National Reactor Innovation Center

NRIC EBR-II Test Bed Pre-Conceptual Design Report

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Idaho National Laboratory

Disclaimer

This work was prepared for the U.S. Department of Energy through the INL National Reactor Innovation Center under DOE-Idaho Operations Office.

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Acronyms

%COV	Percent Coefficient of Variation
AD	Aerodynamic Diameter
AHU	Air Handing Unit
ASCE	American Society of Civil Engineers
BPVC	Boiler and Pressure Vessel
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CMAA	Crane Manufacturing Association of America
COP	Concept of Operations
D&D	Deactivation and Decommissioning
DOE	U.S. Department of Energy
EBR-II	Experimental Breeder Reactor-II
EPA	Electrical Penetrations Assemblies
ETB	EBR-II Test Bed
FOR	Functional and Operational Requirements
HEPA	High-Efficiency Particulate Air
INL	Idaho National Laboratory
MBSE	Model-Based Systems Engineering
MFC	Materials and Fuels Complex
NEICA	Nuclear Energy Innovation Capabilities Act
NRIC	National Reactor Innovation Center
P&ID	Piping and Instrumentation Diagram
PFCN	Private Facility Control Network
PLC	Programmable Logic Controller
PNNL	Pacific Northwest National Laboratory
PWHT	Post Weld Heat Treatment
R&D	Research and Development
SE	Systems Engineer
SMACNA	Sheet Metal and Air Conditioning Contractors National Association
SME	Subject Matter Expert
SSC	Structure, System, Component
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 test beds at Idaho National Laboratory (INL). The Experimental Breeder Reactor-II (EBR-II) Test bed (ETB) and Zero Power Physics Reactor (ZPPR) Test bed (ZTB). The EBR-II test bed will support the demonstration of systems that operate at less than 10 MWt. The baseline objective is for the EBR-II Dome to act as a structure capable of siting reactors that utilize Safeguards Category 4 material for operations. The major areas addressed in the pre-conceptual design include:

- Installation of an access door
- Electrical Power
- Heat Removal
- Ventilation
- Module handling system

1.1 Purpose and Scope of the Pre-Conceptual Design Activities

NRIC has developed a pre-conceptual design. The purpose of the design is to:

- Investigate and identify critical issues
- Develop initial system concepts
- Identify high cost
- Develop a Level 5 cost estimate

2 Systems Analyzed to Enable EBR-II 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 "EBR-II Dome Modifications to Support Demonstration Reactors", FOR-554 [10]. The pre-conceptual design did not cover all aspects of all systems but concentrated on those aspects necessary to demonstrate viability of the project as determined by engineering judgement. An overview of the ETB is shown in Figure 1.

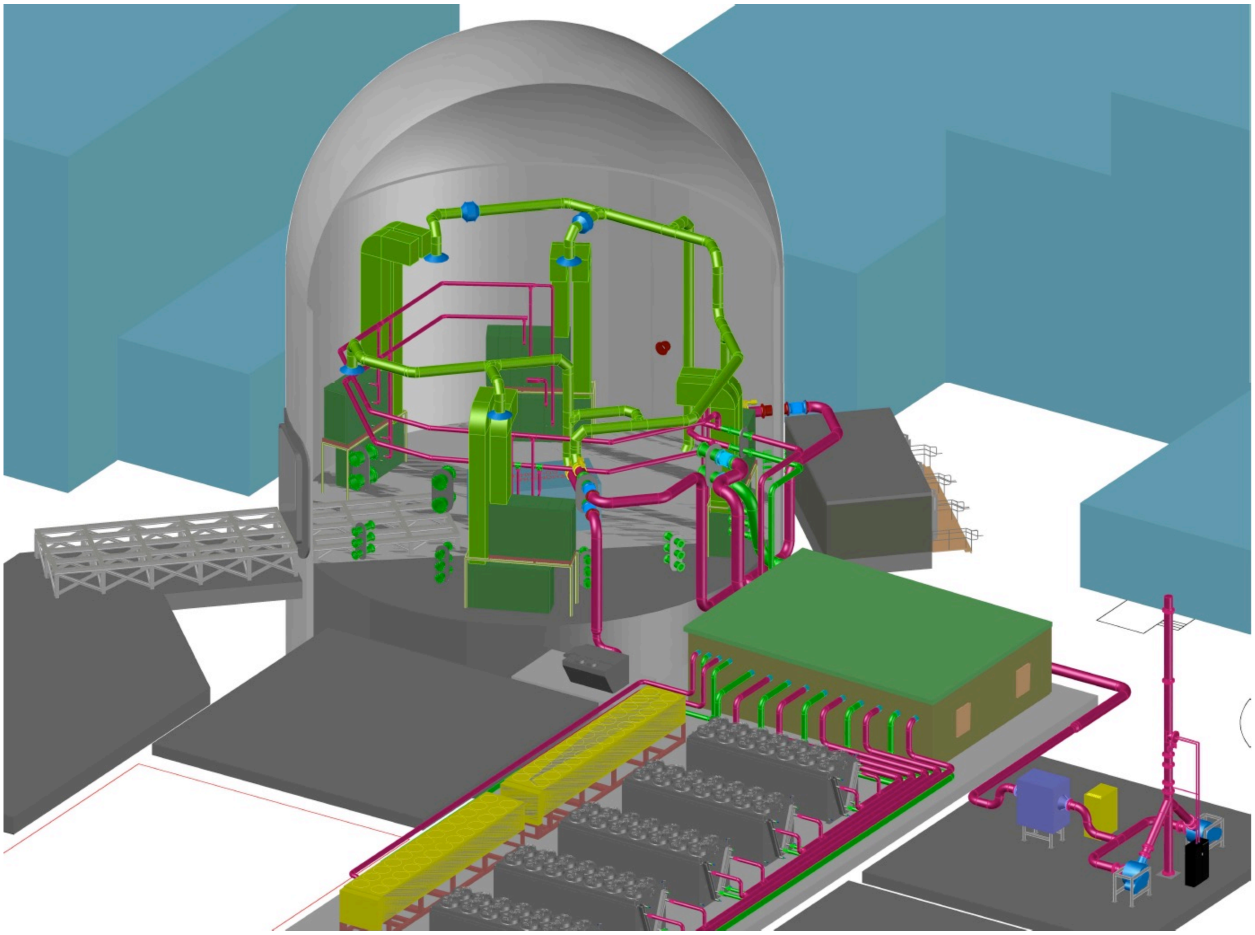


Figure 1. ETB overview.

2.1.1 Safety Classification Assumptions

While it is understood that the final safety classification of all equipment associated with the ETB will be determined by following the process defined in DOE-STD-1189-2016 [1], the design team made preliminary assumptions about safety classification of structures, systems, and components (SSCs) to enable efficient design and cost estimating. These assumptions will be superseded by future design decisions, safety analyses, and DOE decisions. The distinction between safety-significant and safety-class was not a large area of interest since it was assumed 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 safety systems would generally be safety-class as a bounding scenario. With this framework, the following assumptions about safety classifications were made:

- Reactor Containment – safety-class for leak tight boundary and structural integrity during and after NDC-3 hazards
- Ventilation System – safety-class for passive filtration and isolation valves
- Over/Under Pressure Protection – safety-class to protect structural integrity
- 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 24 V. This assumption was made in an effort to be able to support a limited amount of reactor monitoring in accident scenarios and/or to 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 design criteria for active safety-class systems.

