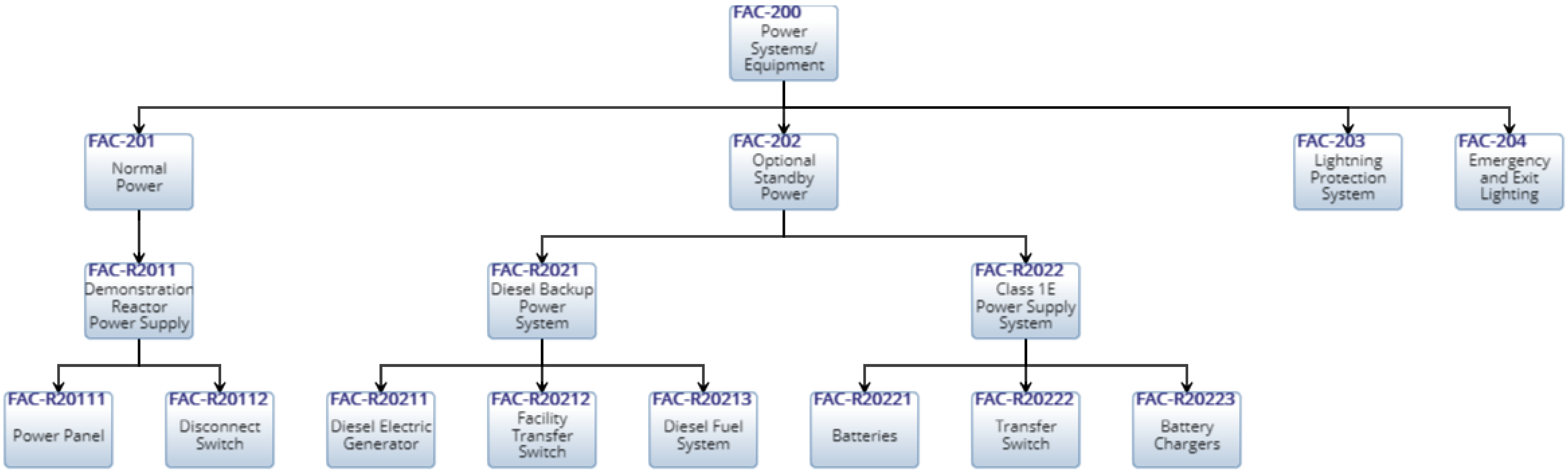
ZTB Design Issues List			
Issue Number	**Name**	**Description**	**Labels**
ZTB-AI-001	Location of Cooling System Interface	Determine the location of the heat exchangers within the ZPPR cell - this impacts piping run lengths from the demonstration reactor cooling system.	Demonstrator Action Item
ZTB-AI-002	Argon Supply	Determine peak demand and steady-state demand supplied to demonstration reactors. 5 L/min assumed sufficient for normal operations but need peak flow. Determine the total volume of argon required for demonstration reactors. Determine whether to use the existing MFC argon distribution system or to design a new system based on the demands of the end users.	Design Activity, Demonstrator Action Item
ZTB-AI-003	Nitrogen Supply/Storage Method	Determine the nitrogen supply, storage, and distribution strategy based on the end user demand.	Design Activity, Demonstrator Action Item
ZTB-AI-004	Instrument Air Supply	Evaluate instrument air demand and quality/capacity of existing MFC distribution system.	Design Activity, Demonstrator Action Item
ZTB-AI-005	Heaviest Demonstration Reactor Component	Determine the heaviest demonstration reactor component that needs to be lifted within the cell	Demonstrator Action Item
ZTB-AI-006	Roof Opening Size and Position	Determine the roof size opening and positioning - impacts demonstration reactor movements and shielding	Design Activity
ZTB-AI-007	Demonstration Reactor Maintenance Strategy	Determine whether maintenance will be performed remotely vs. hands-on. Also, if it will it be possible to open the reactor enclosure while it's operating.	Design Activity
ZTB-AI-010	ZTB Cell Power Supply Configuration	Determine the power supply configuration within the ZTB cell. One panel vs. two (normal and diesel).	Design Activity
ZTB-AI-011	Power Requirements	Determine the power requirements (voltage, current, etc.) for equipment on site. This includes the Class 1E power required (Do ZTB systems need uninterruptible power?). This might generate additional functions (transform, etc.) that the ZTB distribution system must perform.	Design Activity
ZTB-AI-012	Diesel Backup	Determine whether the standby diesel supports Class 1E battery charging. Also determine diesel capacity.	Design Activity

ZTB Design Issues List			
Issue Number	**Name**	**Description**	**Labels**
ZTB-AI-013	Evaluate Argon-41	Evaluate the Argon-41 load on the ventilation system, especially as it relates to leakage from the demonstration reactor.	Design Activity
ZTB-AI-014	SCRAM Signals	Determine what ZTB systems/events trigger demonstration reactor SCRAM	Design Activity
ZTB-AI-015	Post-SCRAM Protocol	Define who does what calculation for reactor re-start and what the strategy is depending on the unexpected SCRAM trigger	Design Activity
ZTB-AI-016	Cyber Security Requirements	Need to determine the cyber security requirements across the respective organizations.	Design Activity
ZTB-AI-018	Cooling Coil Radiation Monitoring	Determine whether area radiation monitors are needed on ZTB cooling coils.	Design Activity
ZTB-AI-019	ZTB Critical Spares	Identify critical spares for ZTB support systems and then determine where to store them at MFC.	Design Activity
ZTB-AI-020	Demonstration Reactor Critical Spares	Identify critical spare for the demonstration reactor systems and then determine where to store them at MFC.	Demonstrator Action Item
ZTB-AI-022	Personnel Access	Determine whether it is going to be possible to grant MFC site access to demonstration reactor personnel.	Design Activity
ZTB-AI-023	Confinement Penetrations	Need to determine whether all confinement penetrations need isolation or if it is just a subset.	Design Activity
ZTB-AI-024	Fire Protection Strategy	Need to determine the fire protection strategy for the ZTB. Is active suppression required?	Design Activity
ZTB-AI-025	Disconnecting Utilities	Need to determine the strategy for disconnecting utilities after reactor operations. Does this need to be done remotely? Are cameras required?	Design Activity
ZTB-AI-026	Sampling During Operations	Need to determine whether samples are required during reactor operations.	Design Activity
ZTB-AI-027	Required I&C Signals	Determine the required I&C signals needed from the demonstration reactor for successful operation of ZTB systems.	Design Activity
ZTB-AI-028	SSC Classifications	Determine the conceptual list of Safety Class and Safety Significant SSCs for the purposes of allocating requirements imposed on safety components.	Design Activity
ZTB-AI-029	Angle of Roof Penetrations	Roof penetrations should be off-angle (e.g., avoid perpendicularity with the roof) to address streaming of radiation through the roof.	Design Activity

ZTB Design Issues List			
Issue Number	**Name**	**Description**	**Labels**
ZTB-AI-030	Compatibility and Rigor of I&C Signals	The instrumentation and control scheme in the pre-conceptual design assumes a basic communication protocol is used between the reactor control system (provided by demonstrator) and the standard industrial controls system used in by the ZTB (provided by INL). If a more complex or robust communication protocol is needed or required, a substantial amount of engineering effort and/or additional hardware may be required.	Design Activity
ZTB-AI-031	Structural Integrity of ZPPR Control Room (MFC-774)	Since Safety-Class electrical equipment will be located in or routed through the ZPPR Control Room (MFC-774) it needs to be analyzed to NDC-3 criteria. If the structure cannot meet the criteria then an alternate location for the batteries must be determined.	Design Activity
ZTB-AI-032	Overpressure Protection Capability	Since the capability of the overpressure protection capability may impact the reactor-specific safety analyses, the maximum capabilities of the design shall be calculated and communicated to RDPs.	Design Activity
ZTB-AI-033	Stand-alone Cell Ventilation	The current design of ZTB assumes the new ventilation system will replace the existing ventilation system. Because of competing requirements for the ventilation system originating from the multiple facilities using it, it may be more cost-effective to construct a stand-alone ventilation system for the cell. This option should be investigated in later stages of ZTB design.	Design Activity

Appendix D
ZTB System Breakdown Structure

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Power Systems/ Equipment
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Normal Power
FAC-202
Optional Standby Power
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Lightning Protection System
FAC-204
Emergency and Exit Lighting
FAC-R2011
Demonstration Reactor Power Supply
FAC-R2021
Diesel Backup Power System
FAC-R2022
Class 1E Power Supply System
FAC-R20111
Power Panel
FAC-R20112
Disconnect Switch
FAC-R20211
Diesel Electric Generator
FAC-R20212
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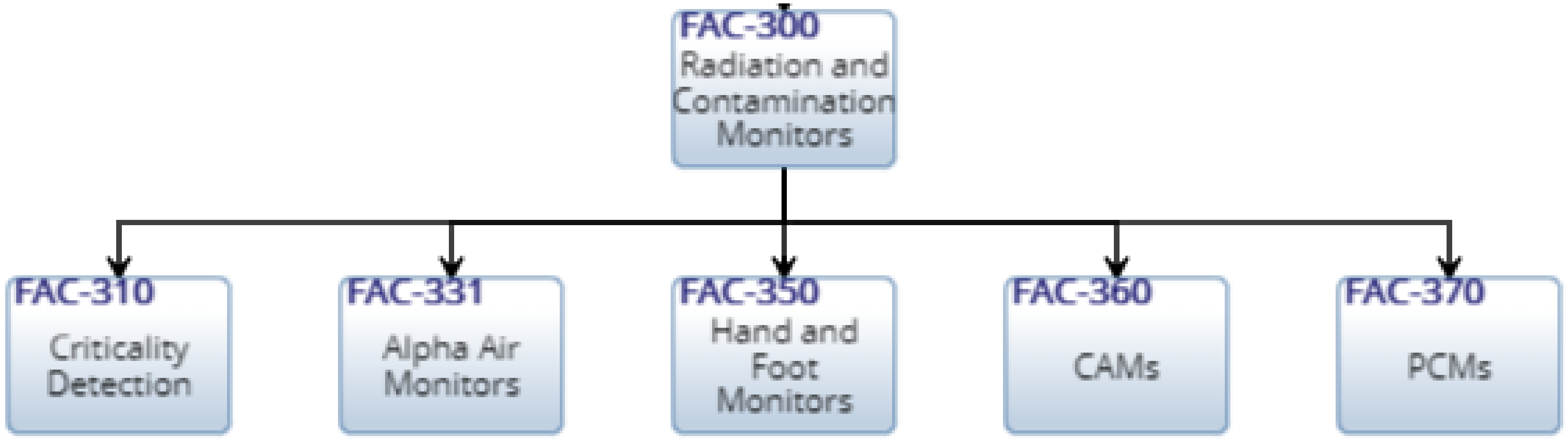
FAC-R20223
Battery Chargers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Criticality Detection
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Alpha Air Monitors
FAC-350
Hand and Foot Monitors
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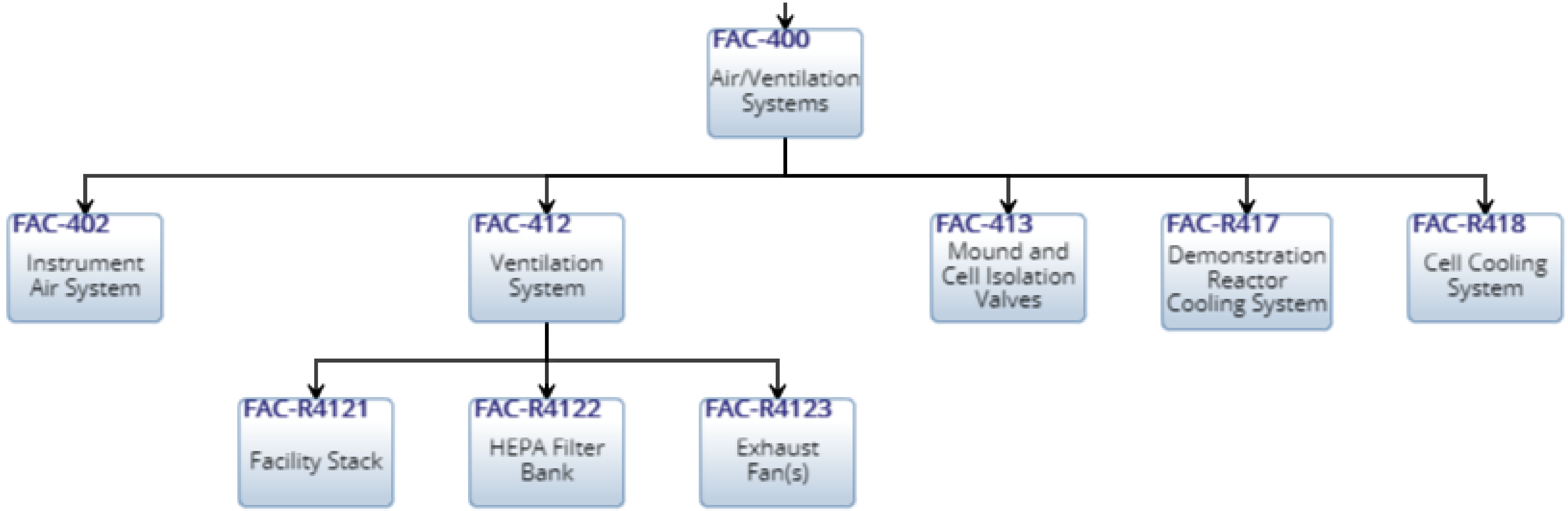
CAMs
FAC-370
PCMs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Ventilation System
FAC-413
Mound and Cell Isolation Valves
FAC-R417
Demonstration Reactor Cooling System
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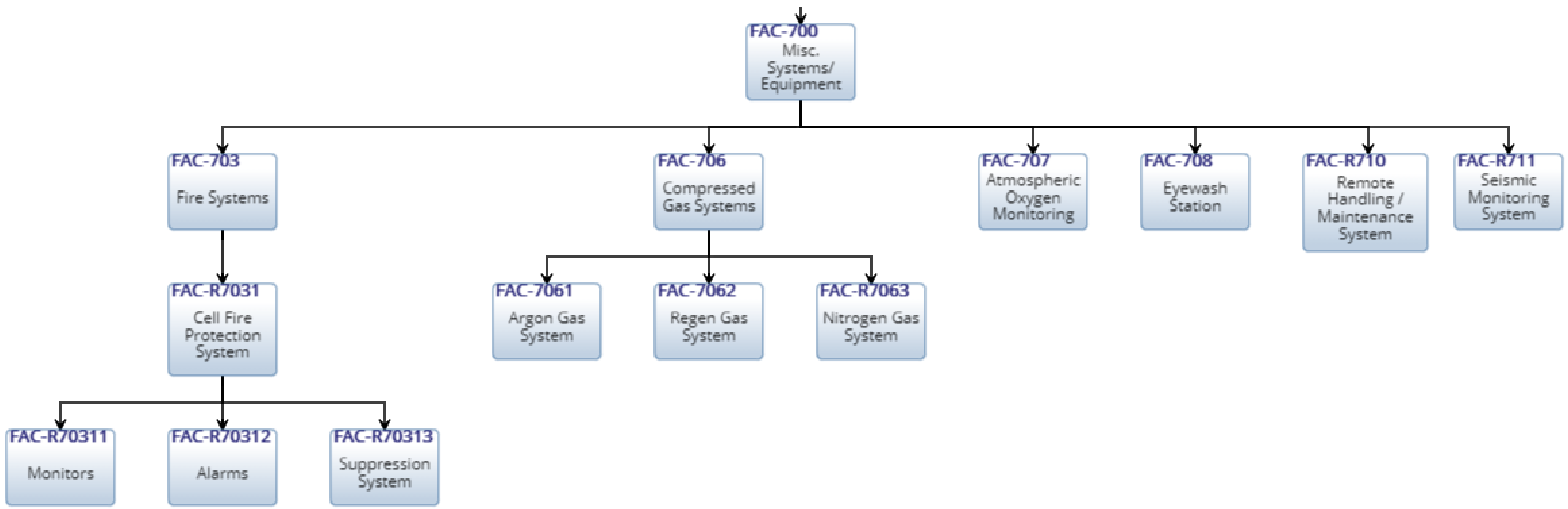
Cell Cooling System
FAC-R4121
Facility Stack
FAC-R4122
HEPA Filter Bank
FAC-R4123
Exhaust Fan(s)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FAC-703
Fire Systems
FAC-706
Compressed Gas Systems
FAC-707
Atmospheric Oxygen Monitoring
FAC-708
Eyewash Station
FAC-R710
Remote Handling / Maintenance System
FAC-R711
Seismic Monitoring System
FAC-R7031
Cell Fire Protection System
FAC-7061
Argon Gas System
FAC-7062
Regen Gas System
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Nitrogen Gas System
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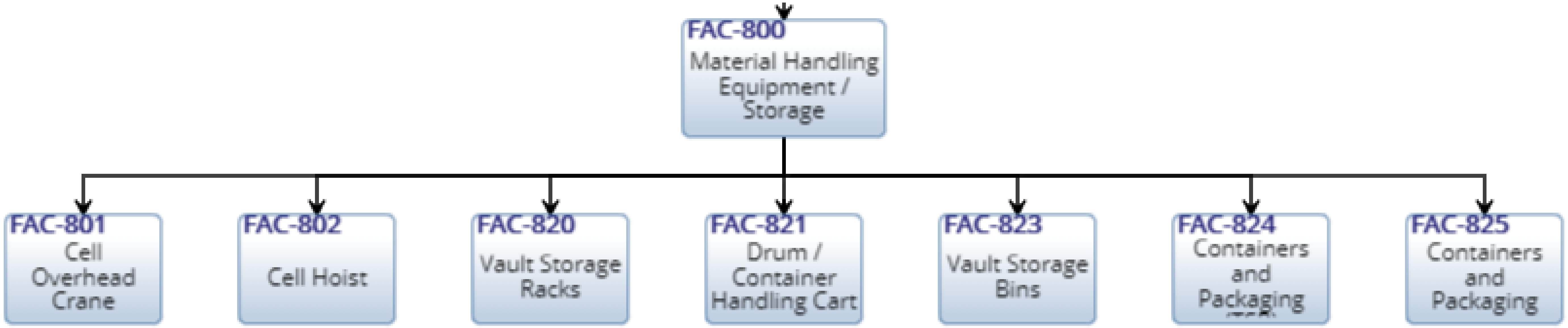
Alarms
FAC-R70313
Suppression System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Material Handling Equipment / Storage
FAC-801
Cell Overhead Crane
FAC-802
Cell Hoist
FAC-820
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FAC-821
Drum / Container Handling Cart
FAC-823
Vault Storage Bins
FAC-824
Containers and Packaging
FAC-825
Containers and Packaging

Attachment 1
ZTB Functional and Operational Requirements

Functional and Operational Requirements

ZPPR Modifications to Support Demonstration Reactors

Idaho National Laboratory

The INL is a U.S. Department of Energy National Laboratory operated by Battelle Energy Alliance.

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1. INTRODUCTION

Demonstration reactors are currently being designed for operation at the Materials and Fuels Complex. Based on the fuel type and quantities, a safeguards category 1 facility will be needed. The Zero Power Physics Reactor (ZPPR) meets the necessary security requirements. This document covers the functional and operational requirements (F&ORs) for the modification to ZPPR to support the demonstration reactors being considered.

2. OVERVIEW

2.1 Ownership of the F&OR

The ZPPR cognizant system engineer is the owner of this F&OR.

2.2 End-User of Engineered Item or Activity

The ZPPR nuclear facility manager is the end-user of the as-modified facility.

3. ENGINEERING INPUTS

3.1 Functional Requirements

Safety-class structures, systems, and components (SSCs) shall be able to accommodate a single failure and still meet their intended safety function, as required, to ensure compliance with the facility acceptance criterion.
Basis: DOE O 420.1C

Safety-class SSCs shall be designed such that they are protected against dynamic effects, including the effects of postulated pipe ruptures, missiles, pipe whipping (applicable for high-energy pipe systems), and discharging of fluids, that may result from equipment failures and from events and conditions outside the nuclear reactor facility.
Basis: DOE O 5480.30

Support systems (e.g., electrical power, cooling) required to ensure that safety SSCs can provide their required safety function shall also be considered safety-class systems.
Basis: DOE O 420.1C

Safety SSCs shall not be prevented from performing their required safety functions by the failure of non-safety SSCs.
Basis: DOE O 420.1C

If required to maintain its safety function, a system to transfer heat from safety-class SSCs to an ultimate heat sink shall be provided.
Basis: DOE O 5480.30

3.1.1 Structural

1. The existing backup containment structure shall be removed, including the catenary cable grid and all mesh, gravel, and sand materials above it.

2. A method for installation of a demonstration-reactor package shall be provide in the ZPPR cell structure.

3. ZPPR cell structure shall be capable of withstanding a differential pressure of 1 iwc without failure.

4. The roof of the ZPPR cell shall be capable of supporting a live load of 100 lb/ft^2.

5. The roof of the ZPPR cell shall incorporate designed lift points on the inside of the cell, on the underside of the roof, for hoisting and rigging of items and equipment.

6. The roof of the ZPPR cell shall be capable of supporting loads from facility equipment that will be installed on the roof.

7. The average cell air temperature shall be maintained below 100°C during reactor operation. Portions of reactor systems may exceed the 100°C limit, but measures must be taken to prevent the cell structure from exceeding the limit.
   Basis: TEV-3774 and ECAR-664 provide documentation that temperatures above 100°C result in degradation of concrete properties. If the average air temperature in the cell is maintained below the limit, and if no localized hot spots or impingement occurs, the limit is considered to be satisfied. If there are concerns about localized hot spots or impingement insulation, baffles or heat shields may be necessary to prevent exceeding the temperature limit.

8. ANSI/ACI-349 shall be followed for new concrete structures.

9. AISC-N690 shall be used for new safety-related steel structures.

10. AISC-360 shall be used for new non-safety-related steel structures.

11. The cell structure shall be designed and analyzed to meet natural phenomenon hazard (NPH) Category NDC-3 for seismic, wind, precipitation, and flooding.

12. The ZPPR cell structure shall be maintained as confinement boundary. The structure shall be designed with features to minimize leakage (see Subsection 3.4.2(2) for leak rate criteria).

13. The ZPPR cell roof shall be accessible by permanently installed structures (e.g., ladders, stairs, etc.) meeting the requirements of 29 Code of Federal Regulations (CFR) 1910, Subpart D.

3.1.2 Cell Temperature Control

1. A cell cooling system shall be provided with the ability to remove 500 kWt total from the cell and demonstration reactor.

2. A cell cooling system shall maintain the cell air temperature at 40°C or below.
   Basis: The 40°C temperature limit for the cooling system will provide sufficient margin for passive decay heat cooling capability (no cooling equipment running) without violating the structural temperature limit of 100°C.

3. The cooling system shall have the capability to operate at a lower capacity and lower power draw.

4. Cell cooling piping shall meet ASME B31.3.

5. Cell cooling equipment shall comply with the applicable standards and codes of AHRI 550/590, ASHRAE 90.1-2016 and the ETL.