2.1.2 Building Structure and Infrastructure

2.1.2.1 Containment Dome

Due to the extensive deactivation and decommissioning (D&D) activities that took place for the EBR-II dome, almost all the penetrations in the dome have been covered by grout that is part of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) closure boundary[1] . It was determined that re-furbishing those penetrations would not be feasible or cost effective. There are three mechanical penetrations that are above the operational floor which may be in a condition that would allow use in the current project. Where practical, these penetrations will be used.

[1] The EBR-II reactor was decommissioned in 1994. Demolition of the EBR-II reactor was conducted as a non-time critical removal action by the environmental management contractor at the INL site. Based on the residual contamination following reactor removal, the subgrade portions of the reactor room were filled with grout to a height of approximately 6 ft above the ground surface in the reactor dome. This grouted area is subject to CERCLA controls. Additionally, in preparation for demolition of the dome, several water-jet cuts were made in the exterior of the dome (since repaired) as well as removal of the equipment hatch (door removed, door frame rough cut).

However, due to the lack of available existing penetrations into the containment dome, substantial modifications will need to be made.

2.1.2.2 Description of Modifications

To support the various systems identified in the pre-conceptual design and to provide for the anticipated need of demonstrators, 11 new groups of penetrations and an enlarged equipment hatch will be needed. The 11 groups of penetrations contain individual penetrations, including 15 locations for electrical penetrations and 18 mechanical penetrations. However, eight of the mechanical penetrations are nominal pipe size (NPS) 4 and smaller. A rolled-out view of the containment vessel with penetrations is shown in Figure 2 below, with a larger view shown on sheet DP-1 of the attached sketches.

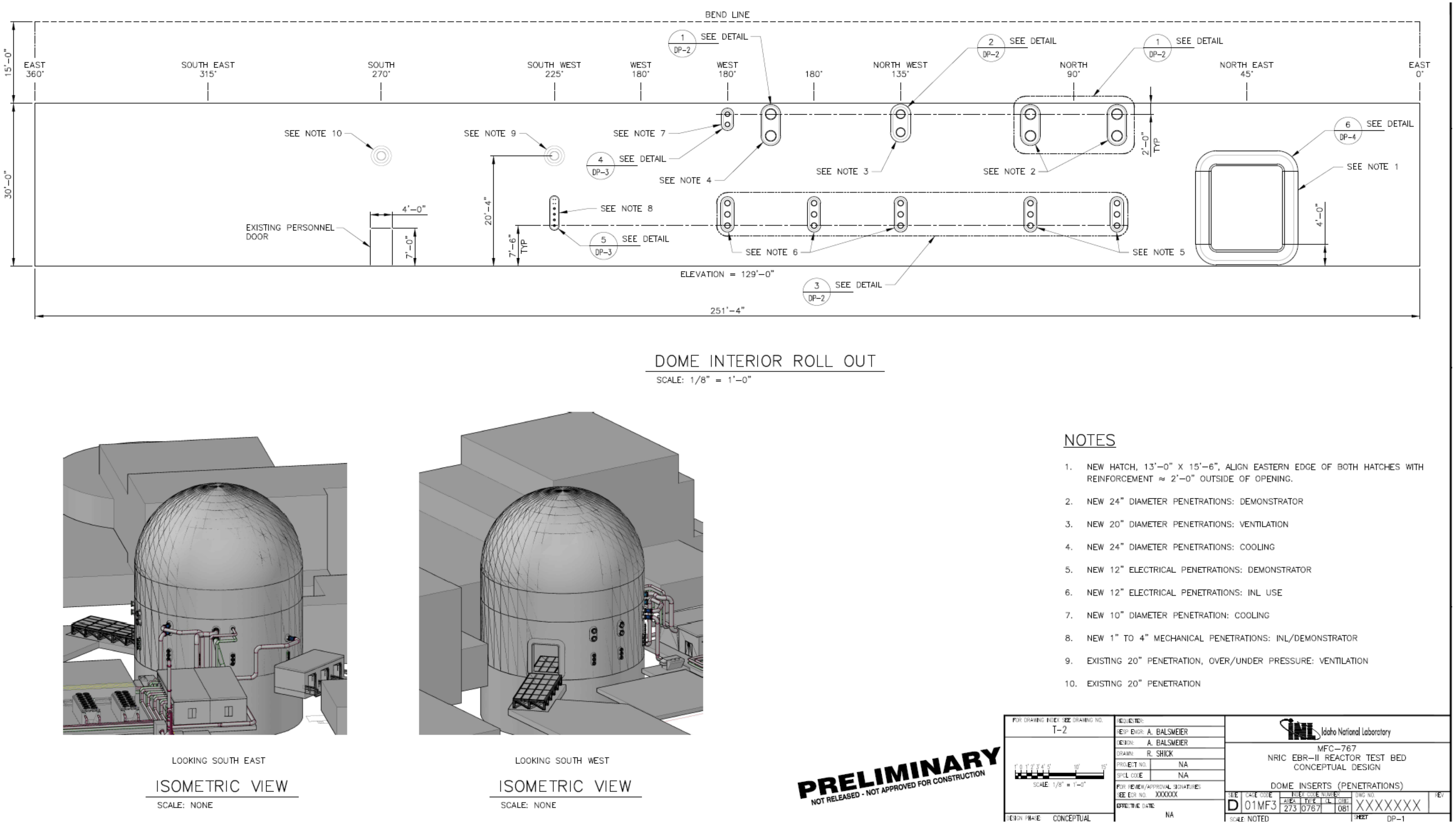


Figure 2. Dome inner roll out with penetrations.

The new penetrations include integral reinforcement that is sized in a similar manner as required by American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME BPVC) Section VIII. Non-integral reinforcement is allowable and possible; however, it would dramatically increase the amount of field welding required to install the penetrations. In addition, the penetrations with shared reinforcement plates can likely be spaced closer together (due to the reduction in space required for field welding) reducing the overall amount of concrete removal necessary in the dome. With integrally reinforced penetrations, only the weld between the containment vessel shell and the outer perimeter of the penetration reinforcement would need to be done in the field, the remaining welding could be done in a fabrication shop.

To add a new penetration to the containment, concrete must be removed, rebar cut, and a hole cut in the steel shell. The concrete must be removed far enough beyond the welding location of the new penetration to avoid overheating the remaining concrete and potentially igniting the joint filler between the concrete and steel shell. After the removal operations, the new penetration must be welded into the steel shell. An example of one of the new penetration details is shown in Figure 3.

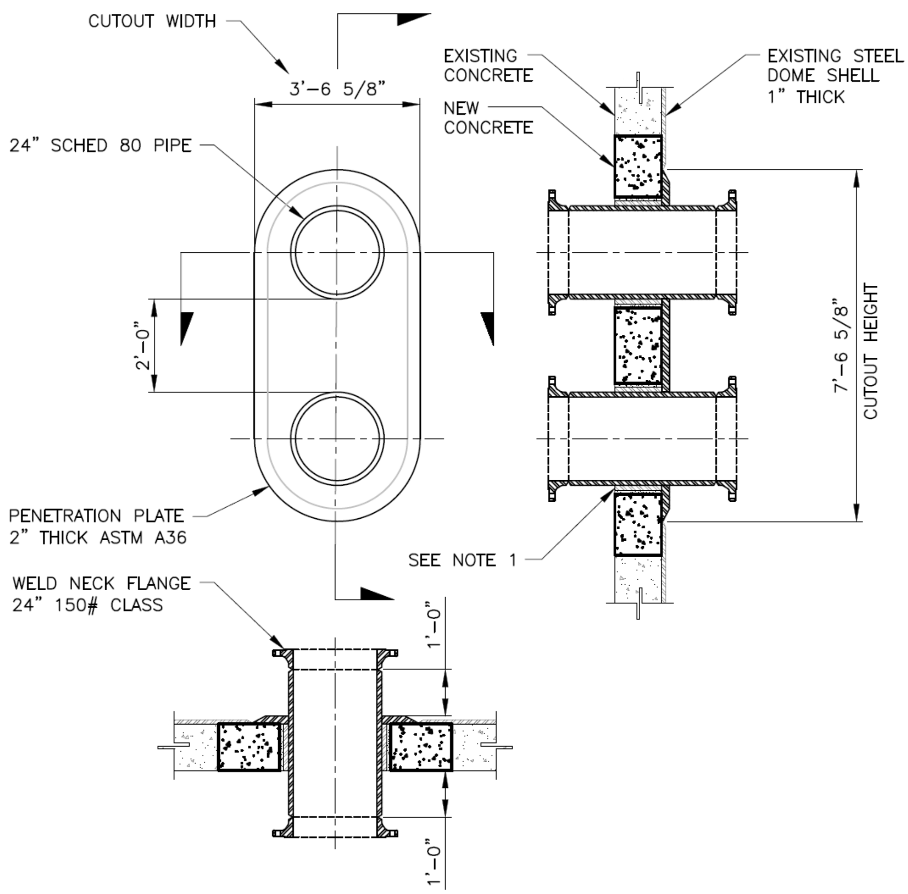


Figure 3. Example Detail for NPS 24 Penetration.

Piping penetrations are generally in groups of two out of necessity, since inlets and outlets are required for these systems. Electrical penetrations are put in groups of three to limit the number of locations where penetrations need to be made in the containment.

The penetrations are all based on schedule 80 pipe of the required size and will have welded Class 150 flanges on each end. The inside flange will have to be welded on after the guard pipe (which prevents concrete from direct contact with penetration pipe) is placed around the penetration. These flanges will allow easy connection to the pipes and allow for pressure/leak testing of penetrations independently of the entire containment vessel.

On large diameter pipe penetrations with attached piping (e.g., a cooling system), bellows expansion joints are planned to ensure the piping system can act independently of the containment during a seismic event. This will reduce the pipe stress and likelihood of pipe rupture during the postulated seismic event.

The electrical penetrations are based on NPS 12 schedule 80 pipe and class 150 flanges. This is consistent with the qualified designs of a supplier that provides electrical penetration assemblies (EPA) to nuclear power plants. EPAs that meet ASME BPVC requirements and NQA-1 are available as a pre-qualified design. In discussions with suppliers, the pressure and temperature limits of the ETB containment are easily bounded by those used at commercial nuclear power plants.

The modified equipment hatch is the largest individual modification to the structure. The proposed internal dimensions of the hatch opening are 13 × 15.5 ft. A layout of the hatch opening, and reinforcement cross section is shown in Figures 4 and 5 below. This opening size was identified in initial discussions with demonstrators. The existing hatch was destroyed during the D&D operations and a portion of the frame and vessel reinforcement was removed using rough flame cutting. Regardless of the size of the hatch, repairs in this area will be required. In an effort to minimize disturbances of the CERCLA boundary underneath the operating deck in the containment, the new hatch reinforcement will start at the height of the bottom of the existing hatch, which is approximately level with the operating deck. However, some disturbance of the CERCLA boundary is likely necessary. This will result in the bottom of the hatch opening being above the operating floor of the containment. The new hatch insert edge will be placed on the southernmost edge of the existing hatch opening. This will have the effect of shifting the azimuth of the new hatch to the north, allowing a slightly larger clearance between the hatch and the MFC-765 security fence.

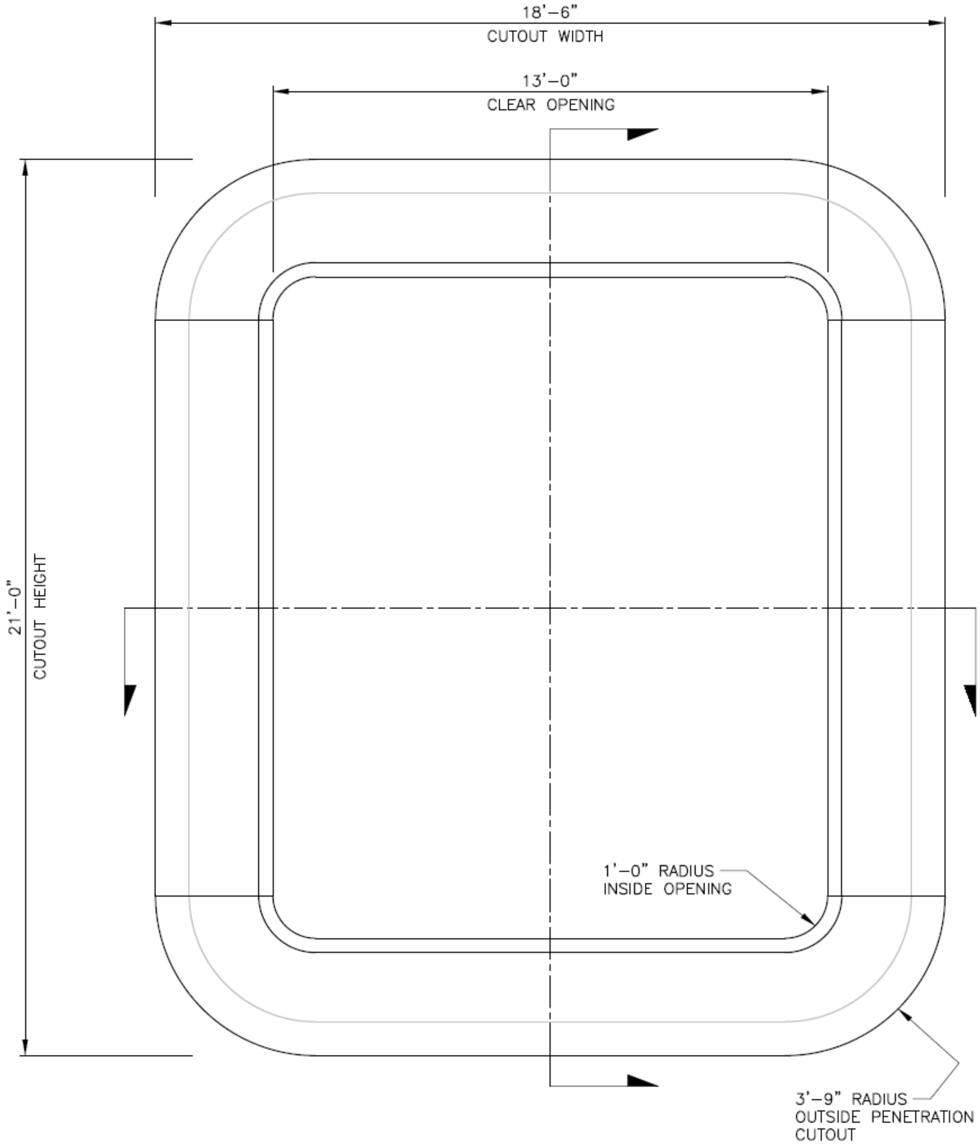


Figure 4. Hatch penetration and reinforcement layout.