6. If required, a system shall be provided to maintain the cell space temperature above 15°C.

7. The cell cooling system shall not be safety related. If the system fails, the demonstration reactor shall shut down, and decay and residual heat shall be removed passively.

3.1.3 Cell Ventilation

1. In order to minimize the spread of contamination to the environment, ventilation systems shall be designed to provide a continuous airflow pattern from the environment into the building and then from noncontaminated areas to potentially contaminated areas and then to normally contaminated areas.
   Basis: DOE O 5480.30

2. An isolation function shall be provided for any penetration in the ZPPR cell.

3. Filtration for the ZPPR cell shall be provided for any ventilation penetrations/ducting.

4. A means to ensure the ZPPR cell is not over pressurized shall be provided.

5. Ventilation and filtration equipment shall meet the requirements of ASME AG-1.

6. Filtration equipment shall meet the requirements of DOE-STD-3020-2005.

7. A means to test and quantify the leak rate of the confinement boundary shall be provided.

8. A means to connect effluent from demonstration reactor filtering systems and delay tanks shall be provided.
   Basis: Filters and delay tanks are to be provided by the demonstration reactor project, but a facility connection needs to be provided.

9. Emissions monitoring shall meet the requirements of 40 CFR 61, Subpart H.

10. The ventilation exhaust stack shall have an effluent monitoring system. Both the stack and monitoring system compliant with ANSI N13.1
    Basis: Multiple reactors concepts that will challenge the limits for unmitigated emissions exist. To provide the flexibility for operation of demonstration reactors a compliant stack monitoring system will be required.

11. Demonstration reactors shall provide engineered systems that mitigate the reactor specific emissions to cause less than 0.1 mrem/year dose to the public.
    Basis: The equipment that may be necessary to ensure this requirement is met will be driven by the specific reactor design. Given the reactor design dependence, it is not feasible for the facility to develop a generic system that covers all potential reactor concepts.

12. During reactor operation, the ZPPR cell shall be maintained at a negative differential pressure and a low flow condition maintained at a negative pressure.

3.1.4 Electrical

1. An on-site electric power system shall be provided to permit functioning of safety class structures, systems, and components.
   Basis: DOE O 5480.30

2. Safety class electric power systems shall be designed to permit appropriate periodic inspection and testing of important areas and features such as wiring, insulation connections, and switchboards to assess the continuity of the systems and the condition of their components.
   Basis: DOE O 420.1C. Requirements for Class 1E electrical systems will be provided in a separate FOR.

3. Electrical power shall be made available to the ZPPR cell to provide for the following:

   A. Temperature Control equipment covered in this FOR

   B. Reactor startup

   C. Reactor operation

   D. Backup power that is capable of carrying the loads from reactor startup and reactor operation.
      Basis: The demonstration reactors may use molten fuels, which should be kept from solidifying until final shutdown.

4. Connections for an alternate portable, backup power supply, shall be available.
   Basis: There may be a need for connecting an alternate backup power supply in the event of an extended loss of commercial power and a failure of the installed backup power system.

3.1.5 Mechanical

1. Compressed air shall be available for use in the ZPPR cell.
2. A compressed-gas header and storage location for bulk compressed-gas supply shall be provided.
3. Modifications, additions, or new pressure-piping systems shall meet the requirements of ASME B31.3.
4. Any effluent from over-pressure protection on pressure systems in the cell shall be routed to the facility exhaust system.

3.1.6 Reactor Control Area

1. An area shall be provided for control of the demonstration reactor during operation.
2. The control area shall be physically separated from the reactor by an approved fire barrier.
3. The control room shall provide sufficient protection to the reactor operators to allow operation through anticipated operational events.

3.2 Operational Requirements

3.2.1 Demonstration Reactor Installation/Removal

1. An equipment staging area shall be provided outside the ZPPR cell.
2. A transit path for reactor installation shall be demonstrated without lifting over the ZPPR vault and workroom or the Fuel Manufacturing Facility (FMF).

3. Preparations for heavy lifting shall be made to allow mobile cranes to access the facility and perform lifting operations.

4. The polar crane shall be removed from the ZPPR cell.
Basis: To provide more vertical clearance and allow for larger equipment placements.

3.2.2 Radiological Controls

1. A visual signal indicating reactor operation shall be provided at normal entry points to the ZPPR cell.

2. Measures shall be taken to ensure the facility or facility equipment is not damaged or interfered with during the operation of a demonstration reactor.

3. Shielding shall be provided to limit the dose to a facility worker on the roof of the ZPPR cell to less than 5 mrem/hr.

3.2.3 Criticality Safety

1. LRD-18001, *INL Criticality Safety Program Requirements Manual*, shall be followed.

2. Methods shall be incorporated to ensure moderators used in the ZPPR cell are prevented from migrating to the other areas of the ZPPR facility.

3. Systems containing moderators shall not be routed through the ZPPR work room or vault.

4. Systems containing moderator shall use construction methods to minimize leaks, with a preference towards welded systems.

5. Leak-detection systems that have the ability to identify leaks in systems containing moderators shall be in place.

3.2.4 Accident Monitoring

1. Provide a means to monitor accident releases as required for emergency response.
Basis: DOE O 420.1C

2. Post accident monitoring signals shall be provided to the ECC.

3.2.5 Human Factors

1. Human-factors engineering shall be considered in the design of systems that have a human interface.
   Basis: DOE O 5480.30

3.3 Maintenance Requirements

Modifications to ZPPR must be designed to facilitate inspections, testing, maintenance, repair, and replacement of safety-SSCs as part of a reliability, maintainability, and availability program with the objective of maintaining the facility in a safe state.
Basis: DOE O 420.1C

3.4 Owner Specified Technical Requirements

3.4.1 Structural Limits

1. The allowable floor loading in the ZPPR cell is 3000 lb/ft^2 on all portions of the concrete floor, with an overall limit of at least 500,000 lb.
   Basis: These floor loadings are the original design limits shown on drawing 757827, Sheet 06. An effort will be made to increase the overall limit. If the effort is successful, a new limit will be document in an engineering calculation and analysis report (ECAR).

2. The allowable floor loading on the steel-frame floor over the pit is 1500 lb/ft^2.
   Basis: ECAR-1670, "ZPPR Reactor Cell Steel Frame Floor Structural Analysis," provides the limits on the steel floor. The steel floor may be removed if necessary.

3.4.2 Safety Classification

1. The ZPPR cell shall be either a safety-class or safety-significant structure to withstand NDC-3 events.
   Note: Final safety designation will be documented in the Safety Analysis Report.

2. The ZPPR cell confinement shall be either safety-class or safety-significant to ensure a leak rate less than or equal to 5% of cell volume per day at -0.5 iwc.
   Note: Final safety designation will be documented in the Safety Analysis Report.

3. The ZPPR cell ventilation system shall be either safety-class or safety-significant to provide isolation and filtration capability. Note: Final safety designation will be documented in the Safety Analysis Report.

3.4.3 Radiological

1. The ZPPR cell shall be operated consistently with the INL Radiation Protection Program.

2. The ZPPR cell shall be designed to keep occupational radiation exposures within regulatory limits, and as low as reasonably achievable.
Basis: DOE O 420.1C

3.4.4 Environmental

1. ZPPR cell must have the means to confine uncontained radioactive materials to minimize their potential release in facility effluents during normal operations and during and following accidents, up to and including design basis accidents (DBAs).
Basis: DOE O 420.1C

2. The ZPPR cell shall be designed to protect against chemical hazards and toxicological hazards consistent with DOE-STD-1189-2008.
Basis: DOE O 420.1C

3. Facility process systems must be designed to minimize waste production and mixing of radioactive and non-radioactive wastes.
Basis: DOE O 420.1C

4. The ZPPR cell shall have a means to prevent or mitigate the release of radioactive gases to the environment.
Basis: DOE O 420.1C

3.4.5 Life Safety

1. DOE-STD-1066 shall be followed for the ZPPR cell and associated systems.
   Basis: DOE O 420.1C
   Note: DOE-ID-FPEX-06-09 is currently in place for ZPPR. The requirements of this exemption still need to be met or the exemption updated.

2. A system capable of detecting reduced oxygen in the ZPPR cell shall be provided.

3.4.6 Natural Phenomenon Hazard Classification

1. Seismic: SDC-3 Limit State B as defined by DOE STD-1020-2016 and ASCE 43

2. Wind: WDC-3 as defined by DOE STD-1020-2016

3. Precipitation: PDC-3 as defined by DOE STD-1020-2016

4. Flooding: FDC-3 as defined by DOE STD-1020-2016

5. The ZPPR cell must have instrumentation or other means to detect and record the occurrence and severity of seismic events.
   Basis: DOE O 420.1C

3.4.7 Security

1. The ZPPR cell shall be maintained as a Safeguard Category 1 facility.

2. Security systems shall be upgraded as necessary to account for an operating reactor in the ZPPR cell.

3.5 Supporting Information

3.5.1 Need for Configuration Management

1. Modifications to ZPPR will be configuration managed.

3.5.2 Sensitive Information

1. ZPPR control room and cell shall be access controlled and managed to those with a need to know while the intellectual property of a demonstrator is in the facility.

3.5.3 Export Control

Demonstration reactors that may be placed in ZPPR will likely involve design organizations outside INL. INL export-control processes shall be followed when providing information to outside entities.

3.5.4 Need for Engineering Change Control

Engineering change control will follow SP-30.1.2, “MFC and TREAT Facility Modification Control.”

3.5.5 Level of Verification Needed

It is anticipated that various elements will be used to cover the necessary modifications to ZPPR. The minimum level of verification for all elements will be technical checking and informal design review Additional rigor will be applied when determined necessary by the technical integrator and based on the quality level of the system.

3.5.6 Technical Integrator

The MFC nuclear remote-systems manager is the technical integrator for this work.

4. APPENDIX

Appendix A, Source Documents

Appendix B, Charts, Diagrams, Drawings, Lists, etc.

Appendix A

Source Documents

DOE O 420.1C, Facility Safety

DOE-STD-1189-2008, Integration of Safety into the Design Process

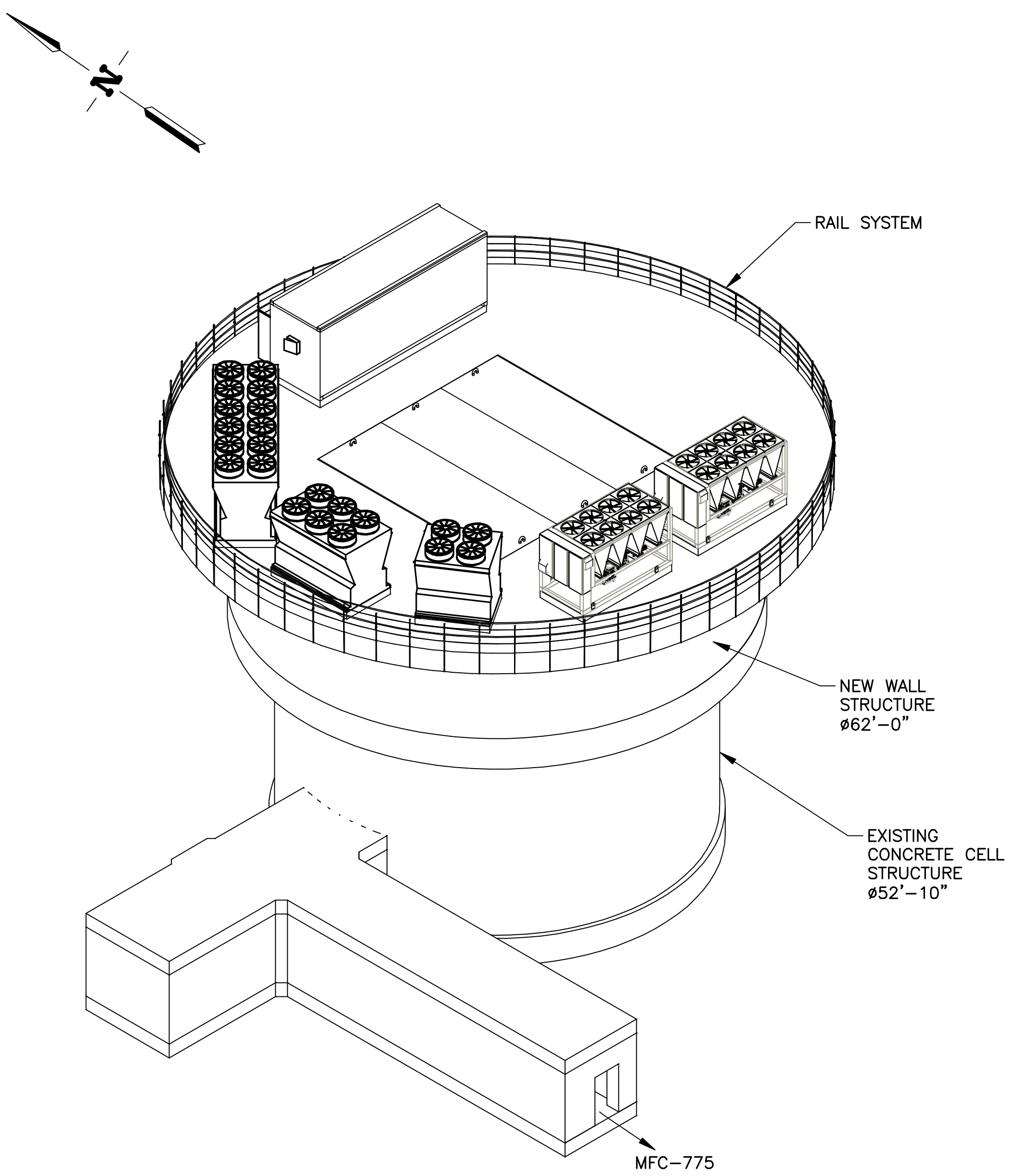
LRD-18001, *INL Criticality Safety Program Requirements Manual*

SP-30.1.2, “MFC and TREAT Facility Modification Control”

Appendix B

Charts, Diagrams, Drawings, Lists, etc.

Attachment 2
Pre-Conceptual Drawings



MOUND NOT SHOWN FOR CLARITY

MFC-776 OUTSIDE ISOMETRIC VIEW

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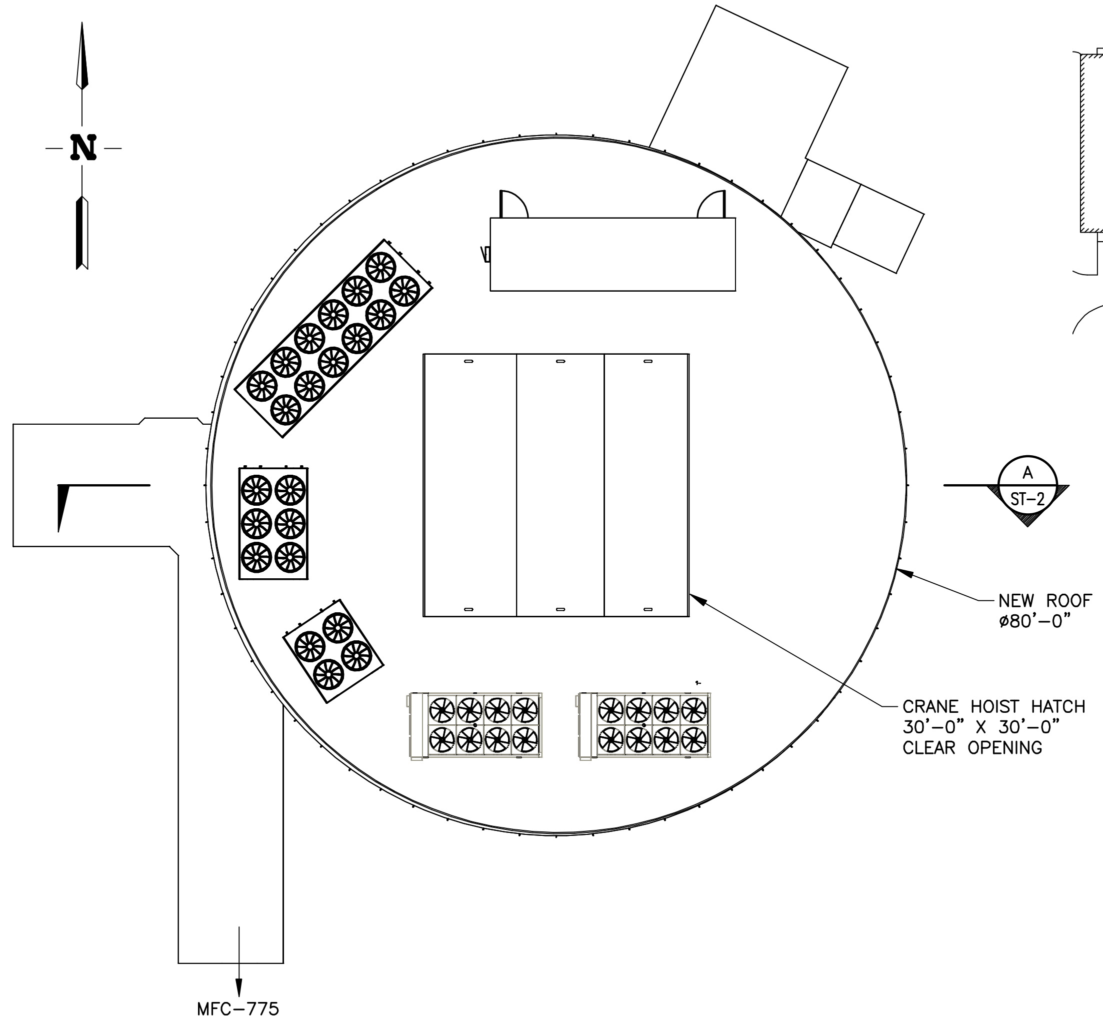

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MFC-776 ROOF PLAN

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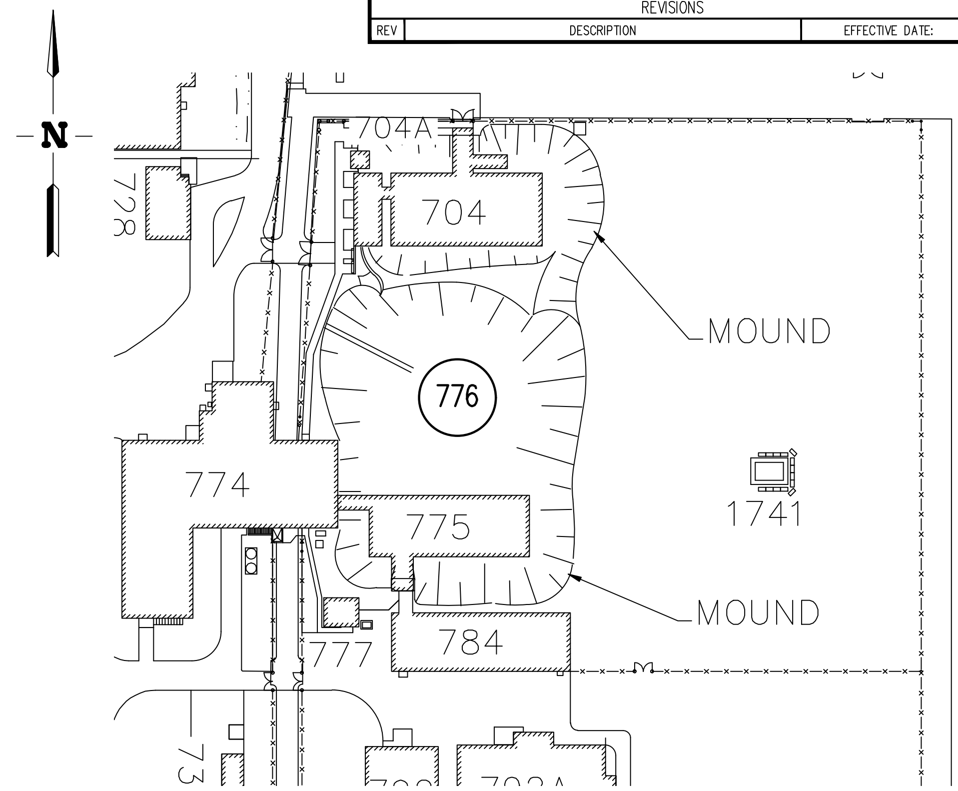

KEY PLAN

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REQUESTER:	A. BALSMEIER
RESP ENGR:	A. BALSMEIER
DESIGN:	A. BALSMEIER
DRAWN:	B. WEISSER
PROJECT NO.	NA
SPCL CODE	NA
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO.	XXXXXX
EFFECTIVE DATE:	7/8/2020

Idaho National Laboratory

MFC-776
NRIC ZPPR REACTOR TEST BED
CONCEPTUAL DESIGN

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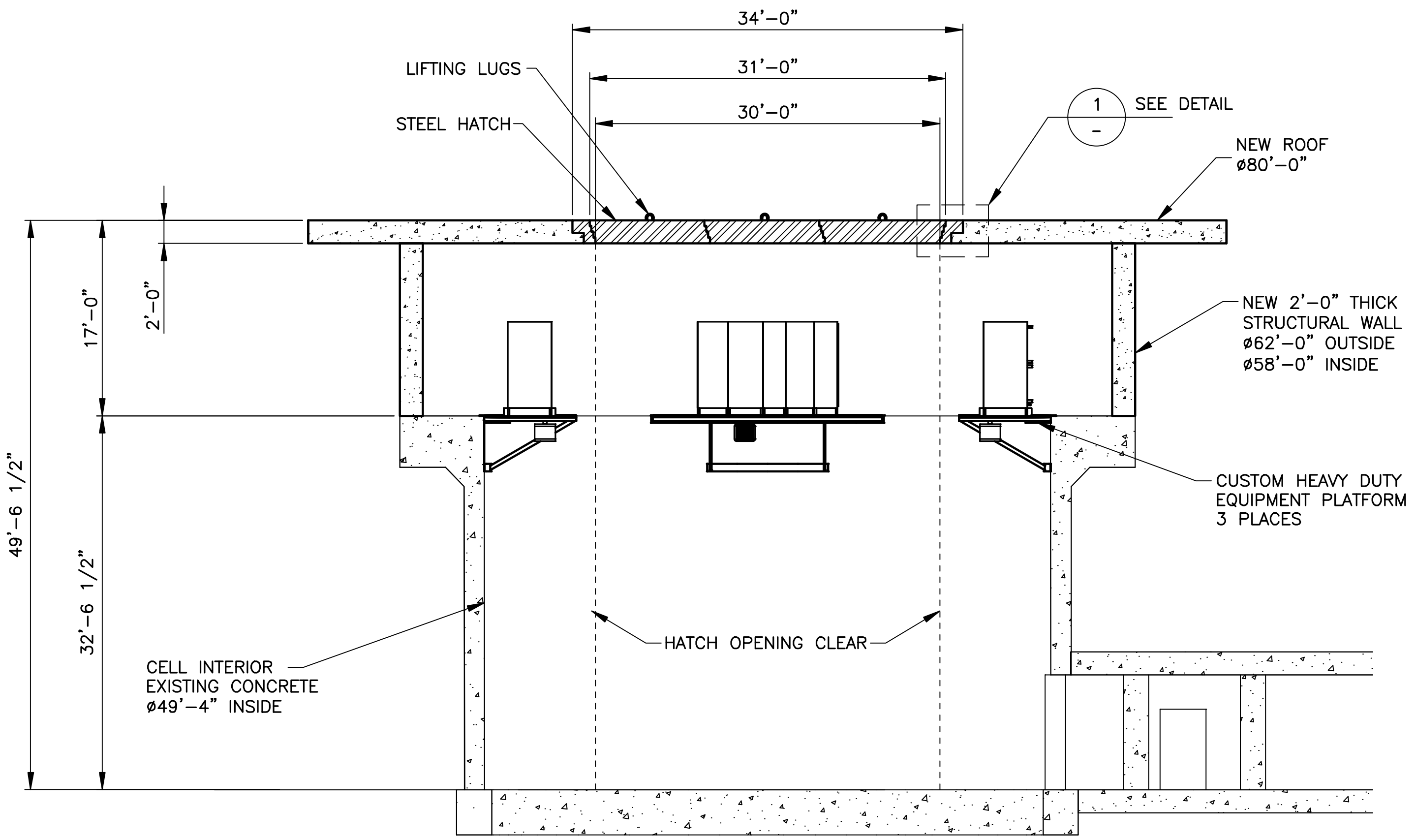