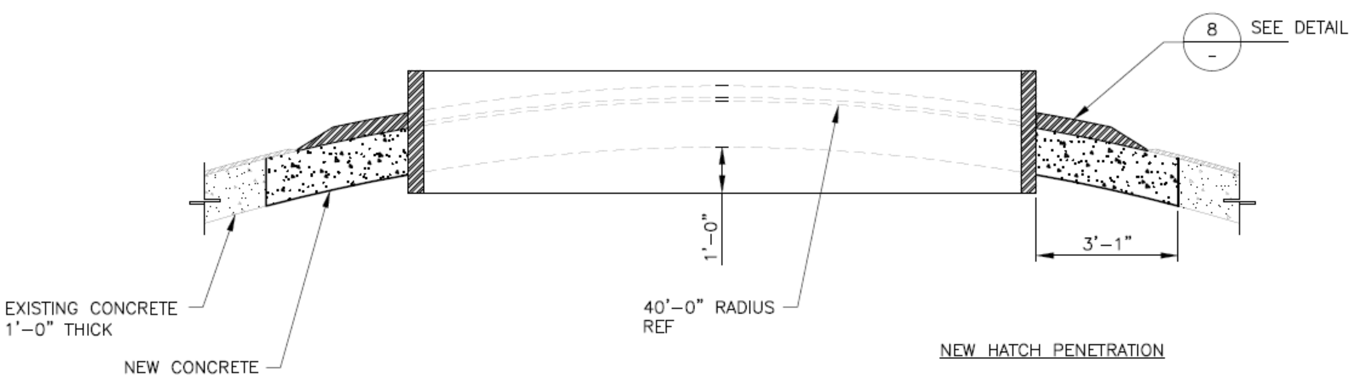


Figure 5: Horizontal cross section of new hatch.

The main mechanical penetrations were located to align as conveniently as possible with the equipment outside the dome. In the initial configuration they were located high on the containment wall based on guidance from structural engineering that this location would have the lowest impact on the containment structure. However, it may be possible to locate the main mechanical penetrations lower in the containment structure. After locating the main mechanical penetrations, electrical penetrations were aligned vertically with a set of mechanical penetrations. This placement also followed the advice of the structural engineer. An external view of the containment model is shown in Figure 6. The majority of the proposed new penetrations can be seen in this view.

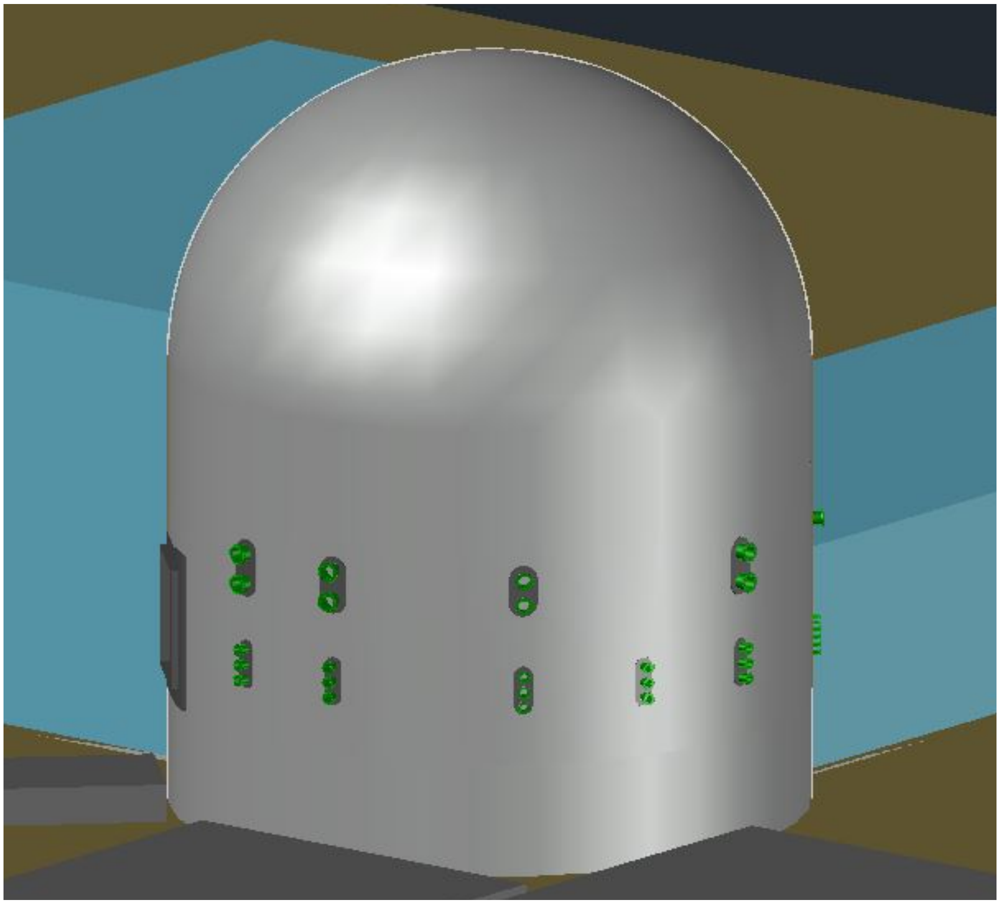


Figure 6. New Penetrations (green, dark gray).

A listing of the penetrations and their anticipated uses is provided below:

- New Equipment Hatch – Demonstration reactor installation and removal
- New NPS 24 Penetrations
    - 2 sets of 2 penetrations for use with demonstration reactor process fluids or with hybrid energy system testing

  - 1 set of 2 penetrations for supply and return of reactor cooling fluid
- New NPS 20 penetrations – Ventilation supply and return
- Existing 20 penetration – 2 available, one will be used for Over/Under pressure protection system
- New NPS 10 penetrations – 1 set of 2 for use with containment air cooling supply and return
- New NPS 12 penetrations
  - 2 sets of 3 penetrations for use as demonstration reactor electrical penetrations
  - 3 sets of 3 penetrations for use as the ETB electrical penetrations
- New NPS 4 penetrations – 1 set of 4 for use as generic mechanical penetrations
- New NPS 1 penetration – 1 set of 4 for use with compressed gases.

As described in FOR-554, the EBR-II steel containment vessel will not be a code stamped vessel. The ASME BPVC will be followed to the extent practicable. The modifications will be made consistent with the original design and construction requirements, which generally followed ASME BPVC Section VIII. However, the necessary engineering evaluations and analysis will be performed to demonstrate the structural safety of the containment vessel.

One aspect of the original design and construction that does not appear to be consistent with ASME Section VIII [2], was the lack of post weld heat treatment (PWHT) for the vessel welds. This is based on the *Hazard Summary Report Experimental Breeder Reactor II*, Volume I, Appendix E, Section 2 a [3]. (1, which states “Stress relieving of the shell as a whole is not contemplated.” PWHT is performed to reduce residual stresses. It is not possible to perform PWHT for the original structure.

Consistent with the original design requirements, performance of PWHT is not planned for the new penetrations. The performance of PWHT would necessitate removal of much larger portions of the concrete structure inside the containment. Based on initial engineering evaluations, PWHT of the new penetrations will not add value given the history of the remainder of the structure. A more detailed evaluation will be performed in subsequent phases of design.

2.1.2.3 Structural Analysis Scoping

A structural analysis model of the dome was created to evaluate wind loads, seismic loads, pressure loads, and dead loads. All of the penetrations were modeled with thickened steel shell around the openings except the large equipment hatch opening. The concrete cutout to install the penetrations was conservatively assumed not to be replaced for this analysis. Loads were assumed to act concurrently except wind and seismic loads. Contact between the steel shell and concrete structure inside the shell was assumed due to the presence of the joint filler material, which was treated as rigid insulation. All analyses were based on the applicable codes and allowable stress design.

For simplification, several items were excluded from the model including: soil-structure interaction, any below grade structure, detailed analysis of welds, detailed analysis of the equipment hatch door or the equipment hatch penetration reinforcement, and ductility of the reinforced concrete structure. These items will be evaluated as the design progresses.

Wind loads were applied to the dome in accordance with ASCE 7 and evaluated from the north-east and north-west as they were expected to be limiting. This is due to the location of the equipment hatch on the north-east side of the dome. Wind loads were anticipated to be minimal compared to the design pressure load on the steel vessel. An example of the wind loading applied is shown in Figure 7.

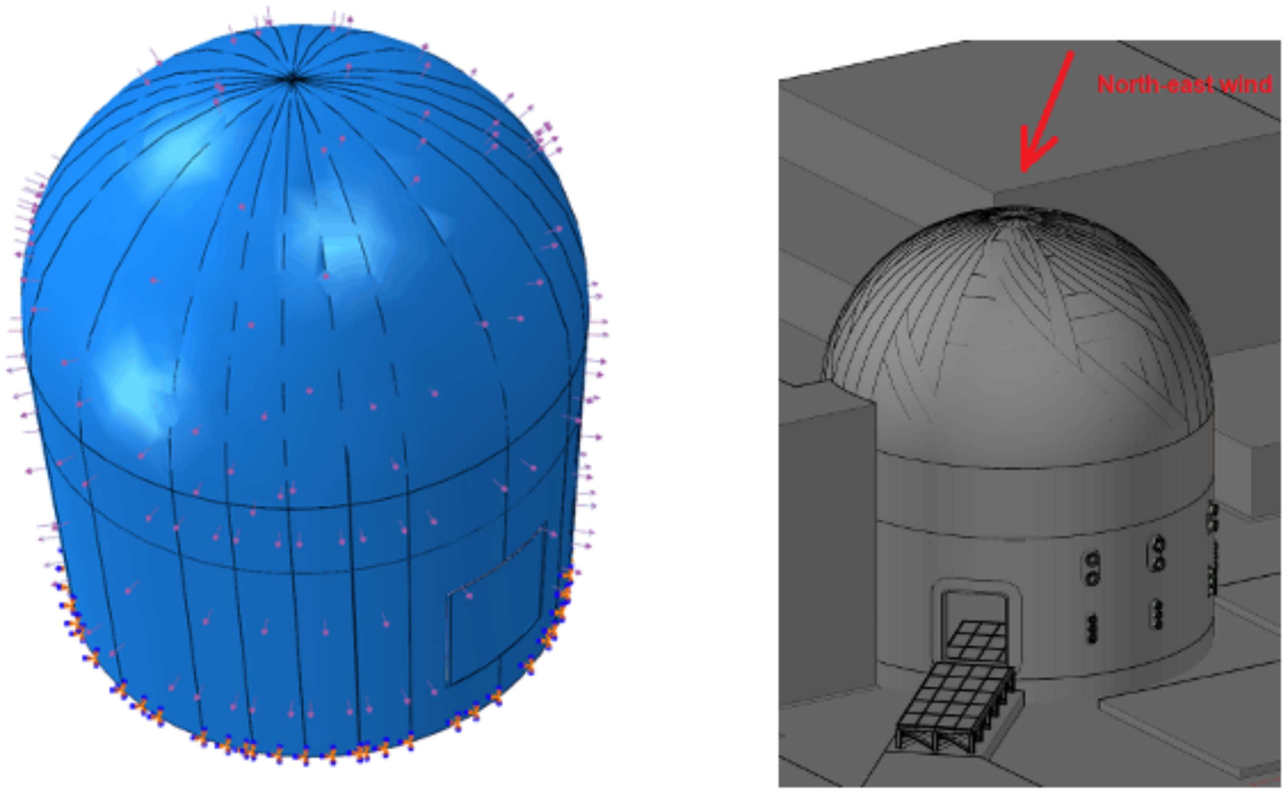


Figure 7. Example of wind loading applied.

The design response spectra for an SDC-3 earthquake were taken from INL/EXT-05-00925 [4] (MFC rock spectra) and used in the analysis. To capture the non-linearity of the system, a time history was matched to the spectra using a spectral matching process. See Figures 8 and 9 for the spectra and time history. Both horizontal and vertical time histories were produced. Ground motions were applied to a rigid base at the foundation.

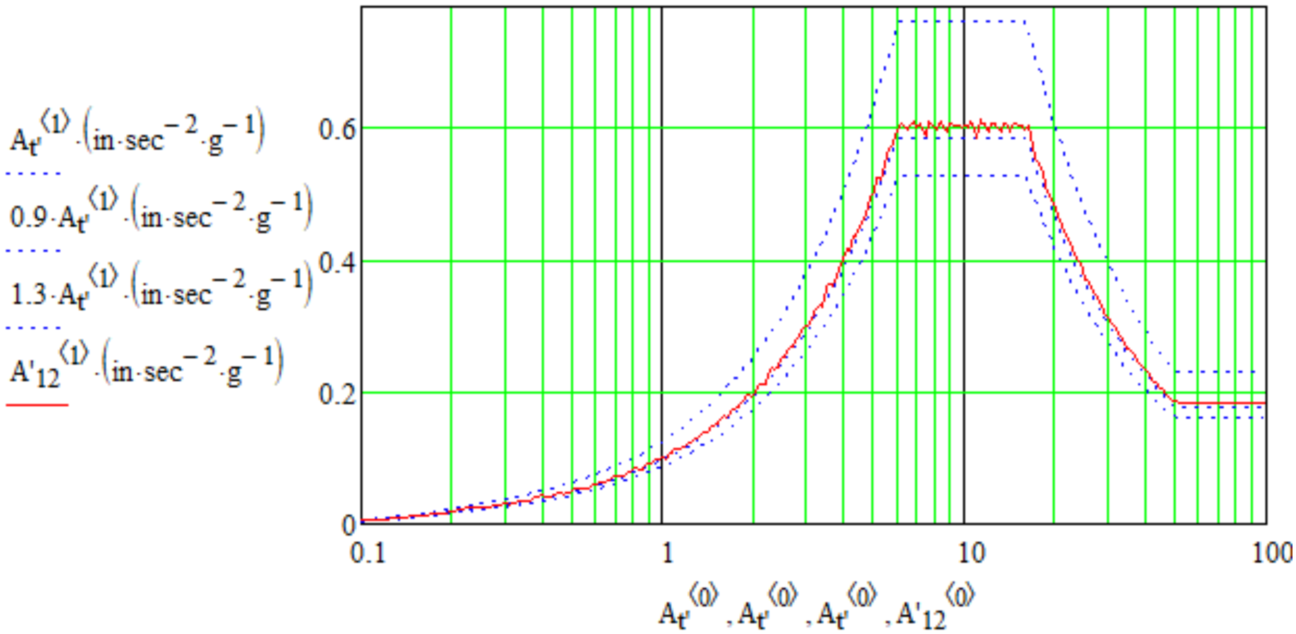


Figure 8. Design response spectra for SDC-3 Earthquake.