ROOF TOP ITEMS NOT SHOWN FOR CLARITY

MOUND NOT SHOWN FOR CLARITY

SECTION A / ST-1

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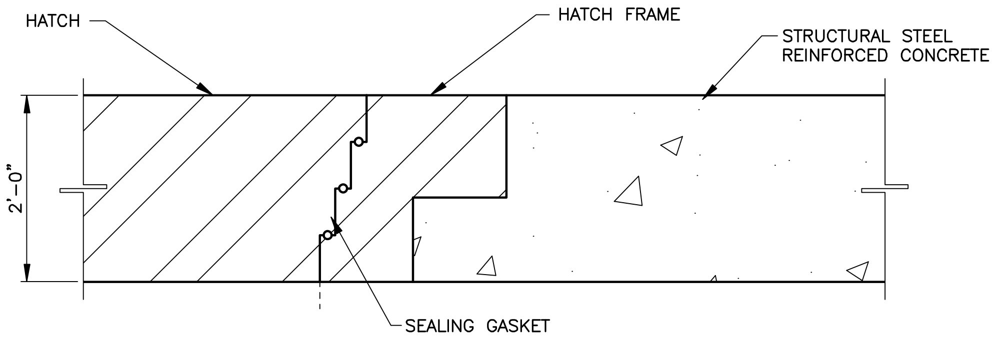

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DESIGN:	A. BALSMEIER
DRAWN:	B. WEISSER
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EFFECTIVE DATE:	7/8/2020

Idaho National Laboratory

MFC-776
NRIC ZPPR REACTOR TEST BED
CONCEPTUAL DESIGN

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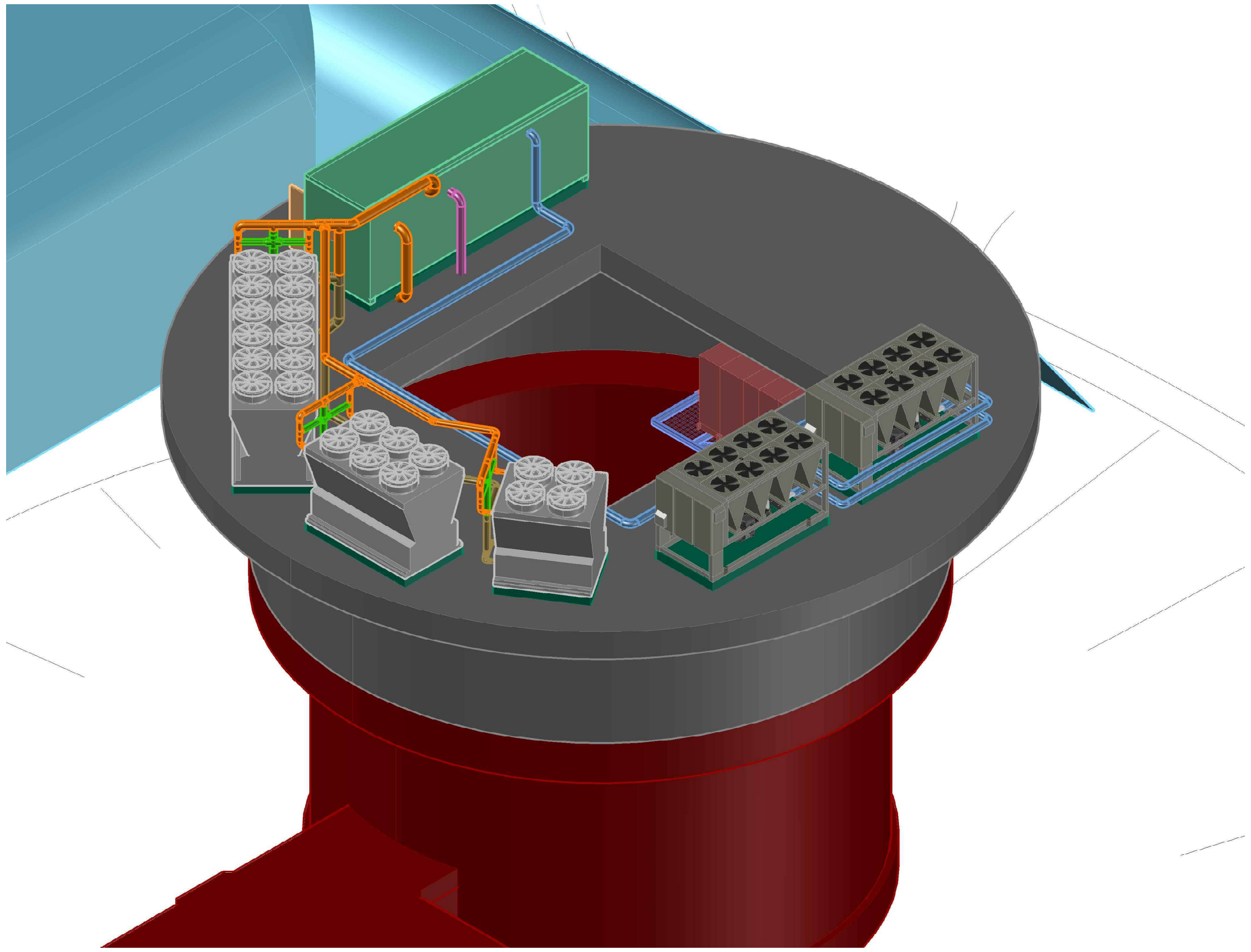

LOOKING SOUTH EAST
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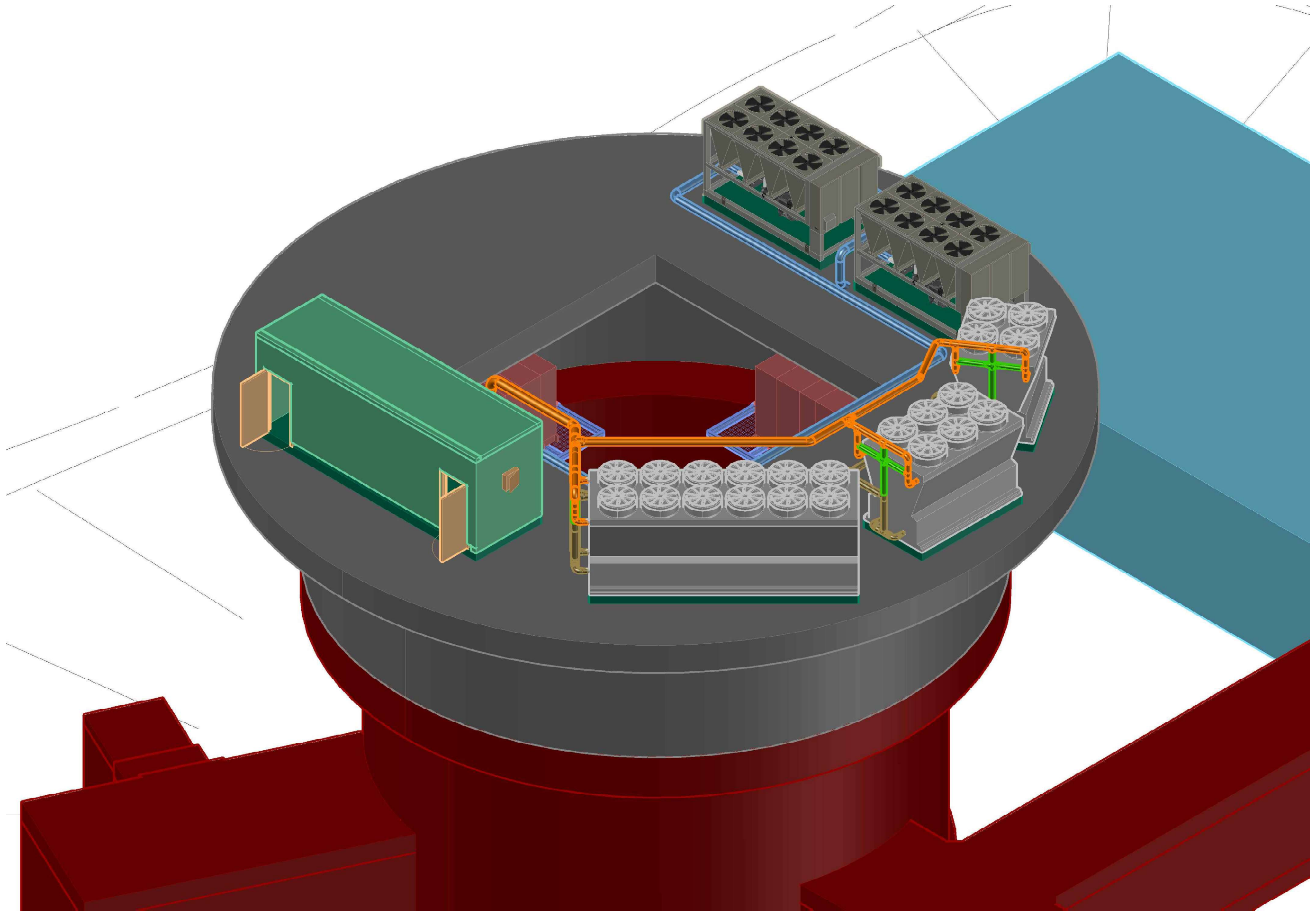

LOOKING NORTH WEST
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	DESIGN: C. BECK	
	DRAWN: R. SHICK	
	PROJECT NO. NA	
	SPCL CODE NA	
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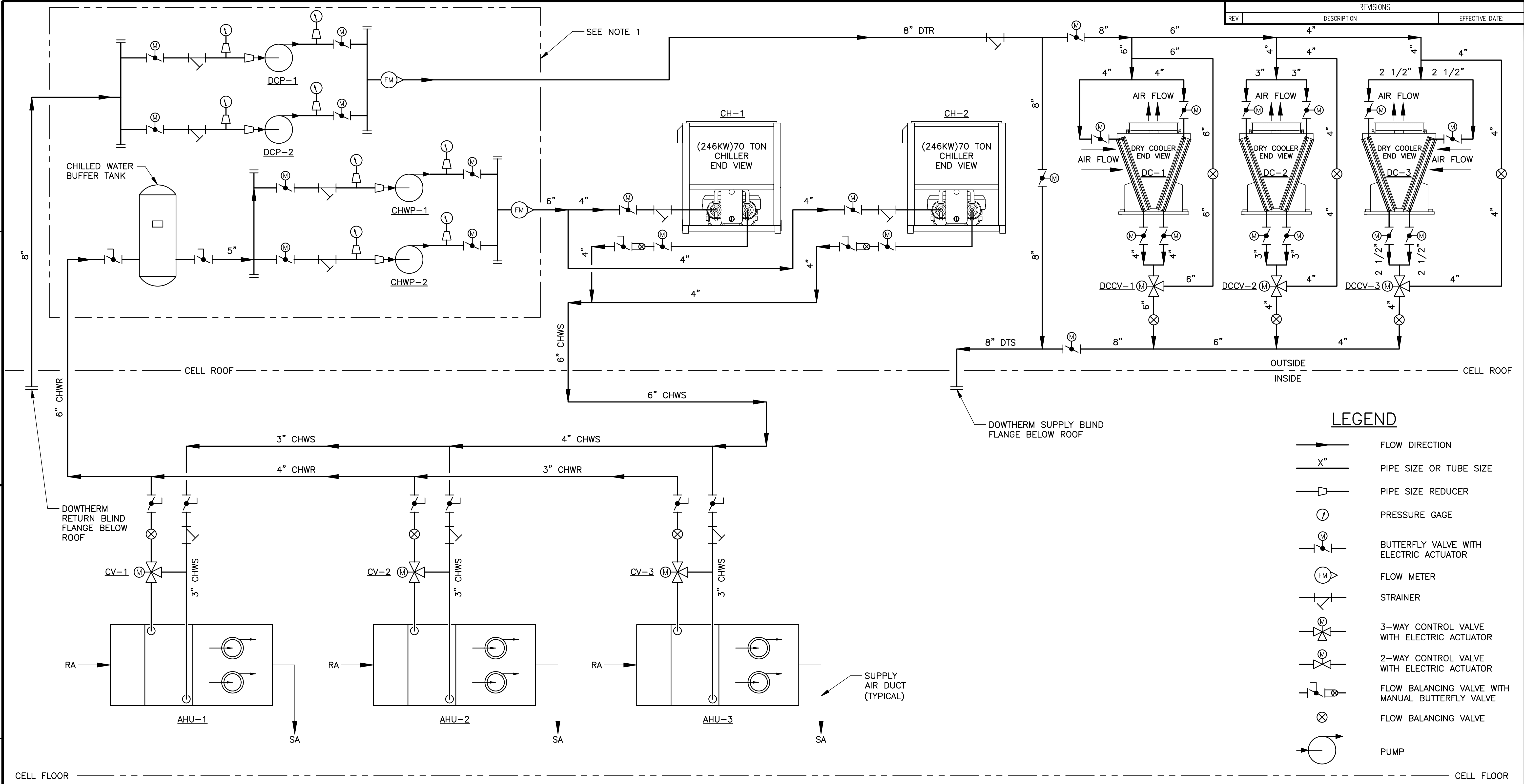

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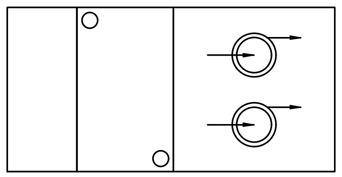

AIR HANDLING UNIT WITH COOLING COIL

SA	SUPPLY AIR
RA	RETURN AIR
CHWS	CHILLED WATER SUPPLY
CHWR	CHILLED WATER RETURN
CC	COOLING COIL
CV	CONTROL VALVE
DCCV	DRY COOLER CONTROL VALVE
PG	PROPYLENE GLYCOL
DCP	DRY COOLER PUMP
CHWP	CHILLED WATER PUMP
AHU	AIR HANDLING UNIT
DC	DRY COOLER
DTS	DOWTHERM SUPPLY
DTR	DOWTHERM RETURN

45% PG CHILLED WATER AND DOWTHERM DRY COOLER COOLING SYSTEMS PROCESS AND INSTRUMENTATION DIAGRAM

DESIGN ITERATION #1

PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION

NOTE

1. PRE-FABRICATED, PRE-PIPED/PRE-WIRED PUMP HOUSE WITH PUMPS AND VARIABLE SPEED DRIVES (NEMA-4 CABINETS), ONE-STANDBY AND LEAD/LAG (460V/3ϕ).

REVISIONS		
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RESP ENGR: A. BALSMEIER
DESIGN: C. BECK
DRAWN: R. SHICK
PROJECT NO. NA
SPCL CODE NA
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO. NA
EFFECTIVE DATE: XX/XX/2020

Idaho National Laboratory

MFC-776
ZPPR CELL MODIFICATION
REACTOR COOLING SYSTEM DESIGN
CHILLED WATER AND DRY COOLER COOLING SYSTEM
PROCESS AND INSTRUMENTATION DIAGRAM

SIZE D | CAGE CODE 01MF3 | INDEX CODE NUMBER: AREA 273, TYPE 0776, DL 52, ORIG 081 | DWG NO. NA | REV

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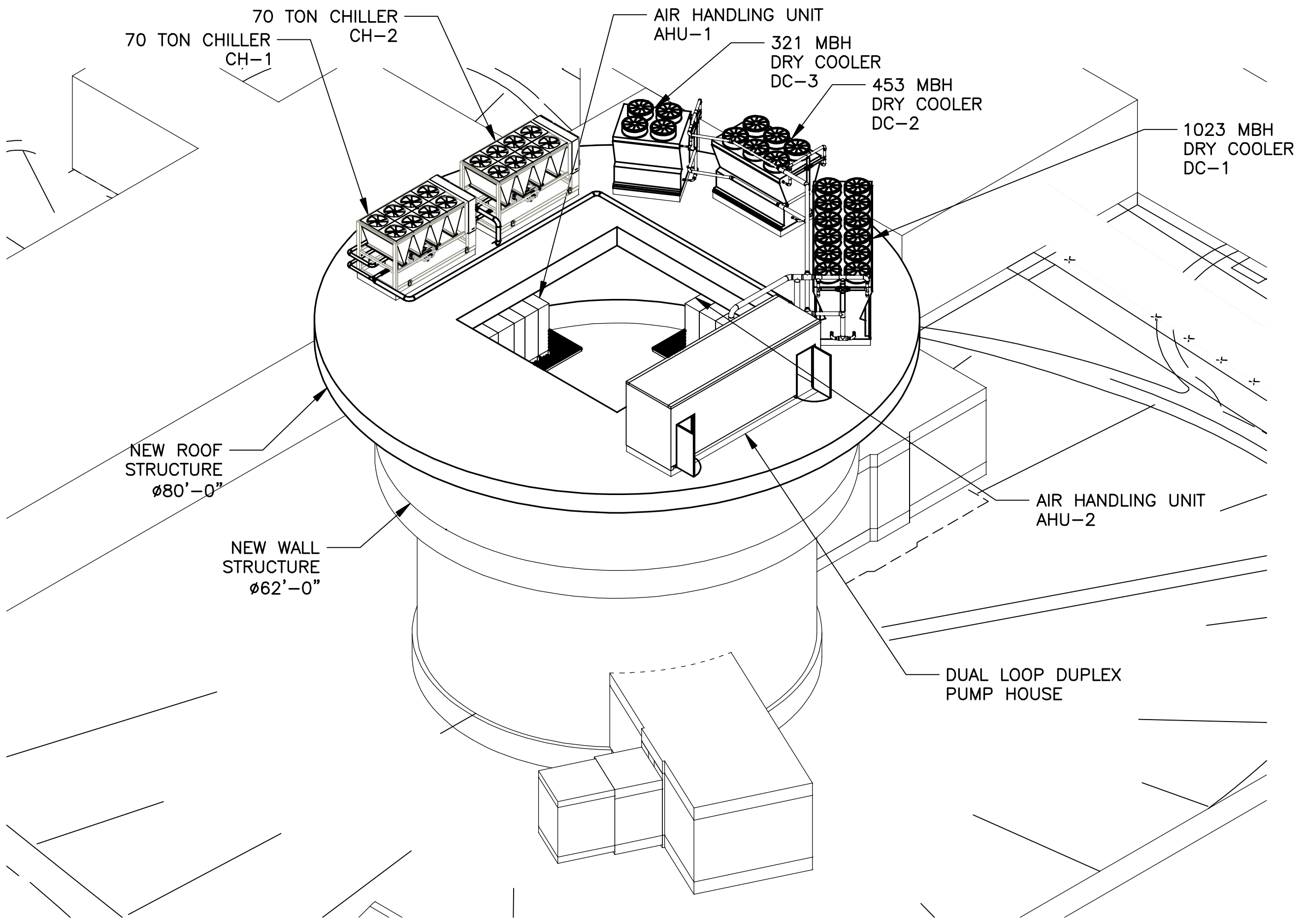

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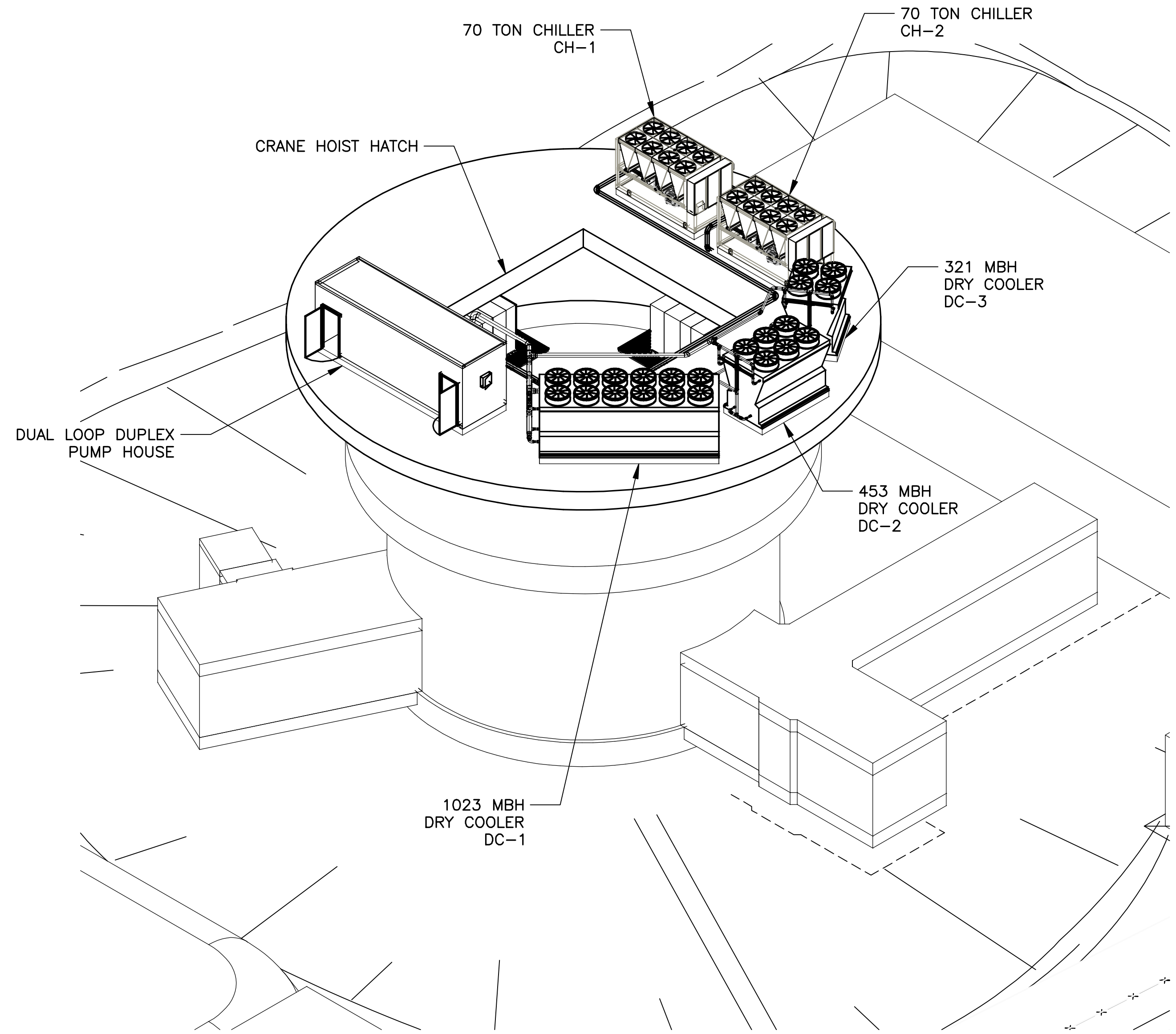