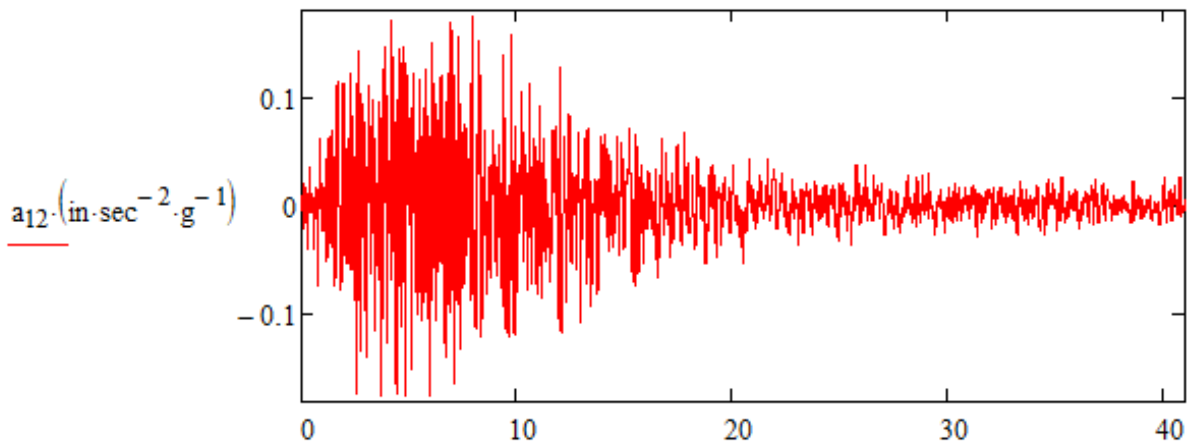
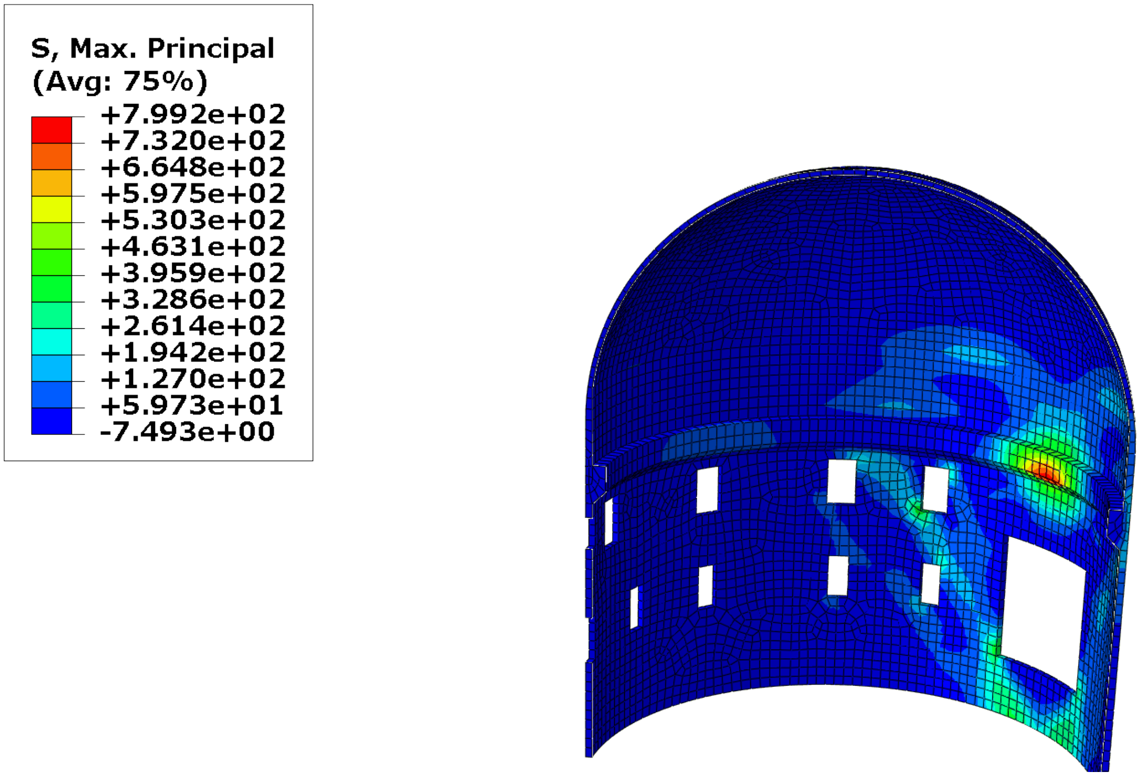


Figure 9. Seismic time history load applied in the model.

An evaluation was performed for the concrete inside the containment that included the polar crane loads (i.e., a 75-ton load on the crane). This evaluation is representative of both construction loads and reactor installation loads. For this evaluation, the crane was placed on the corbel directly above the large equipment hatch opening as a conservative analysis. The corbel appears to be adequately-designed for the stresses placed on it due to crane loads. Additionally, low stresses resulted in the concrete from other loads, such as seismic and wind loads, because the joint filler material does not transfer large loads from the steel vessel to the concrete. A verification of the isolation material properties is warranted. A stress plot of this evaluation is shown in Figure 10.