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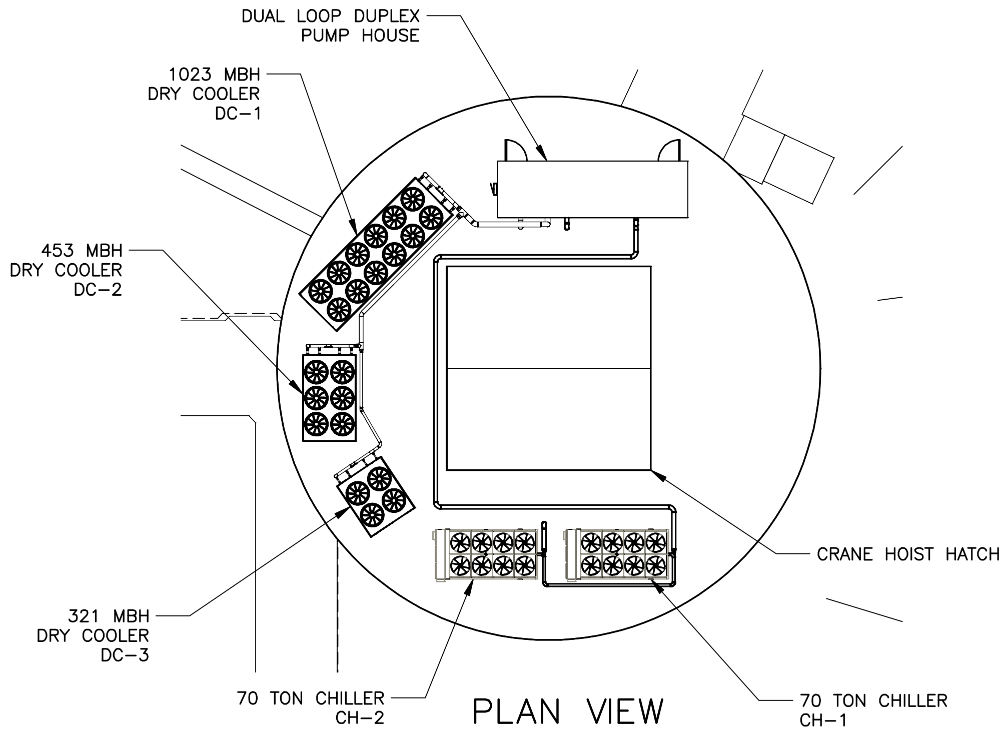

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PRELIMINARY
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REQUESTER:
RESP ENGR: A. BALSMEIER
DESIGN: C. BECK
DRAWN: R. SHICK
PROJECT NO. NA
SPCL CODE NA
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO. XXXXXX
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Idaho National Laboratory

MFC-776
NRIC ZPPR REACTOR TEST BED
CONCEPTUAL DESIGN

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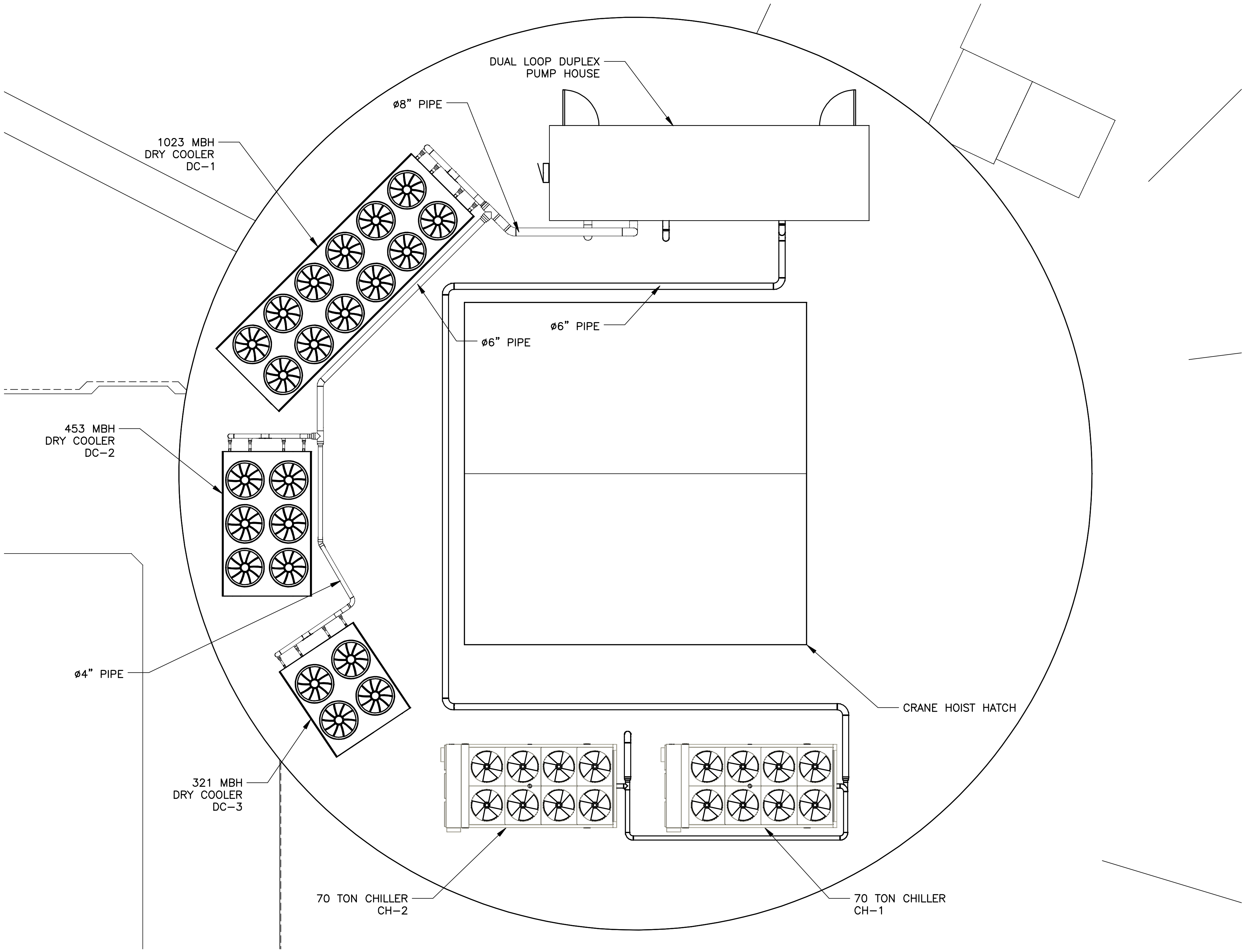

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RESP ENGR:	A. BALSMEIER
DESIGN:	C. BECK
DRAWN:	R. SHICK
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Idaho National Laboratory

MFC-776
NRIC ZPPR REACTOR TEST BED
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SCALE: NOTED | SHEET VIEW2

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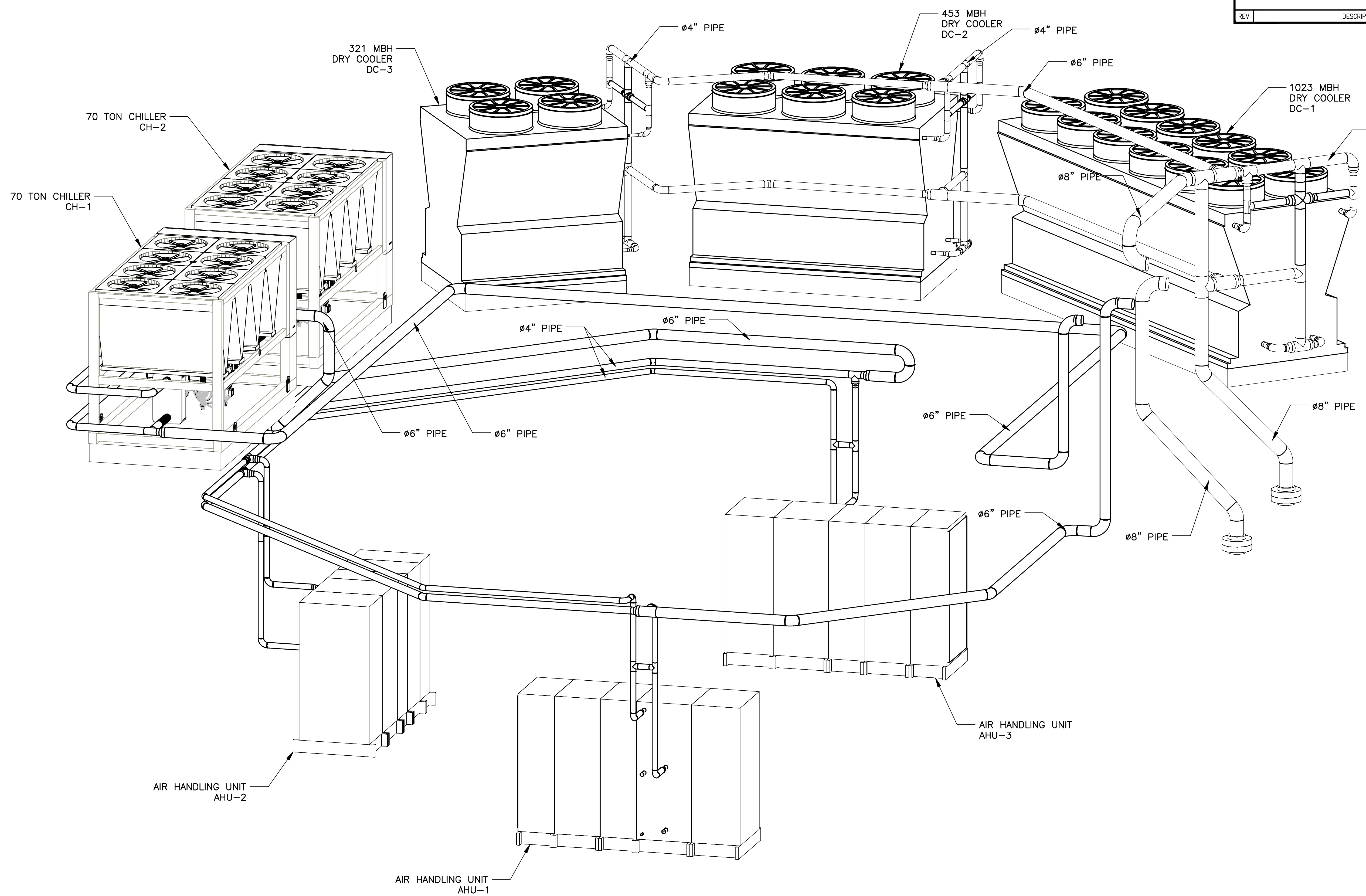
File: ZPPR_MASTER.dwg
Path: C:\Users\WEISBA\Desktop\ZP
Date: 09/23/20 - 1:39 PM Layout Name: VIEWS (2) ID: WEISBA



BUILDING NOT SHOWN FOR CLARITY

BREAKOUT VIEW

SCALE: NONE

PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION

REVISIONS		
REV	DESCRIPTION	EFFECTIVE DATE:

FOR DRAWING INDEX SEE DRAWING NO. NA

NO SCALE

DESIGN PHASE: CONCEPTUAL

REQUESTER:
RESP ENGR: A. BALSMEIER
DESIGN: C. BECK
DRAWN: R. SHICK
PROJECT NO. NA
SPCL CODE NA
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO. XXXXXX
EFFECTIVE DATE: NA

Idaho National Laboratory

MFC-776
NRIC ZPPR REACTOR TEST BED
CONCEPTUAL DESIGN

SIZE D | CAGE CODE 01MF3 | INDEX CODE NUMBER: AREA 273 TYPE 0767 CL ORIG 081 | DWG NO. XXXXXXX | REV

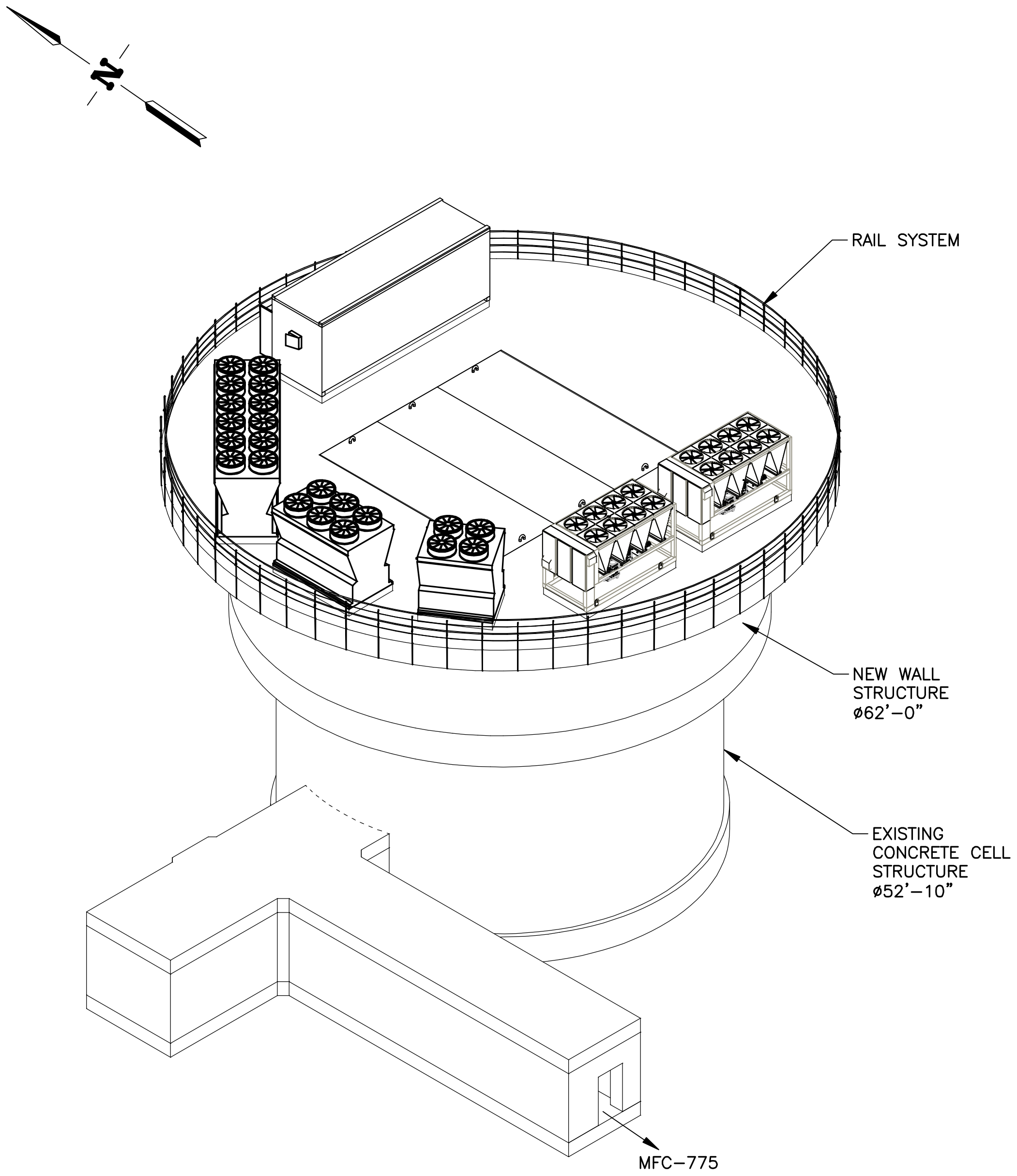
SCALE: NOTED | SHEET VIEW3

3

File: ZPPR_MASTER.dwg Path: C:\Users\WEISBA\Desktop\ZB Date: 09/23/20 - 1:39 PM Layout Name: VIEWS (3) ID: WEISBA

FMT-D1-INL, R-1

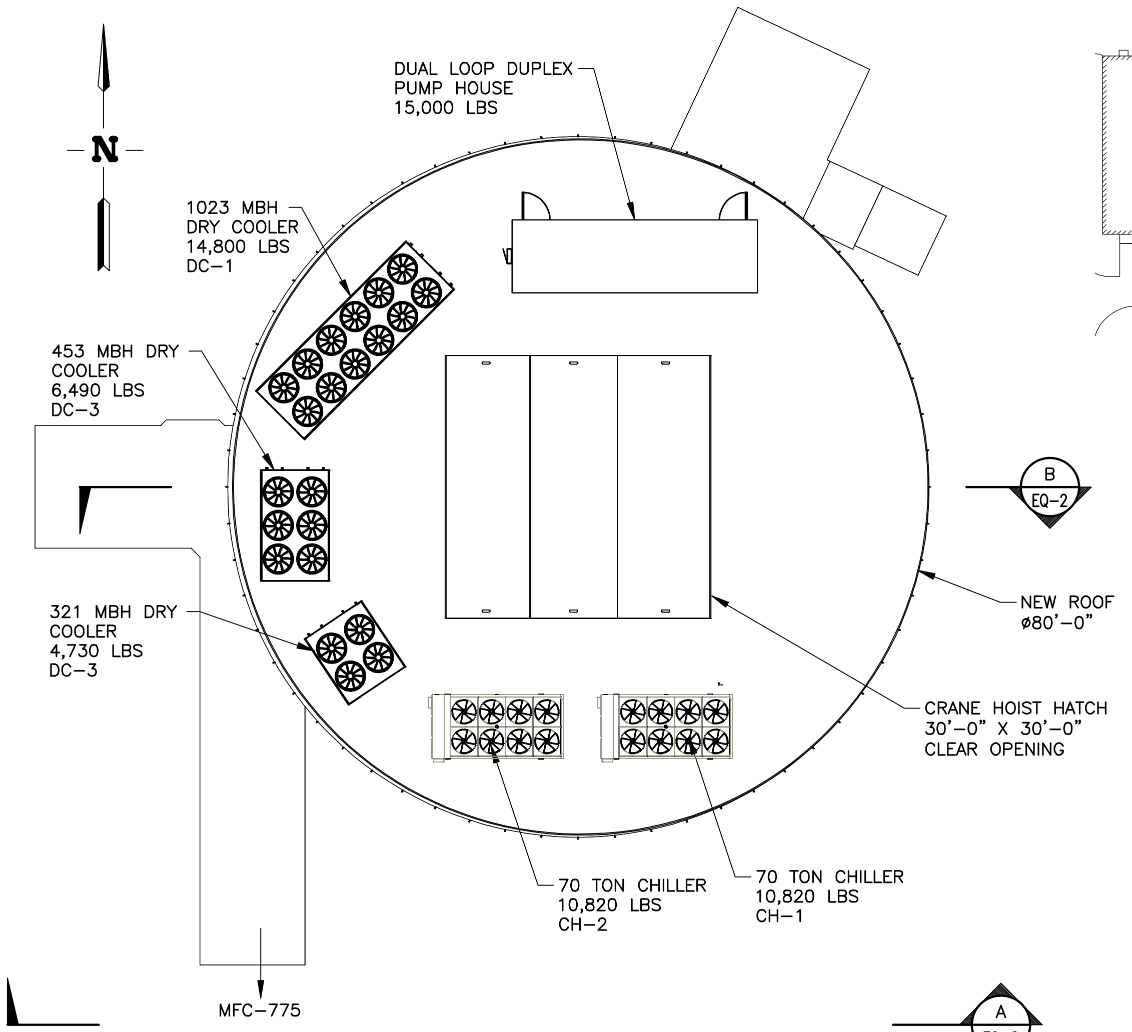
REV	DESCRIPTION	EFFECTIVE DATE:



MOUND NOT SHOWN FOR CLARITY

MFC-776 OUTSIDE ISOMETRIC VIEW

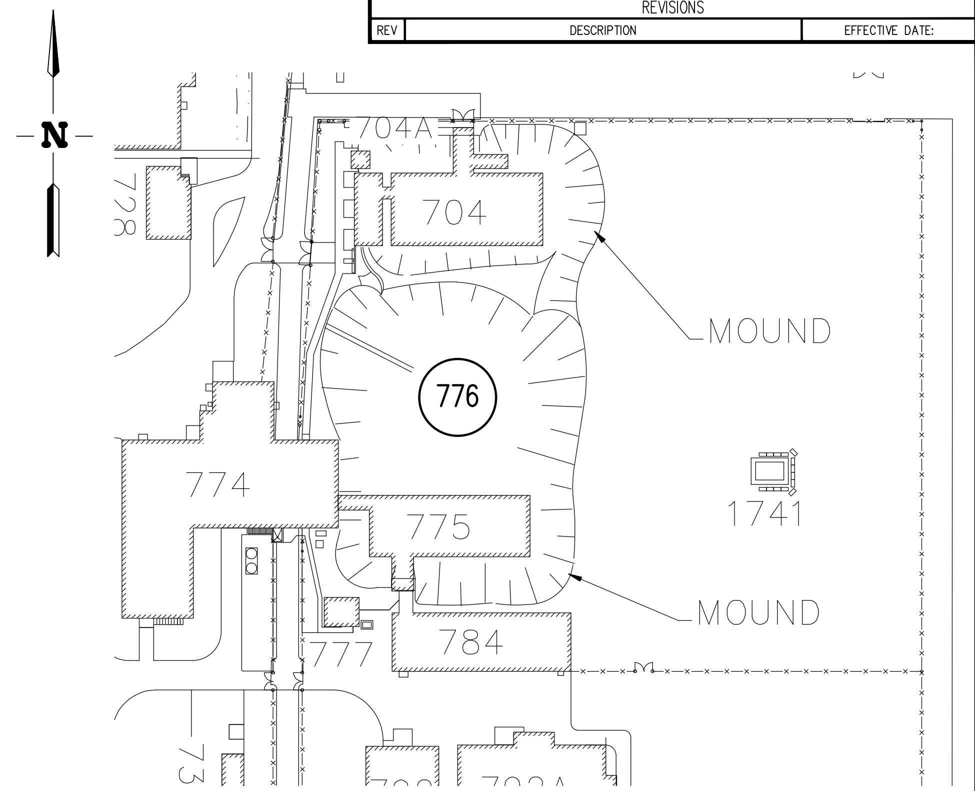
NO SCALE



MOUND NOT SHOWN FOR CLARITY

MFC-776 ROOF PLAN

SCALE: 3/32" = 1'-0"



KEY PLAN

NO SCALE

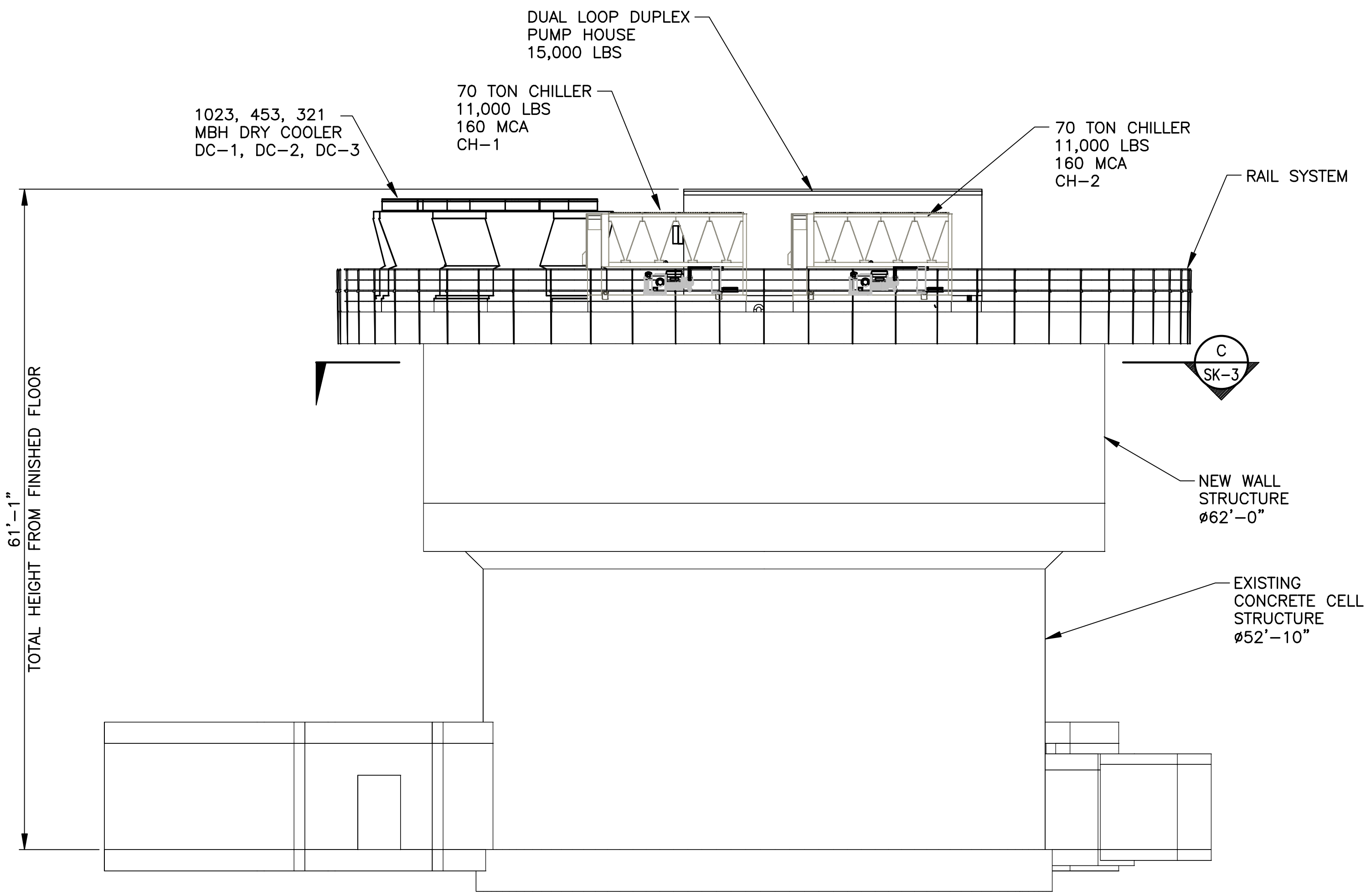
PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION

FOR DRAWING INDEX SEE DRAWING NO. NA	REQUESTER: A. BALSMEIER	Idaho National Laboratory
SCALE: 3/32" = 1'-0"	RESP ENGR: A. BALSMEIER	MFC-776 NRIC ZPPR REACTOR TEST BED CONCEPTUAL DESIGN
	DESIGN: A. BALSMEIER	EQUIPMENT LOCATION DETAILS
	DRAWN: B. WEISSER	SIZE: D; CAGE CODE: 01MF3; INDEX CODE NUMBER: AREA 273, TYPE 0776, CL 52, ORIG 081; DWG NO. XXXXXXX; REV
	PROJECT NO. NA	SCALE: NOTED; SHEET EQ-1
	SPCL CODE NA	
	FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO. XXXXXX	
DESIGN PHASE: AFC	EFFECTIVE DATE: 7/8/2020	

FMT-D1-INL, R-1
File: EQUIPMENT_LOCATION.dwg Path: C:\Users\WEISBA\Desktop\ZE Date: 09/17/20 - 3:34 PM Layout Name: EQ-1 ID: WEISBA

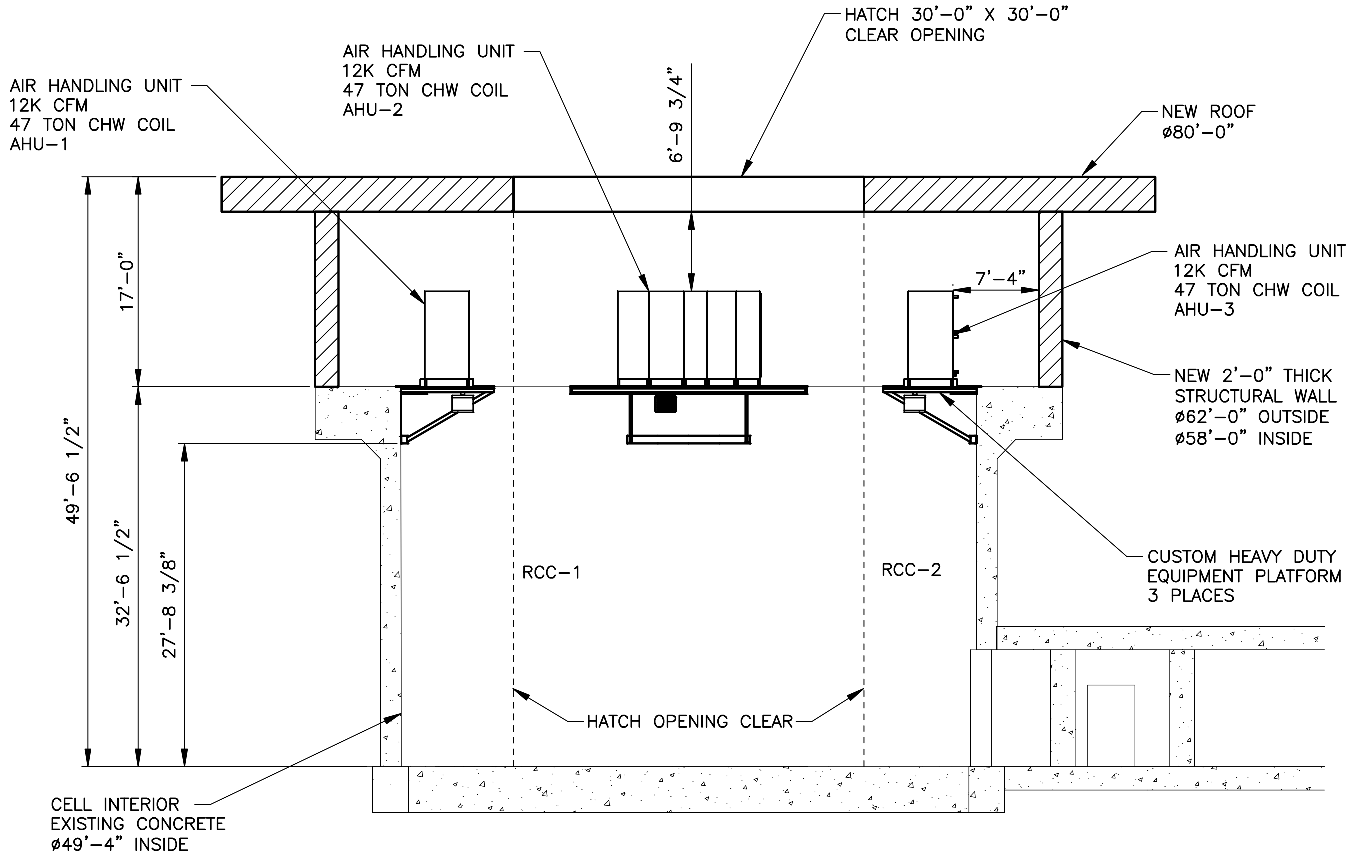
FMT-D1-INL, R-1

REVISIONS		
REV	DESCRIPTION	EFFECTIVE DATE:



MOUND NOT SHOWN FOR CLARITY

SECTION A EQ-1
SCALE: 1/8" = 1'-0"



LADDER AND HAND RAIL DESIGN TBD

ROOF TOP ITEMS NOT SHOWN FOR CLARITY

MOUND NOT SHOWN FOR CLARITY

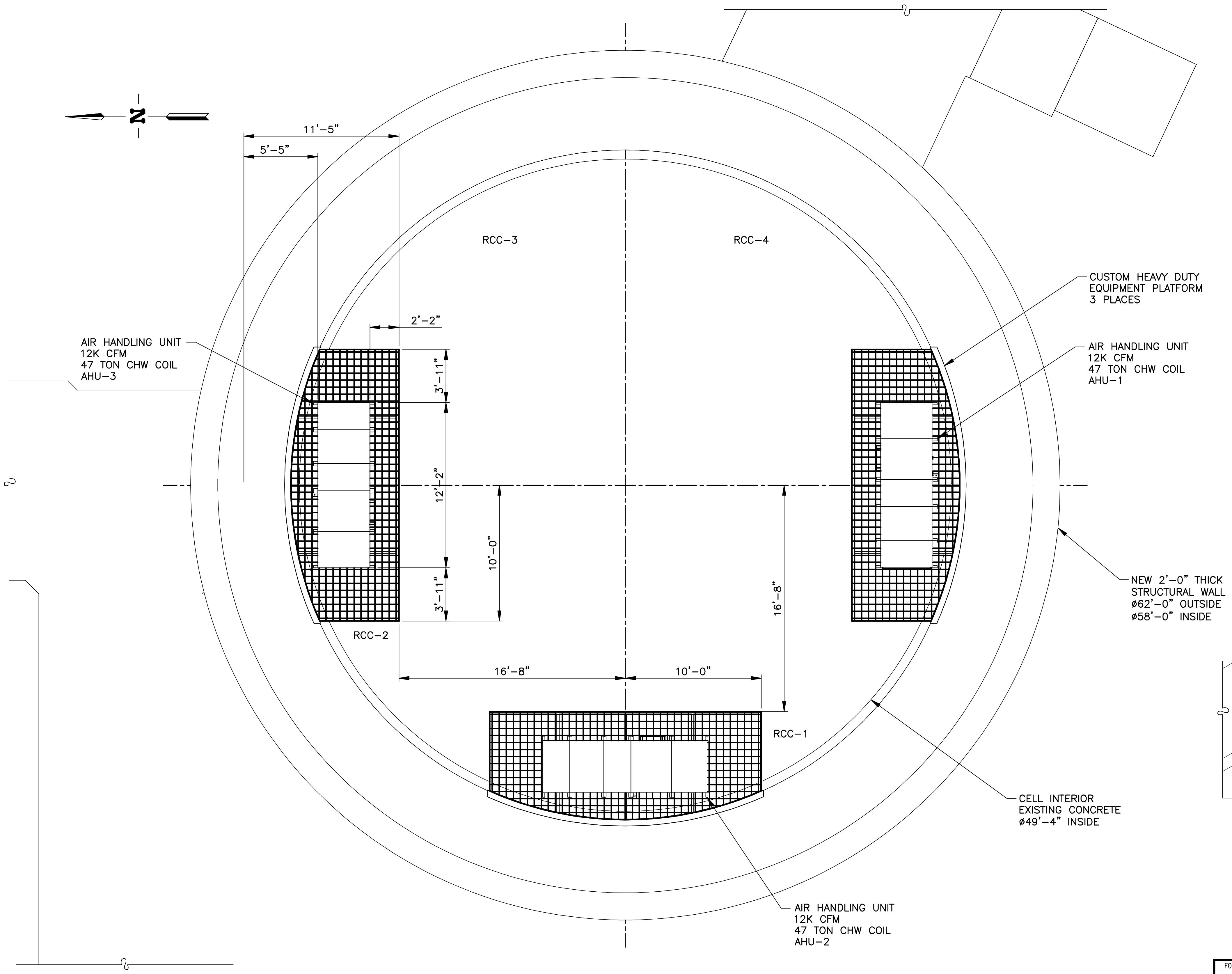
SECTION B EQ-1
SCALE: 1/8" = 1'-0"

PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION

FOR DRAWING INDEX SEE DRAWING NO. NA	REQUESTER: A. BALSMEIER	Idaho National Laboratory
1' 0 1' 2' 3' 4' 5' 10' 15' SCALE: 1/8" = 1'-0"	RESP ENGR: A. BALSMEIER	MFC-776 NRIC ZPPR REACTOR TEST BED CONCEPTUAL DESIGN
	DESIGN: A. BALSMEIER	EQUIPMENT LOCATION DETAILS
	DRAWN: B. WEISSER	SIZE D CAGE CODE 01MF3 INDEX CODE NUMBER AREA 273 TYPE 0776 OL 52 ORIG 081 DWG NO. XXXXXXX REV
	PROJECT NO. NA	SCALE: NOTED SHEET EQ-2
	SPCL CODE NA	
	FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO. XXXXXX	
DESIGN PHASE: AFC	EFFECTIVE DATE: 7/8/2020	

File: EQUIPMENT_LOCATION.dwg
Path: C:\Users\WEISBA\Desktop\ZB
Date: 09/17/20 - 3:34 PM Layout Name: EQ-2
ID: WEISBA

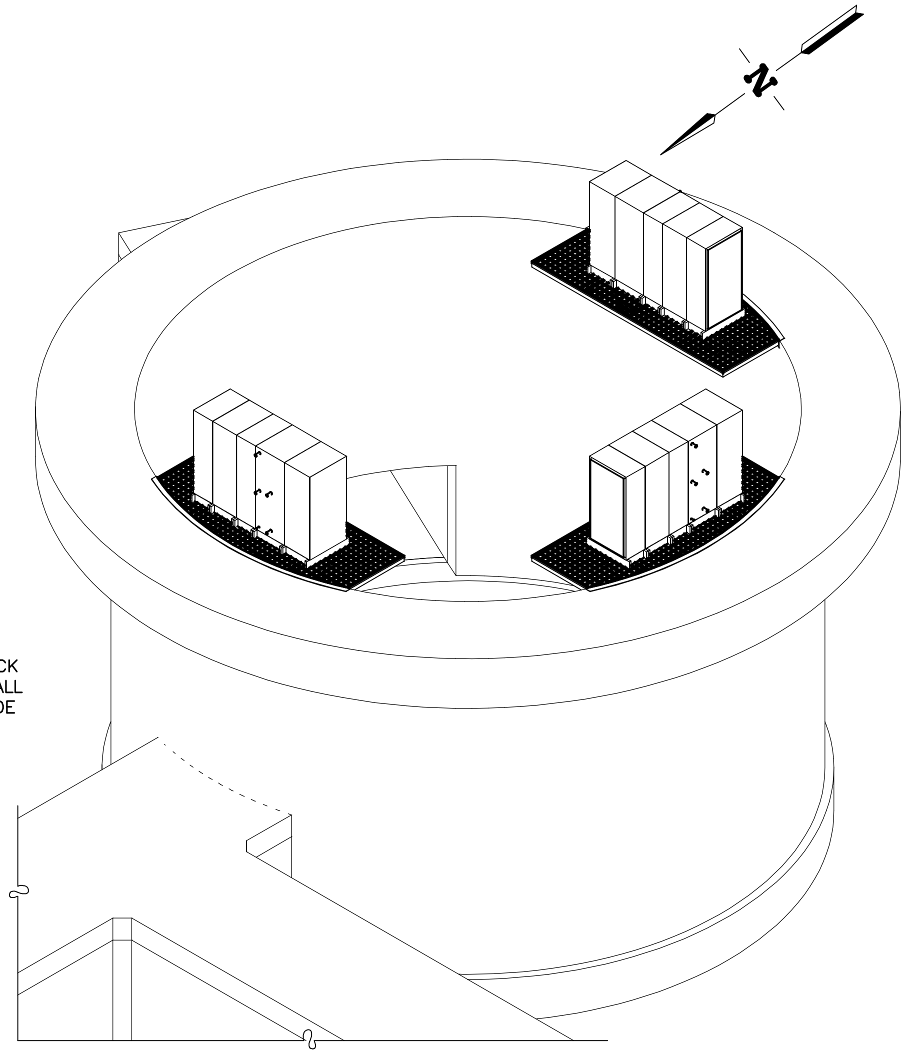
REVISIONS		
REV	DESCRIPTION	EFFECTIVE DATE:



MOUND NOT SHOWN FOR CLARITY

SECTION C / EQ-2

SCALE: 1/4" = 1'-0"



MOUND AND UPPER STRUCTURE NOT SHOWN FOR CLARITY

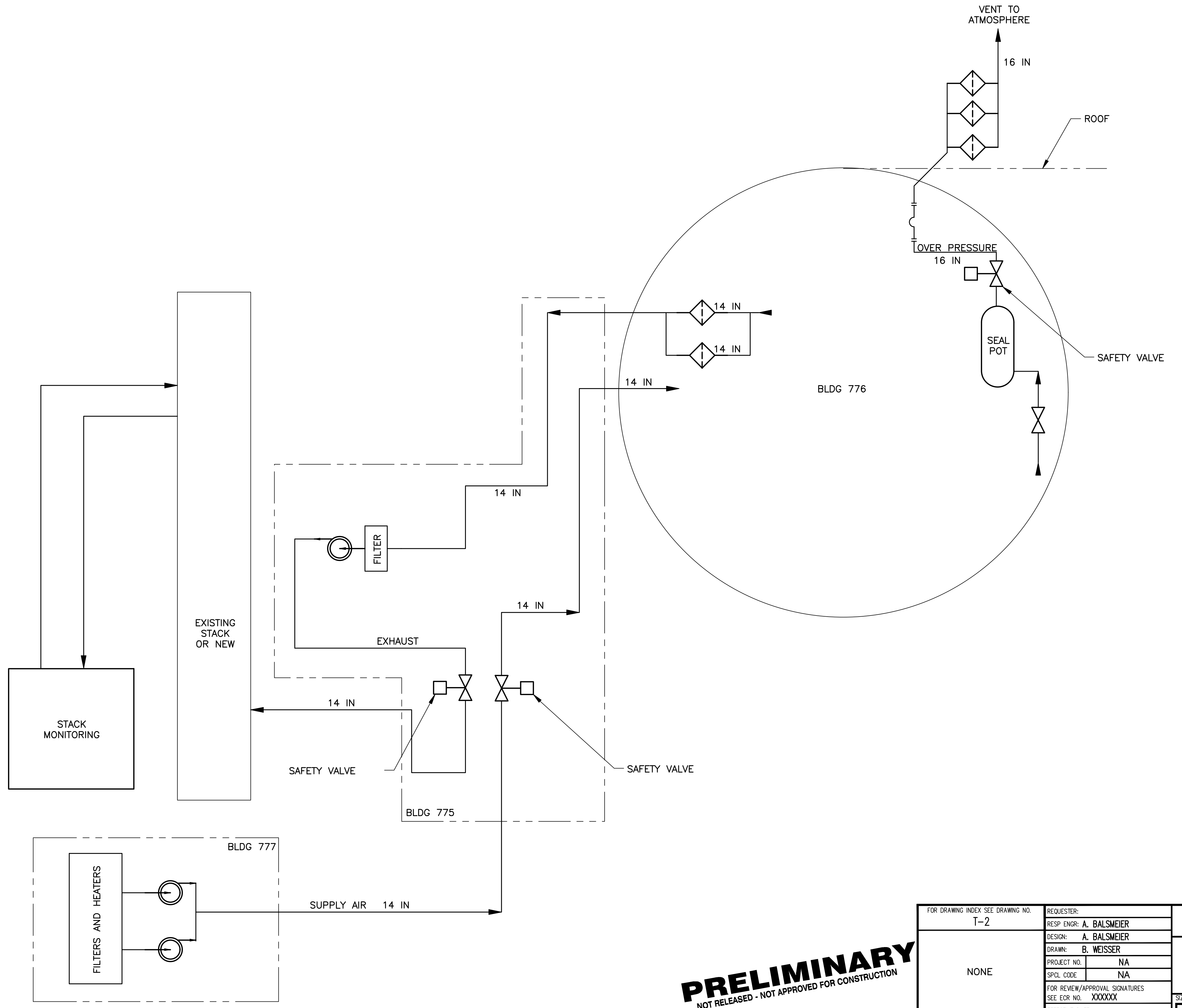
MFC-776 INSIDE ISOMETRIC VIEW

NO SCALE

PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION

FOR DRAWING INDEX SEE DRAWING NO. NA	REQUESTER: A. BALSMEIER	Idaho National Laboratory
SCALE: 1/4" = 1'-0"	RESP ENGR: A. BALSMEIER	MFC-776 NRIC ZPPR REACTOR TEST BED CONCEPTUAL DESIGN
	DESIGN: A. BALSMEIER	EQUIPMENT LOCATION DETAILS
	DRAWN: B. WEISSER	SIZE: D; CAGE CODE: 01MF3; INDEX CODE NUMBER: AREA 273, TYPE 0776, CL 52, ORIG 081; DWG NO. XXXXXXX; REV
	PROJECT NO. NA	
	SPCL CODE NA	
	FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO. XXXXXX	
DESIGN PHASE: AFC	EFFECTIVE DATE: 7/8/2020	SCALE: NOTED; SHEET EQ-3

File: EQUIPMENT_LOCATION.dwg ID: WEISBA Layout Name: EQ-3 Date: 09/17/20 - 3:34 PM
Path: C:\Users\WEISBA\Desktop\ZE