S, Max. Principal
(Avg: 75%)
+7.992e+02
+7.320e+02
+6.648e+02
+5.975e+02
+5.303e+02
+4.631e+02
+3.959e+02
+3.286e+02
+2.614e+02
+1.942e+02
+1.270e+02
+5.973e+01
-7.493e+00

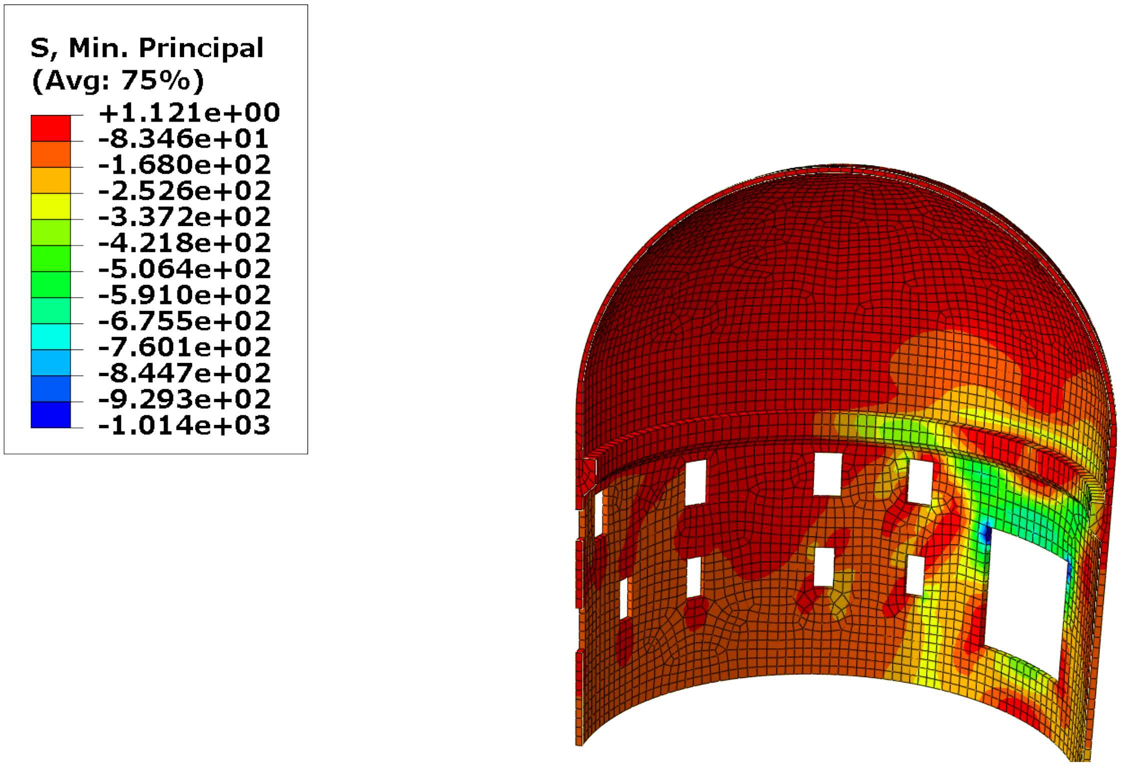

S, Min. Principal
(Avg: 75%)
+1.121e+00
-8.346e+01
-1.680e+02
-2.526e+02
-3.372e+02
-4.218e+02
-5.064e+02
-5.910e+02
-6.755e+02
-7.601e+02
-8.447e+02
-9.293e+02
-1.014e+03

Figure 10. Concrete Stress plot with polar crane above hatch, maximum and minimum principal stress.

A non-seismic evaluation was performed on the steel shell. The design pressure load is the dominating factor in the steel shell. There are areas of significant overstress directly around the equipment hatch opening, see Figures 11 and 12.

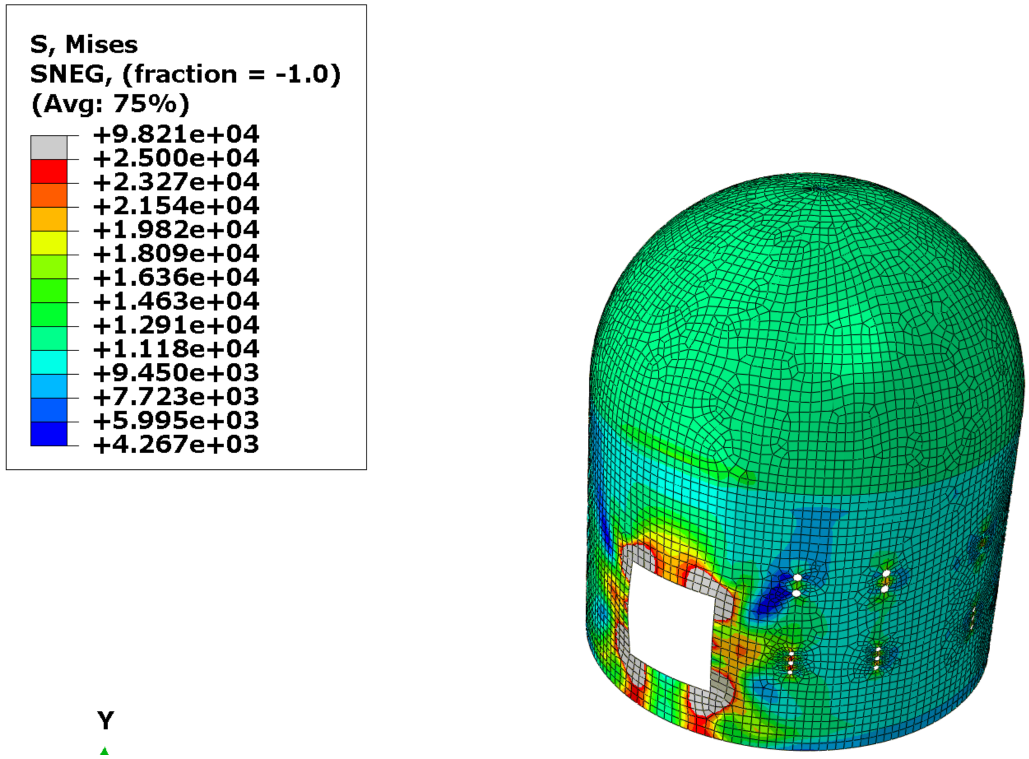


Figure 11. Steel stress plot, non-seismic with pressure loads.

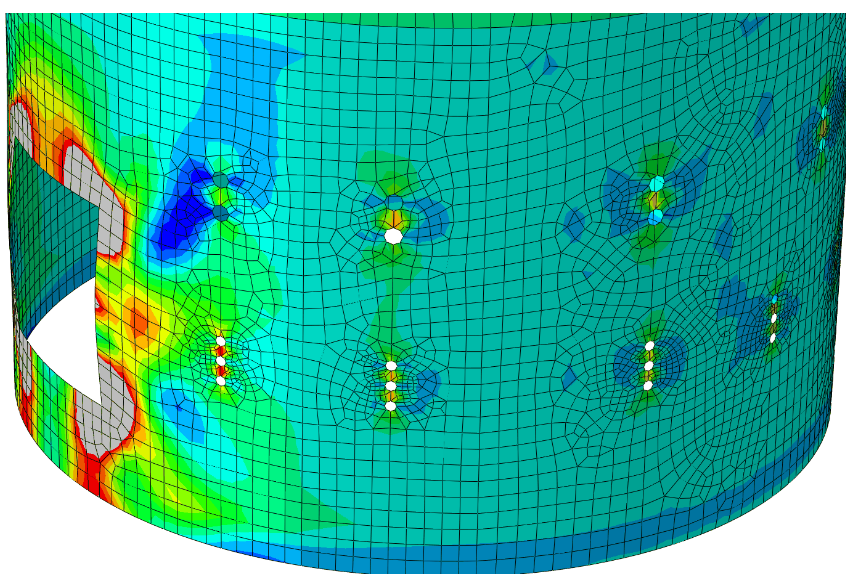


Figure 12. Close-up view of hatch from Figure 11.