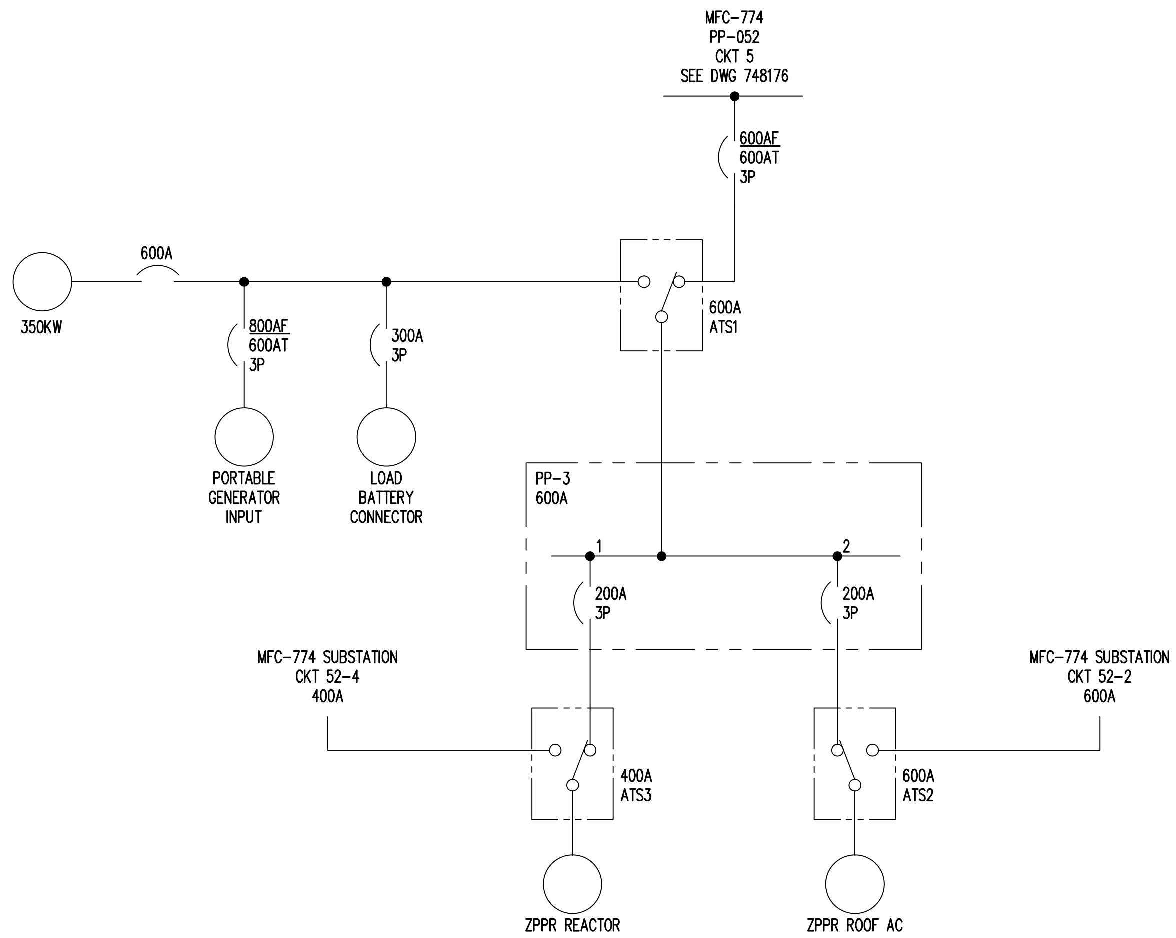
REVISIONS		
REV	DESCRIPTION	EFFECTIVE DATE:

PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION

FOR DRAWING INDEX SEE DRAWING NO. T-2	REQUESTER:	Idaho National Laboratory
NONE	RESP ENGR: A. BALSMEIER	MFC-776 NRIC ZPPR REACTOR TEST BED CONCEPTUAL DESIGN
	DESIGN: A. BALSMEIER	VENTILATION PROCESS FLOW DIAGRAM
	DRAWN: B. WEISSER	SIZE D; CAGE CODE 01MF3; INDEX CODE NUMBER AREA 273, TYPE 0776, CL, ORIG 081; DWG NO. XXXXXXX; REV
	PROJECT NO. NA	SCALE: NONE
	SPCL CODE NA	SHEET V-1
	FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO. XXXXXX	
DESIGN PHASE: CONCEPTUAL	EFFECTIVE DATE: NA	

FMT-D1-INL, R-1

File: ZPPR_VENTILATION_PFD.dwg Path: C:\Users\WEISBA\Desktop\ZPPR Date: 09/18/20 - 3:45 PM Layout Name: V-1 ID: WEISBA



REVISIONS		
REV	DESCRIPTION	EFFECTIVE DATE:

PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION

FOR DRAWING INDEX SEE DRAWING NO. T-2

NO SCALE

DESIGN PHASE: CONCEPTUAL

REQUESTER:
RESP ENGR: A. BALSMEIER
DESIGN: T. BAKES
DRAWN: M. LEE
PROJECT NO. NA
SPCL CODE NA
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO. XXXXXX
EFFECTIVE DATE: NA

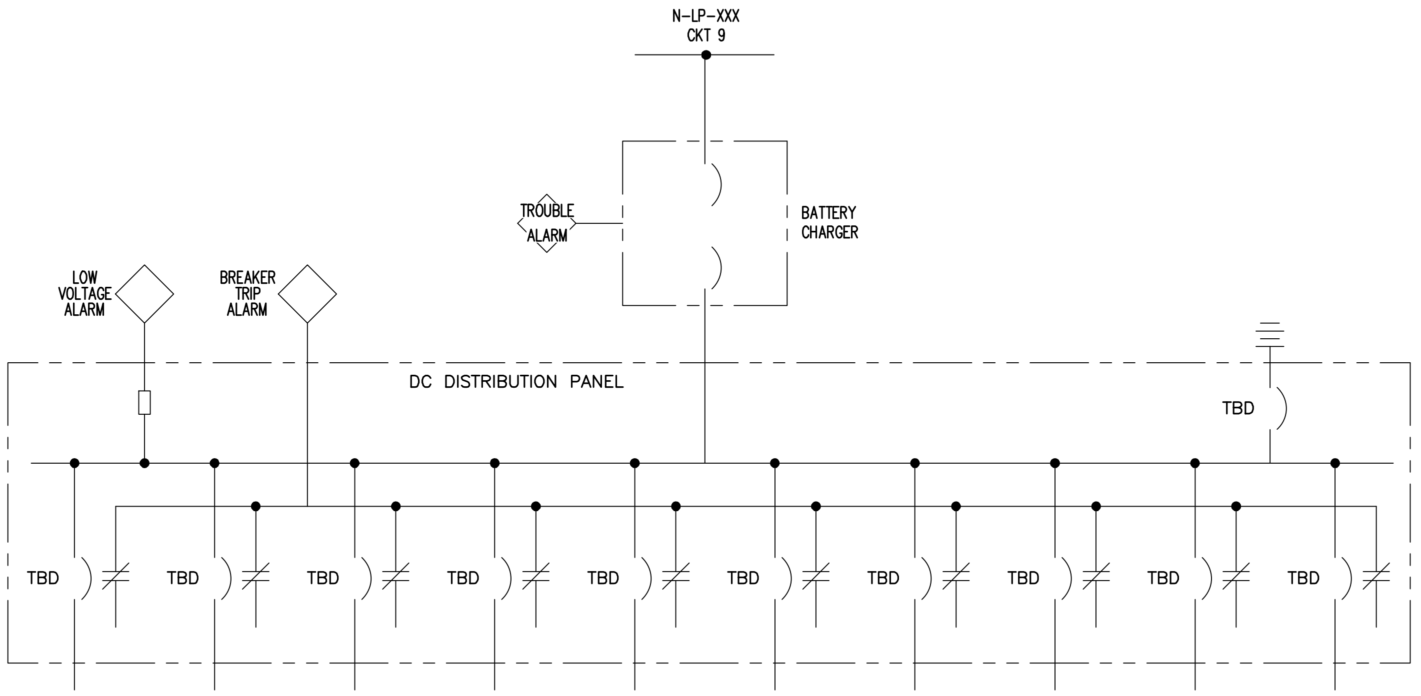
Idaho National Laboratory

MFC-774
NRIC ZPPR REACTOR TEST BED
CONCEPTUAL DESIGN
ZPPR POWER
ONE LINE DIAGRAM

SIZE D | CAGE CODE 01MF3 | INDEX CODE NUMBER: AREA 273, TYPE 0774, DL 10, ORIG 081 | DWG NO. XXXXXXX | REV

SCALE: NONE | SHEET E-1

FMT-D1-INL, R-1
Date: 09/17/20 - 2:45 P.M. ID: LEEMS
Layout Name: X-X
Path: Y:\LEEMS\2020\NRIC
File: E-1.dwg



PANEL: N-LP-XXX	ALTERNATE ID:	REVISION DATE:	
NORMAL POWER	STATUS:		
LOCATION: MFC 774 BATTERY ROOM	MDL / SER NO:		
	MAIN BKR AMPACITY: MLO		
FED FROM: N-LP-173	KVA RATING:		
	AMPACITY RATING: 800		
VOLTAGE RATING: 480 3 -PHASE/ 3 -WIRE	INTERRUPTING RATING:		

	PH. A	PH. B	PH. C	DATE
VOLT-AMPS:	0	0	0	
AMPS:	0	0	0	
MEAS. AMPS:	0	0	0	
MEAS. VOLT:		0		

STATUS	LOAD	CKT	AMPS	KVA	PH	KVA	AMPS	CKT	LOAD	STATUS
	GFCI RECEPTACLES	1	20A		A		20A	2	BATTERY ROOM LIGHTS	
	GENERATOR BLOCK HEATER	3	20A		B		20A	4	MITSUBISHI SPLIT AC-HEAT PUMP SYSTEM	
	GENERATOR BATTERY CHARGER	5	20A		C		20A	6	MITSUBISHI SPLIT AC-HEAT PUMP SYSTEM	
	GENERATOR ENCLOSURE HEATER	7	20A		A		20A	8	BATTERY ROOM VENT FAN	
	BATTERY ROOM CHARGER	9	20A		B		20A	10	EXPLOSIVE GAS DETECTOR	
	TBD	11			C			12	TBD	
	TBD	13			A			14	TBD	
	TBD	15			B			16	TBD	
	TBD	17			C			18	TBD	
	TBD	19			A			20	TBD	
	TBD	21			B			22	TBD	
	TBD	23			C			24	TBD	
	TBD	25			A			26	TBD	
	TBD	27			B			28	TBD	
	TBD	29			C			30	TBD	
TOTAL KVA:										

REVISIONS

REV	DESCRIPTION	EFFECTIVE DATE:

PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION

FOR DRAWING INDEX SEE DRAWING NO. T-2

NO SCALE

DESIGN PHASE: CONCEPTUAL

REQUESTER:
RESP ENGR: A. BALSMEIER
DESIGN: T. BAKES
DRAWN: M. LEE
PROJECT NO. NA
SPCL CODE NA
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO. XXXXXX
EFFECTIVE DATE: NA

Idaho National Laboratory

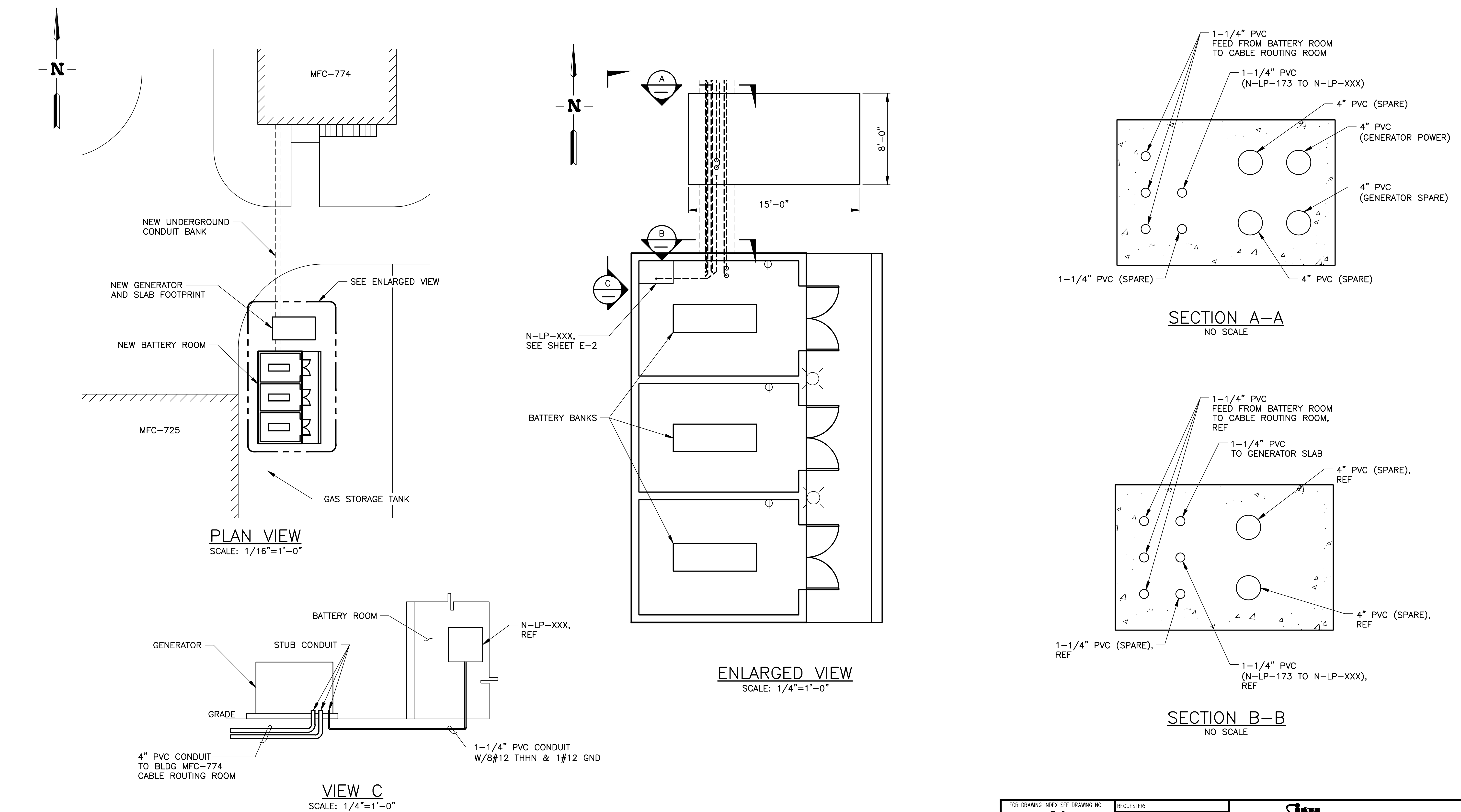
MFC-774
NRIC ZPPR REACTOR TEST BED
CONCEPTUAL DESIGN
N-LP-XXX
ONE LINE DIAGRAM AND PANEL SCHEDULE

SIZE D | CAGE CODE 01MF3 | INDEX CODE NUMBER: AREA 273, TYPE 0774, CL 10, ORIG 081 | DWG NO. XXXXXXX | REV

SCALE: NONE | SHEET E-2

FMT-D1-INL, R-1

ID: LEEMS
Date: 09/22/20 - 4:19 P.M.
Layout Name: X-X
Path: Y:\LEEMS\2020\NRIC
File: E-2.dwg



REVISIONS		
REV	DESCRIPTION	EFFECTIVE DATE:

PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION

FOR DRAWING INDEX SEE DRAWING NO.	T-2
SCALE: 1/16" = 1'-0"	
SCALE: 1/4" = 1'-0"	
DESIGN PHASE:	CONCEPTUAL
REQUESTER:	
RESP ENGR:	A. BALSMEIER
DESIGN:	T. BAKES
DRAWN:	M. LEE
PROJECT NO.	NA
SPCL CODE	NA
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO.	XXXXXX
EFFECTIVE DATE:	NA

Idaho National Laboratory

MFC
NRIC ZPPR REACTOR TEST BED
CONCEPTUAL DESIGN
BATTERY ROOM
PLAN VIEW, ENLARGED VIEW, AND SECTIONS

SIZE	CAGE CODE	AREA	TYPE	CL	ORIG	DWG NO.	REV
D	01MF3	273	0100	10	081	XXXXXXX	

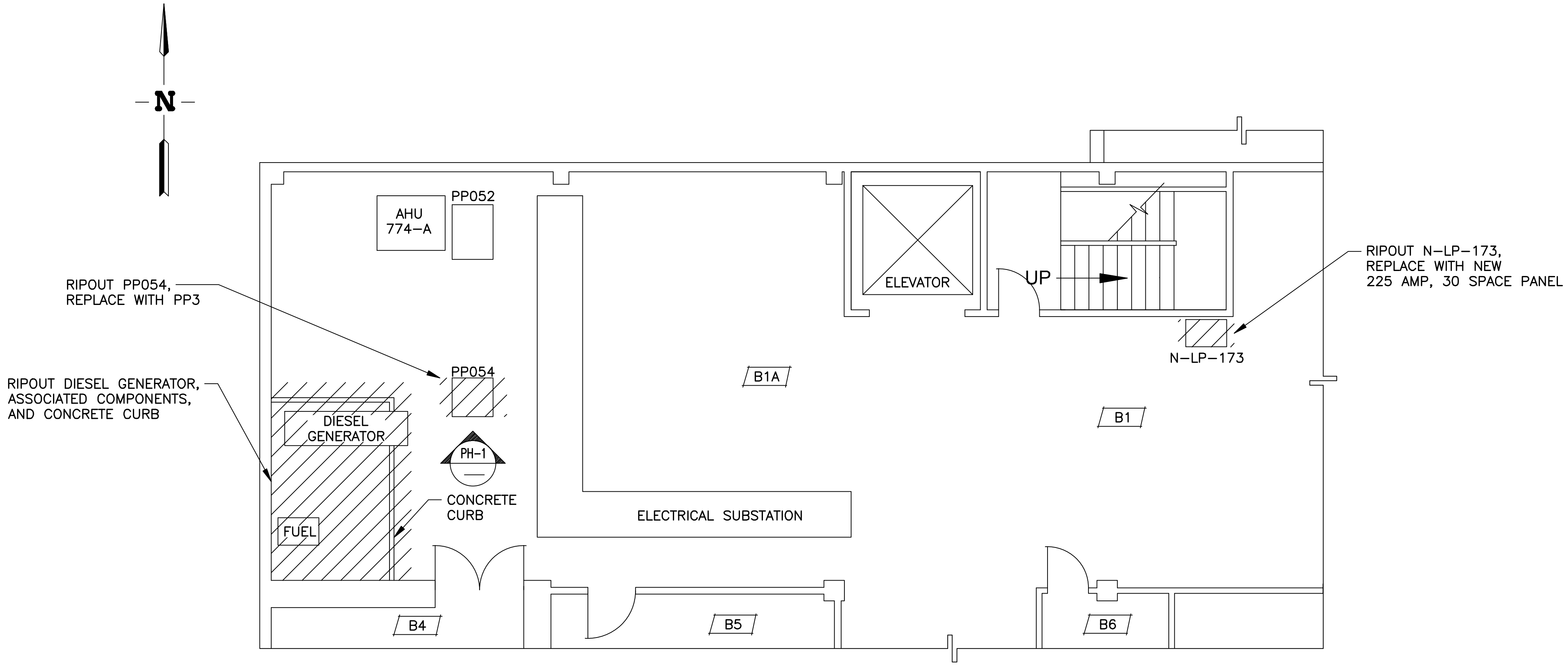
SCALE: NOTED
SHEET E-3

FMT-D1-INL, R-1
Date: 09/23/20 - 1:39 P.M. ID: LEEMS
Layout Name: T-1
Path: Y:\LEEMS\2020\NRIC
File: E-3.dwg

FMT-D1-INL, R-1

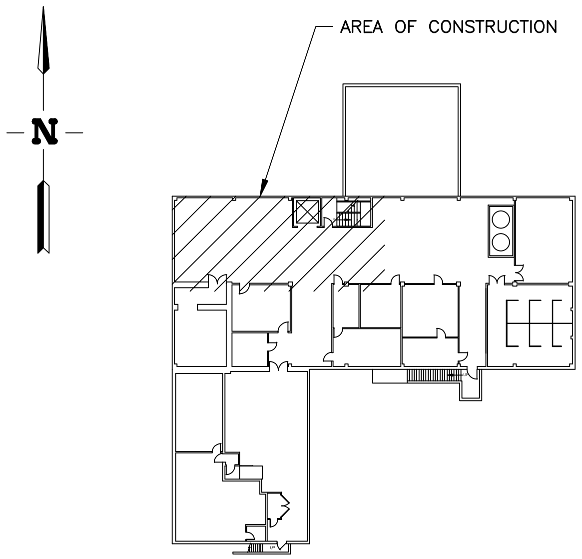
REVISIONS		
REV	DESCRIPTION	EFFECTIVE DATE:

PHOTO (PH-1)



BASEMENT ELECTRICAL PLAN

SCALE: 3/16" = 1'–0"



KEY PLAN

NTS

LEGEND

HATCH INDICATES RIPOUT

PRELIMINARY

NOT RELEASED - NOT APPROVED FOR CONSTRUCTION

FOR DRAWING INDEX SEE DRAWING NO.	T–2
SCALE: 3/16" = 1'–0"	
DESIGN PHASE:	CONCEPTUAL
REQUESTER:	
RESP ENGR:	A. BALSMEIER
DESIGN:	T. BAKES
DRAWN:	M. LEE
PROJECT NO.	NA
SPCL CODE	NA
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO.	XXXXXX
EFFECTIVE DATE:	NA

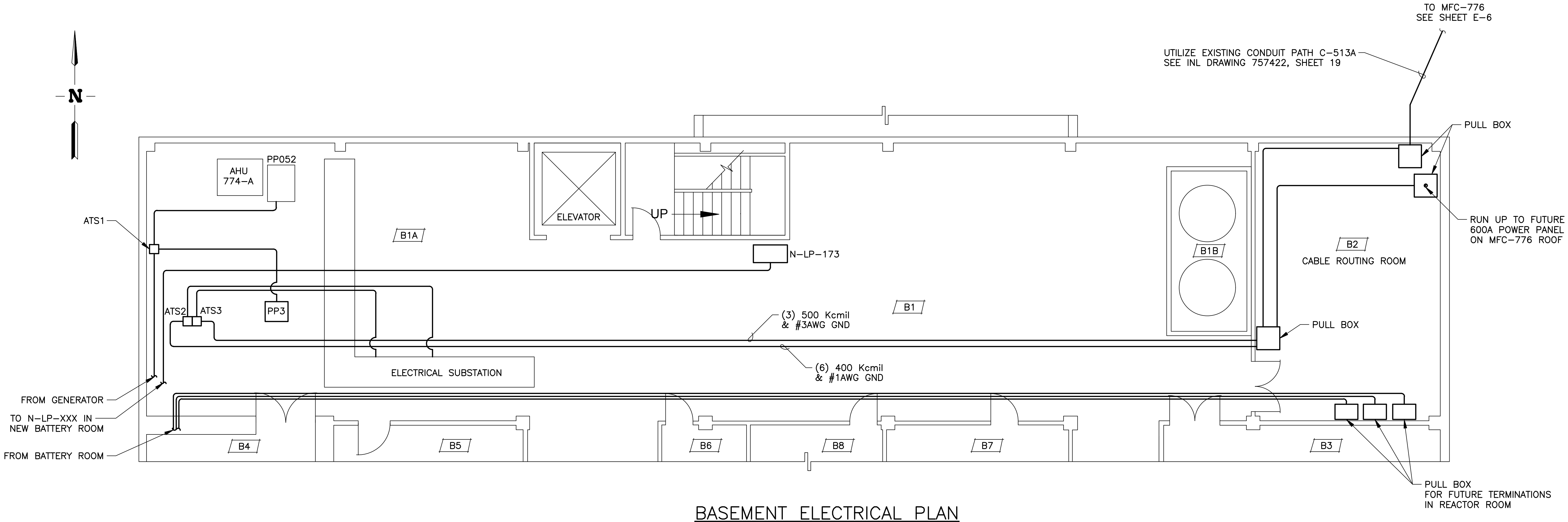
Idaho National Laboratory

MFC–774
NRIC ZPPR REACTOR TEST BED
CONCEPTUAL DESIGN
LEGACY DEVICE RIPOUT
KEY PLAN, PLAN VIEW, AND PHOTO

SIZE	CAGE CODE	AREA	TYPE	OL	ORIG	DWG NO.	REV
D	01MF3	273	0774	10	081	XXXXXXX	

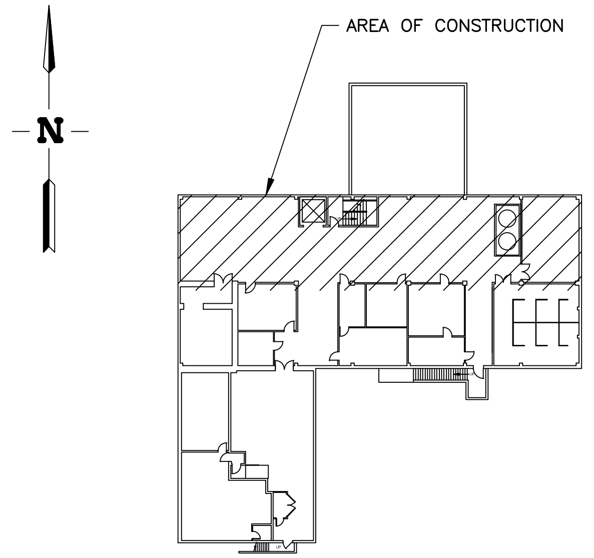
SCALE: 3/16" = 1'–0" SHEET E–4

ID: LEEMS
Date: 09/17/20 – 5:32 P.M.
Layout Name: X–X
Path: Y:\LEEMS\2020\NRIC
File: E–4.dwg



BASEMENT ELECTRICAL PLAN

SCALE: 3/16" = 1'-0"



KEY PLAN

NTS

NOTES

1. 52-2 (ACCU-774A-001 & AHU-MFC774A-001 30 Amp) TO 52-9A. THEN MOVE UP BREAKERS 52-3, 52-4 AND 52-4A TO PROVIDE PHYSICAL SPACE FOR A 600 AMP BREAKER.
2. USE EXISTING RACES, IF POSSIBLE, FOR CONDUIT RUNS.

PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION

REVISIONS		
REV	DESCRIPTION	EFFECTIVE DATE:

FOR DRAWING INDEX SEE DRAWING NO. T-2

SCALE: 3/16" = 1'-0"

DESIGN PHASE: CONCEPTUAL

REQUESTER:
RESP ENGR: A. BALSMEIER
DESIGN: A. BALSMEIER
DRAWN: M. LEE
PROJECT NO. NA
SPCL CODE NA
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO. XXXXXX
EFFECTIVE DATE: NA

Idaho National Laboratory

MFC-774
NRIC ZPPR REACTOR TEST BED
CONCEPTUAL DESIGN

COPY FROM INDEX

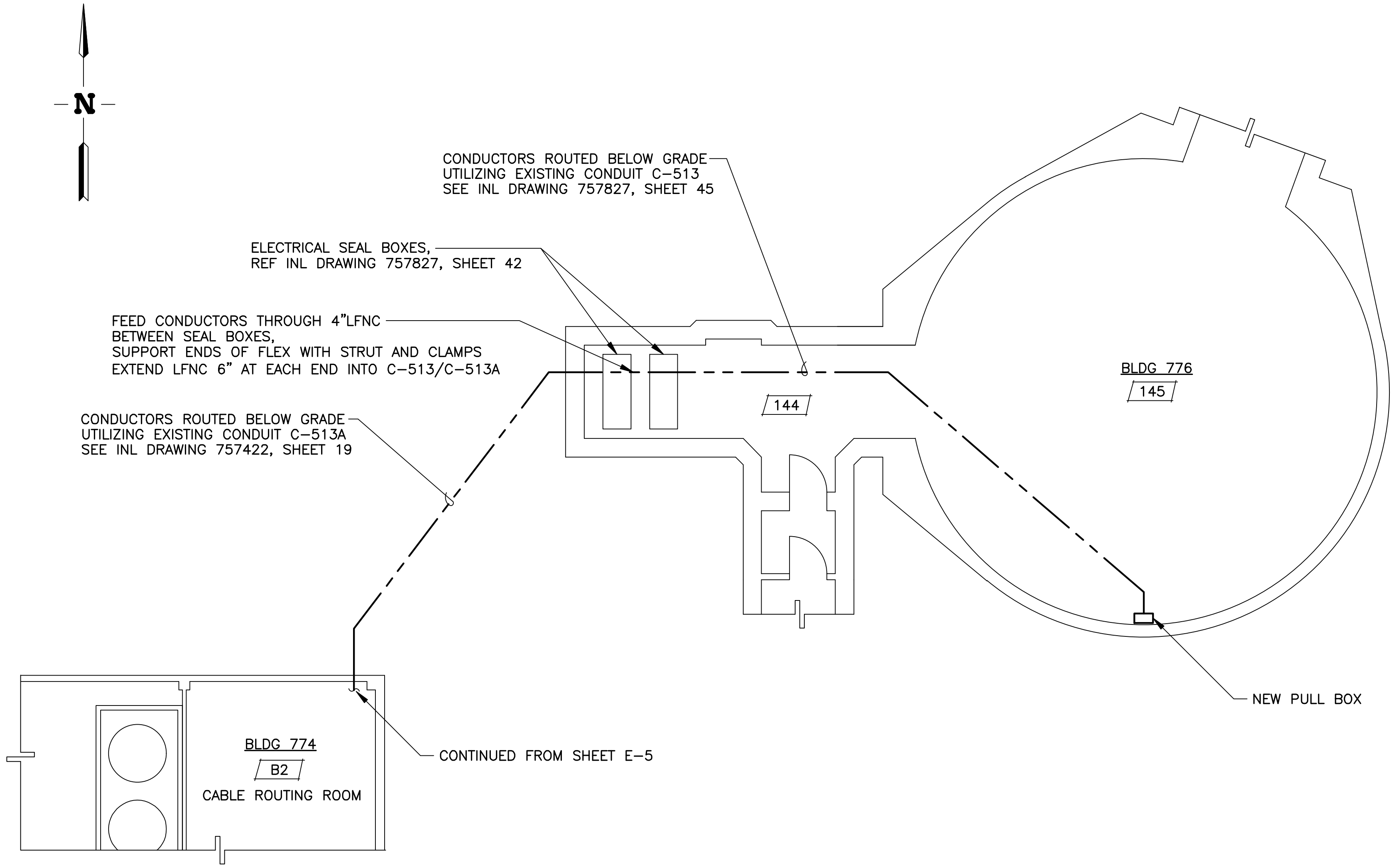
SIZE	CAGE CODE	AREA	TYPE	OL	ORIG	DWG NO.	REV
D	01MF3	273	0774	10	081	XXXXXXX	

SCALE: 3/16" = 1'-0" SHEET E-5

FMT-D1-INL, R-1
Path: Y:\LEEMS\2020\NRIC File: E-5.dwg
Date: 09/17/20 - 5:23 P.M. Layout Name: X-X
ID: LEEMS

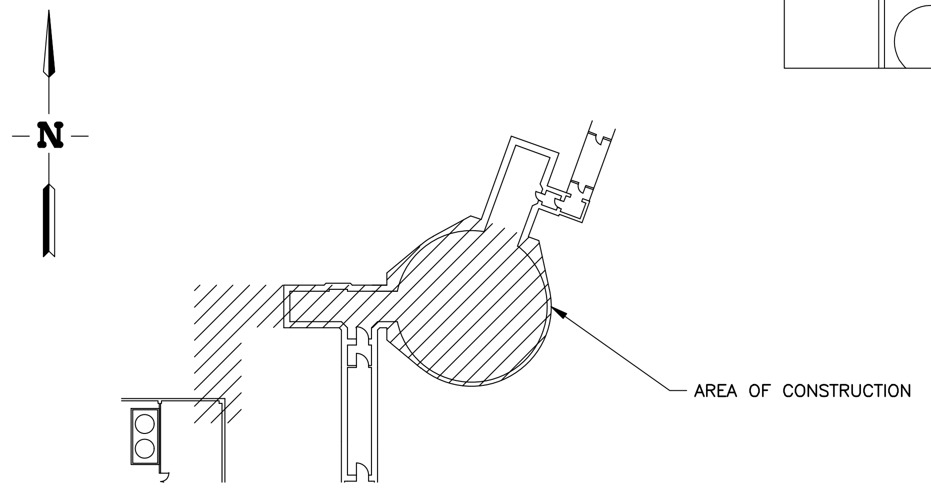
FMT-D1-INL, R-1

REVISIONS		
REV	DESCRIPTION	EFFECTIVE DATE:



ZPPR CELL ROUTING PLAN

SCALE: 1/8" = 1'-0"



KEY PLAN

NTS

PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION

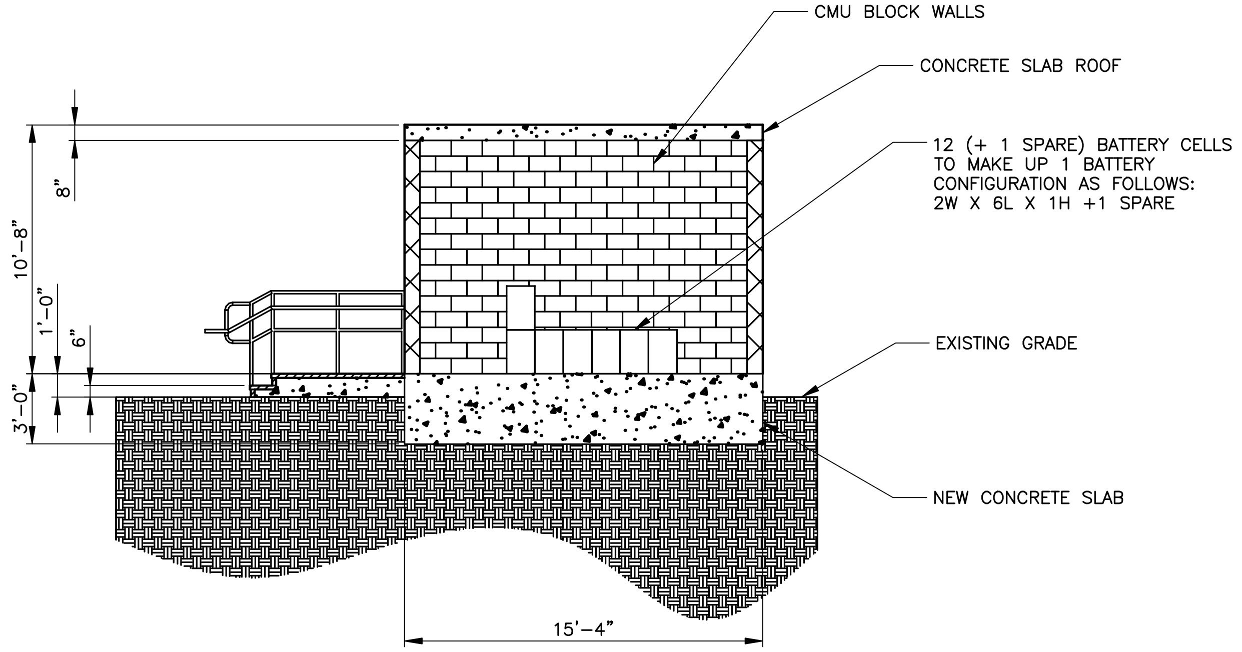
FOR DRAWING INDEX SEE DRAWING NO. T-2	REQUESTER:	Idaho National Laboratory
	RESP ENGR: A. BALSMEIER	MFC-774
	DESIGN: T. BAKES	NRIC ZPPR REACTOR TEST BED
	DRAWN: M. LEE	CONCEPTUAL DESIGN
SCALE: 1/8" = 1'-0"	PROJECT NO. NA	ZPPR CELL ROUTING PLAN
	SPCL CODE NA	SIZE D; CAGE CODE 01MF3; INDEX CODE NUMBER: AREA 273, TYPE 0774, OL 10, ORIG 081; DWG NO. XXXXXXX; REV
	FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO. XXXXXX	
DESIGN PHASE: CONCEPTUAL	EFFECTIVE DATE: NA	SCALE: 1/8" = 1'-0"; SHEET E-6

Date: 09/17/20 - 4:06 P.M. ID: LEEMS
Layout Name: X-X
Path: Y:\LEEMS\2020\NRIC
File: E-XXX.dwg

FMT-D1-INL, R-1

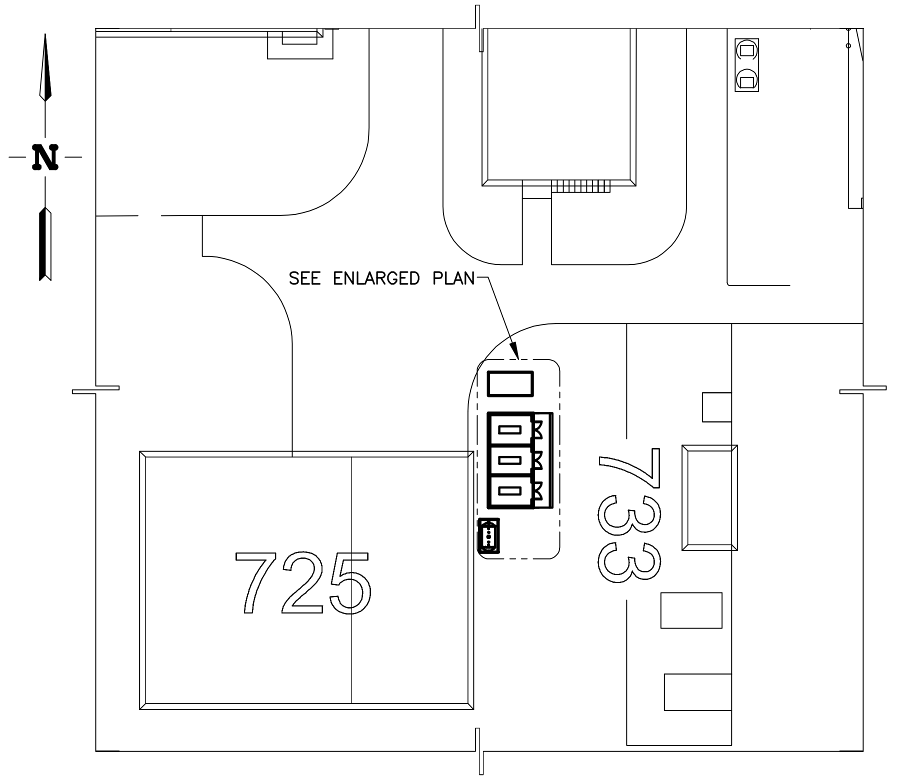
REV	DESCRIPTION	EFFECTIVE DATE:

REVISIONS



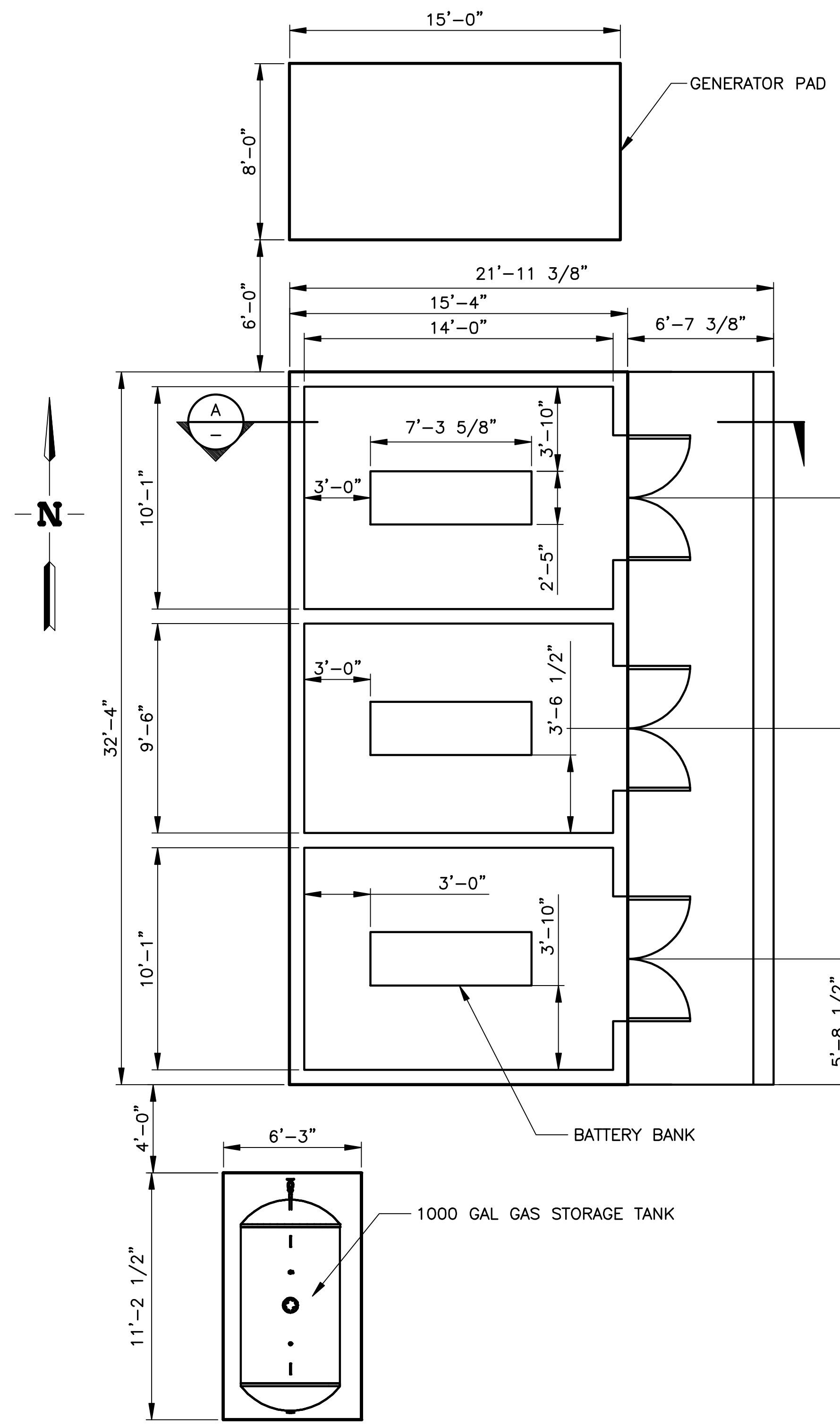
SECTION A

SCALE: 1/4" = 1'-0"



SITE KEY

SCALE: 1/32" = 1'-0"



ENLARGED PLAN VIEW

SCALE: 1/4" = 1'-0"

PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION

FOR DRAWING INDEX SEE DRAWING NO. T-2

SCALE: 3" = 1'-0"

DESIGN PHASE: CONCEPTUAL

REQUESTER:	
RESP ENGR:	A. BALSMEIER
DESIGN:	A. BALSMEIER
DRAWN:	B. WEISSER
PROJECT NO.	NA
SPCL CODE	NA
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO.	XXXXXX
EFFECTIVE DATE:	NA

Idaho National Laboratory

MFC-776
NRIC ZPPR REACTOR TEST BED
CONCEPTUAL DESIGN

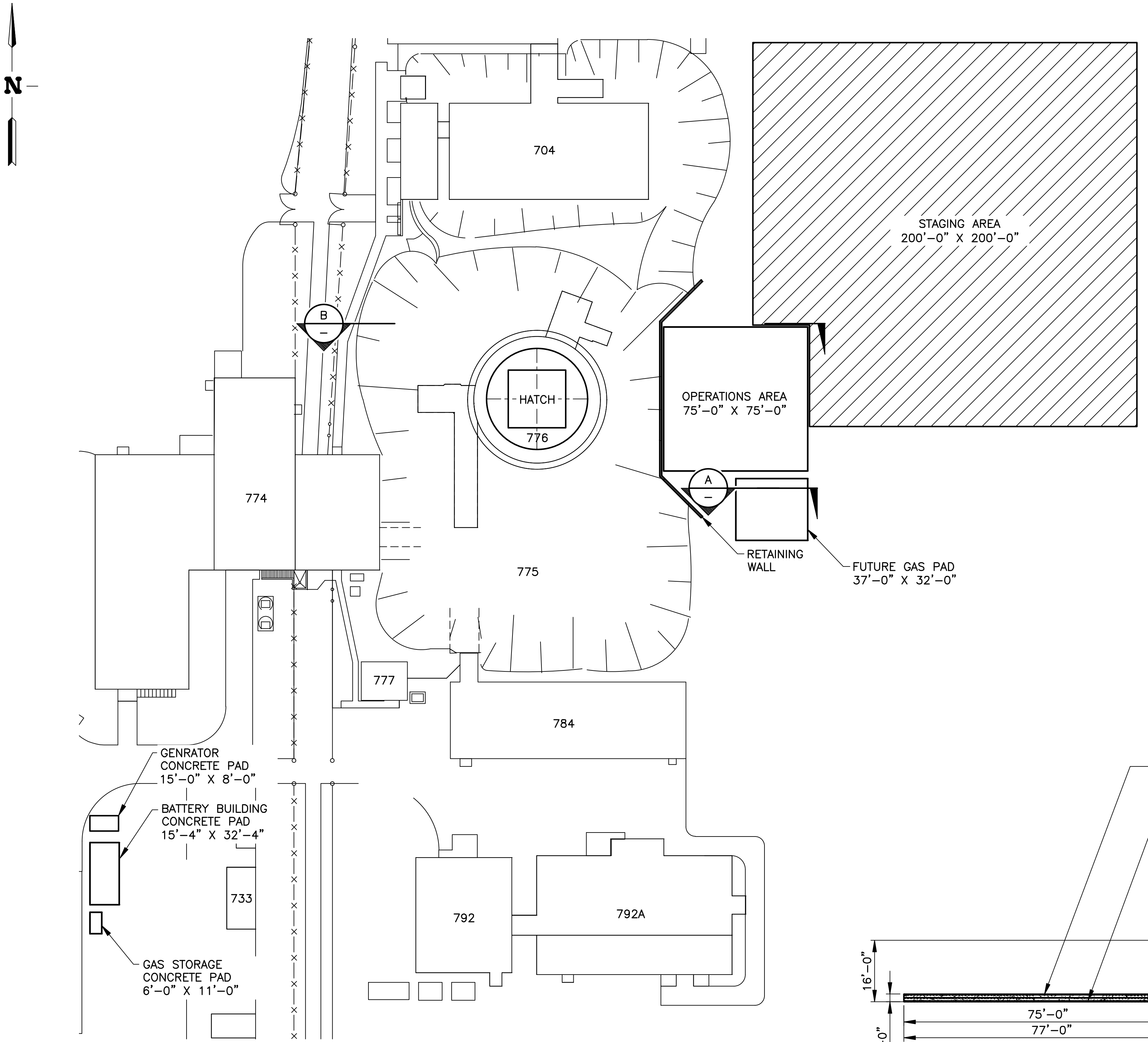
BATTERY BUILDING

SIZE	CAGE CODE	AREA	TYPE	CL	ORIG	DWG NO.	REV
D	01MF3	273	0776		081	XXXXXXX	

SCALE: NOTED SHEET BB-1

File: ZPPR_BATTERY_BUILDING.dwg
Path: C:\Users\WEISBA\Desktop\ZB
Date: 09/16/20 - 3:21 PM Layout Name: BB-1
ID: WEISBA

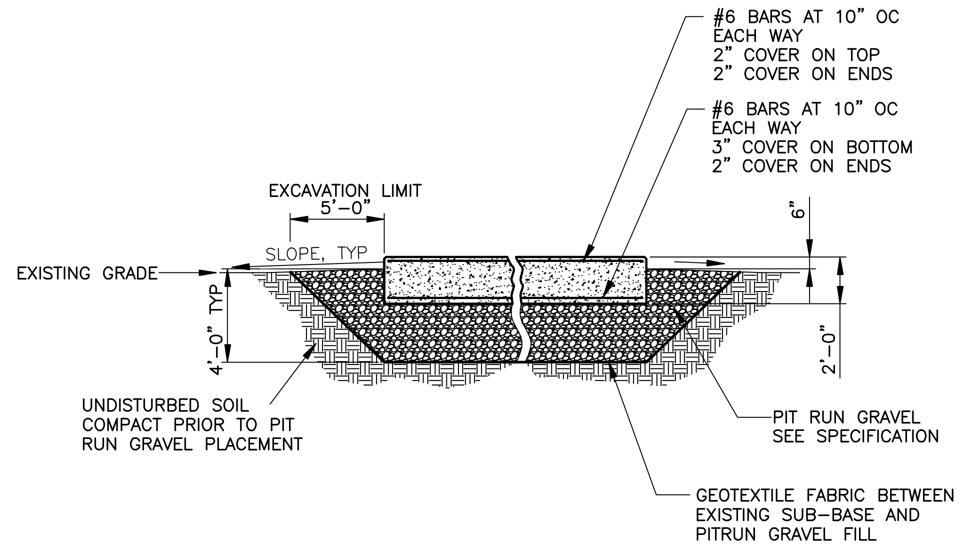
REVISIONS		
REV	DESCRIPTION	EFFECTIVE DATE:



MOUNDS NOT SHOWN FOR CLARITY

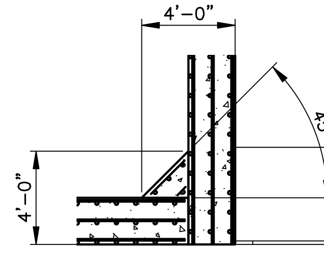
SITE PLAN – CONCRETE PADS

SCALE: 1/32" = 1'-0"



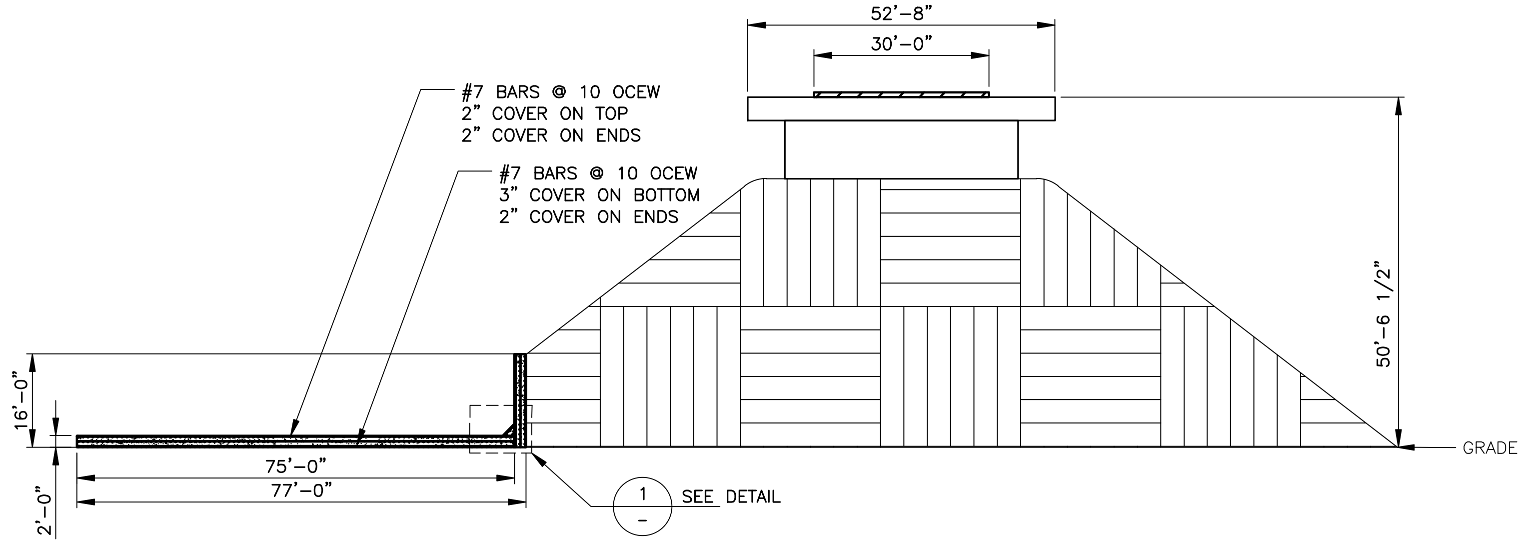
SECTION – CONCRETE PADS A

SCALE: 1/4" = 1'-0"



DETAIL 1

SCALE: 1/4" = 1'-0"



SECTION – CRANE PAD B

SCALE: 1/16" = 1'-0"

PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION

FOR DRAWING INDEX SEE DRAWING NO.	T-2
SCALE: 1/32" = 1'-0"	
SCALE: 1/16" = 1'-0"	
SCALE: 1/4" = 1'-0"	
DESIGN PHASE:	CONCEPTUAL

REQUESTER:	
RESP ENGR:	A. BALSMEIER
DESIGN:	S. QIAOHONG
DRAWN:	B. WEISSER
PROJECT NO.	NA
SPCL CODE	NA
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO.	XXXXXX
EFFECTIVE DATE:	NA

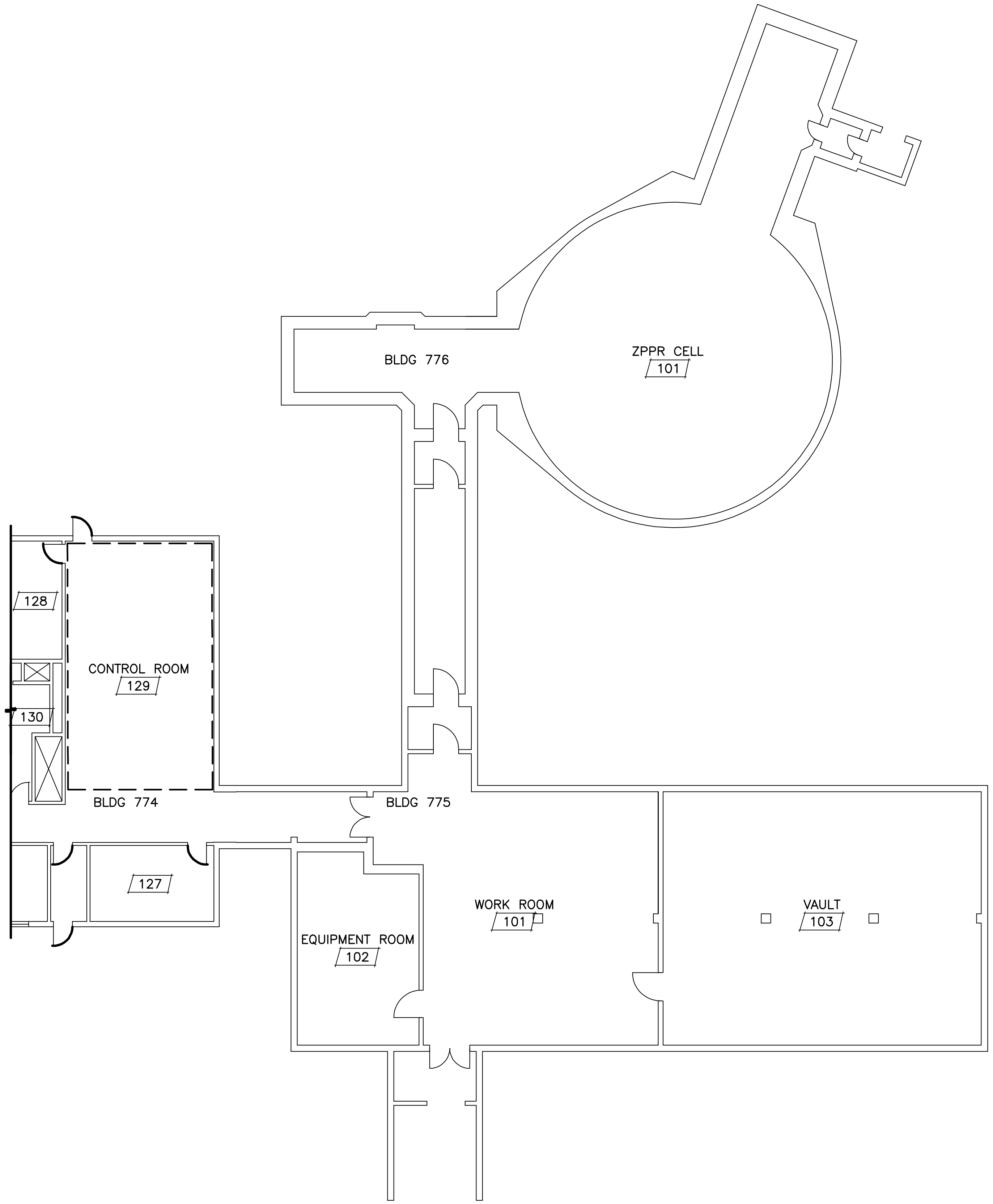
Idaho National Laboratory

MFC-776
NRIC ZPPR REACTOR TEST BED
CONCEPTUAL DESIGN

CONCRETE PADS

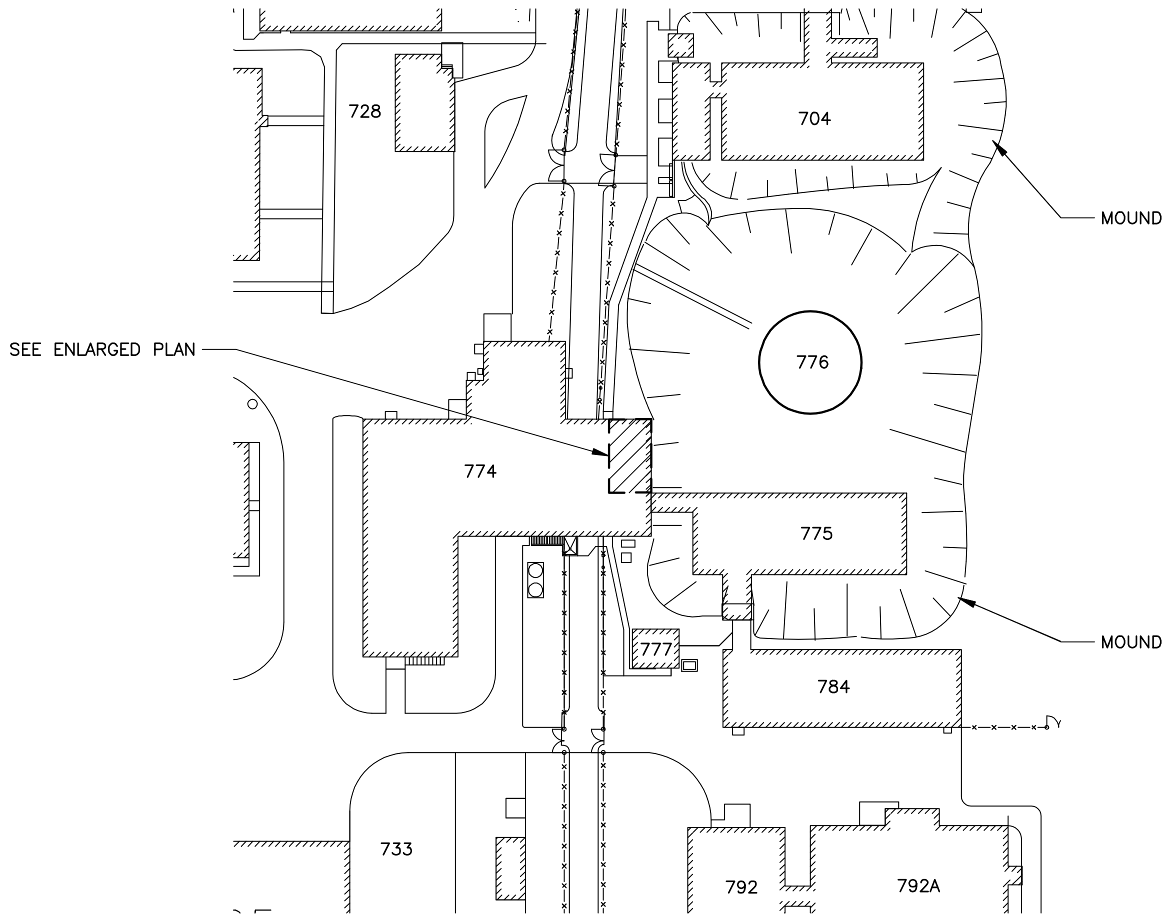
SIZE	CAGE CODE	AREA	TYPE	CL	ORG	DWG NO.	REV
D	01MF3	273	0776		081	XXXXXXX	

SCALE: NOTED — SHEET CP-1



ENLARGED PLAN

SCALE: 3/32" = 1'-0"



KEY PLAN

SCALE: NONE

PRELIMINARY

NOT RELEASED - NOT APPROVED FOR CONSTRUCTION

REVISIONS		
REV	DESCRIPTION	EFFECTIVE DATE:

FOR DRAWING INDEX SEE DRAWING NO.	T-2
SCALE: 3/32" = 1'-0"	
DESIGN PHASE:	CONCEPTUAL
REQUESTER:	
RESP ENGR:	A. BALSMEIER
DESIGN:	A. BALSMEIER
DRAWN:	B. WEISSER
PROJECT NO.	NA
SPCL CODE	NA
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO.	XXXXXX
EFFECTIVE DATE:	NA

Idaho National Laboratory

MFC-776
NRIC ZPPR REACTOR TEST BED
CONCEPTUAL DESIGN

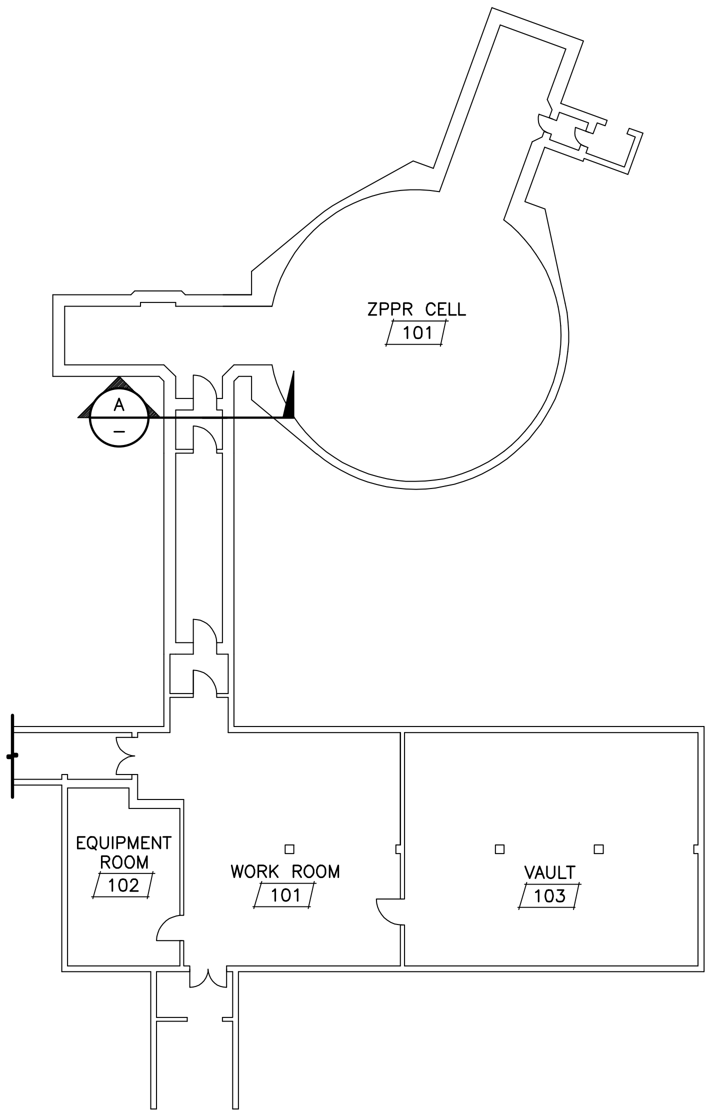
CONTROL ROOM

SIZE	CAGE CODE	AREA	TYPE	CL	ORIG	DWG NO.	REV
D	01MF3	273	0776		081	XXXXXXX	

SCALE: NOTED — SHEET CR-1

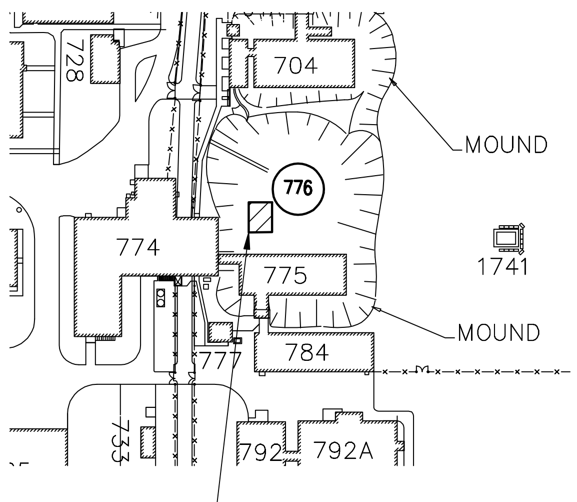
FMT-D1-INL, R-1

REVISIONS		
REV	DESCRIPTION	EFFECTIVE DATE:



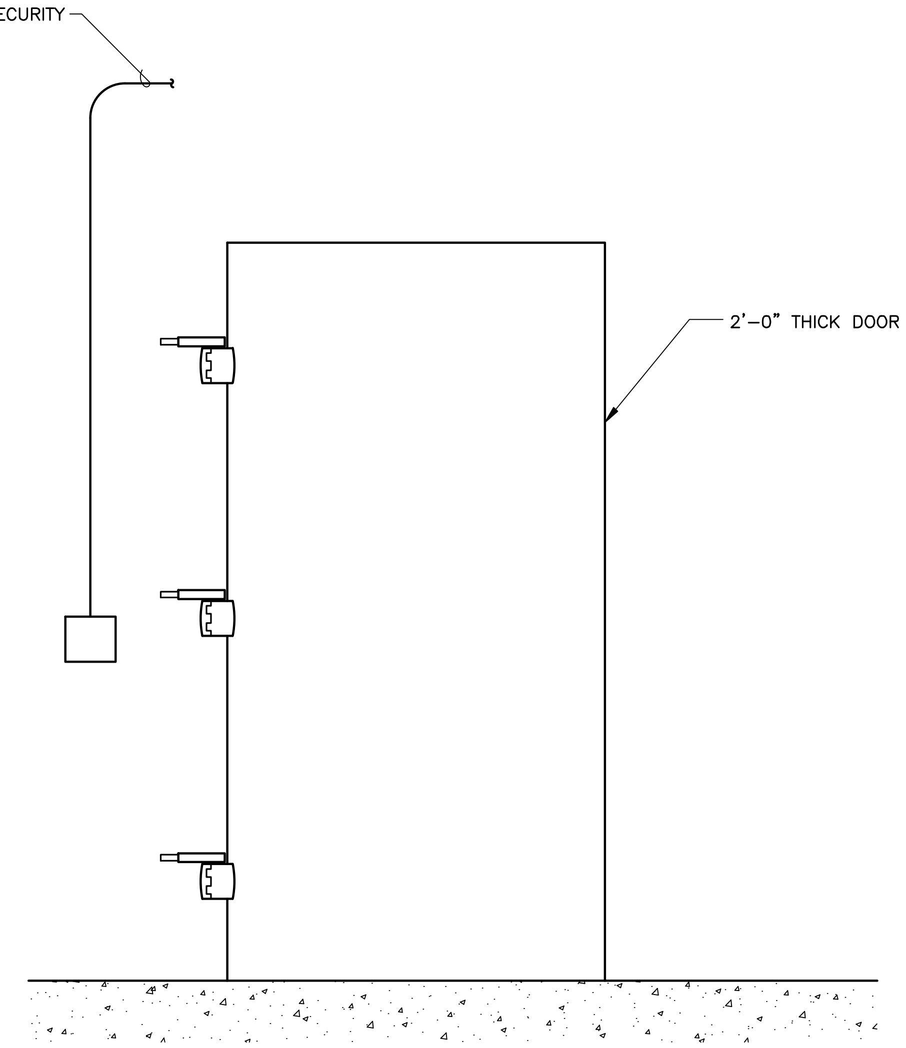
ENLARGED PLAN

SCALE: 1/16" = 1'-0"



KEY PLAN

SCALE: NONE



SECTION A –

SCALE: NONE

PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION

FOR DRAWING INDEX SEE DRAWING NO. T-2

SCALE: 1/16" = 1'-0"

DESIGN PHASE: CONCEPTUAL

REQUESTER:
RESP ENGR: A. BALSMEIER
DESIGN: A. BALSMEIER
DRAWN: B. WEISSER
PROJECT NO. NA
SPCL CODE NA
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO. XXXXXX
EFFECTIVE DATE: NA

Idaho National Laboratory

MFC-776
NRIC ZPPR REACTOR TEST BED
CONCEPTUAL DESIGN

SECURITY DOOR

SIZE D | CAGE CODE 01MF3 | INDEX CODE NUMBER: AREA 273, TYPE 0776, CL, ORIG 081 | DWG NO. XXXXXXX | REV

SCALE: NOTED | SHEET SD-1

File: ZPPR_SECURITY_DOOR.dwg
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Date: 09/18/20 – 9:51 AM Layout Name: SD-1 ID: SHIR001