With the simplified model used, the hatch opening results in over-stressed areas. This was anticipated due to the lack of reinforcement, the simplified geometry used (sharp corners), and the large size of the opening. The planned reinforcement uses 4-in.-thick steel approximately 20-in.-wide (without taper) tapered down to 1-in. to match the existing steel vessel and another reinforcement of 4-in.-thick steel approximately 20-in.-wide normal to the vessel surface. The various reinforcements will be welded together to make an integral reinforcement. The planned reinforcement will also include 1-ft radius on the corners. These adjustments are anticipated to resolve the overstressed locations of the equipment hatch; however, they have not been modeled/analyzed yet. If not completely resolved, then additional refinement will be necessary for the hatch reinforcement.

In addition to the hatch overstress locations, some of the other penetrations may be located too close to each other, especially those penetrations located close to the hatch. This issue should be re-evaluated once the hatch reinforcement is included in the model. For the penetrations that are potentially located too close to each other, adding additional space between penetrations is an easy solution, if necessary.

A seismic evaluation was performed on the steel and concrete simultaneously. The resultant stresses do not challenge the structures even with the simplified versions of the geometry used, and without replacing concrete after installing penetrations, see Figures 13 and 14.

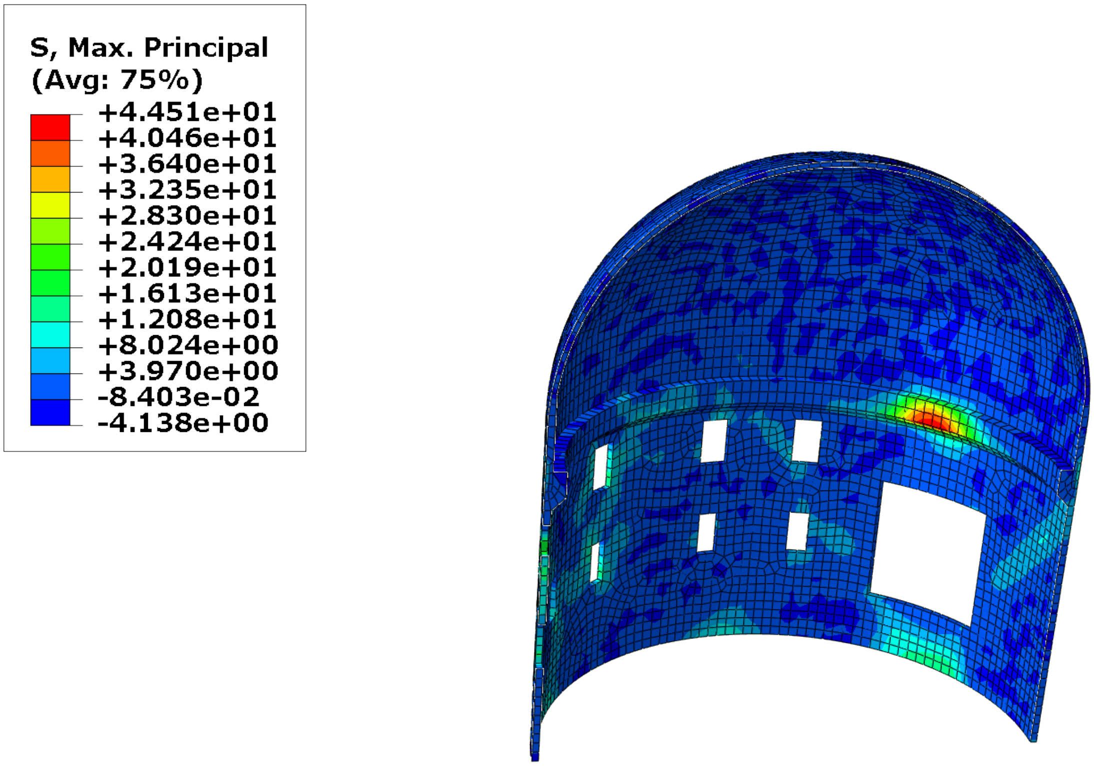


Figure 13. Concrete maximum principal stress plot from seismic evaluation.

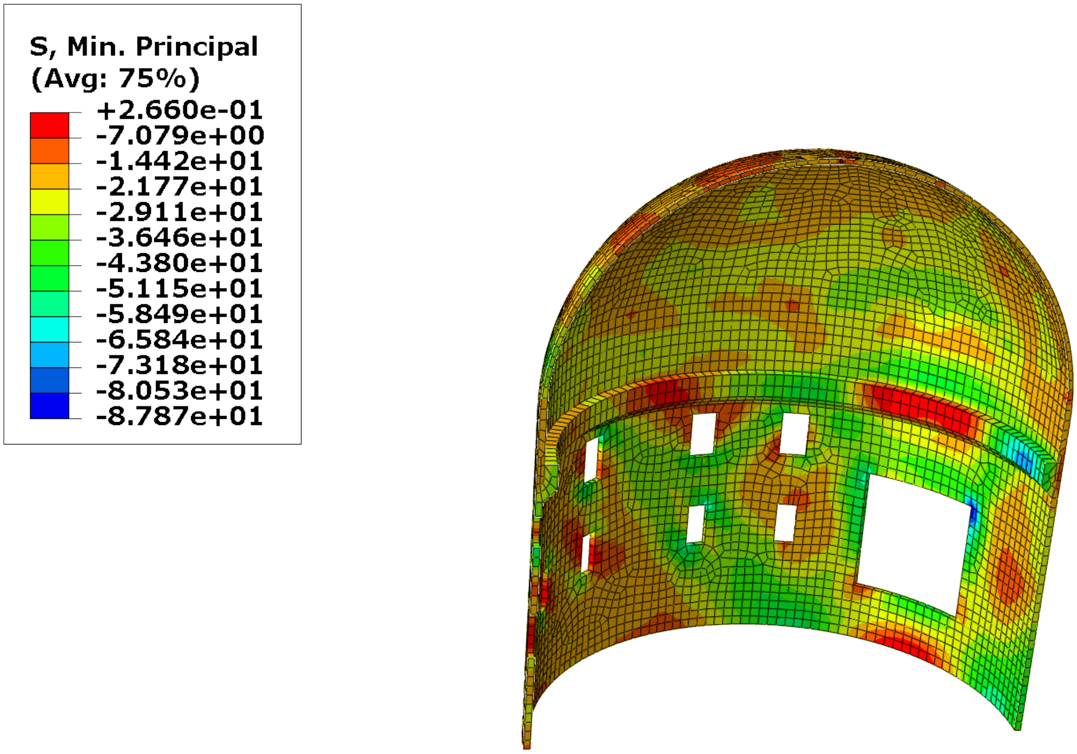


Figure 14. Concrete minimum principal stress plot from seismic evaluation.

Overall, the ETB containment structure does not face significant challenges to be able to handle the required loads or pass stress analysis. Based on the analysis results, consideration should be given to not replacing the concrete that is removed during the penetration installation.

As stated in FOR-554, there must be instrumentation, or some 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 it will be provided in conjunction with the demonstration reactor.

2.1.2.4 Reactor Loading/Removal

A low-profile skidding system was chosen in pre-conceptual design as the method for translating demonstration reactor modules through the equipment hatch. There were several factors that contributed to this decision:

- Relatively inexpensive
- Safer than overhead lifting through hatch or rollers
- Slow controlled movement
- Additional vertical clearance required limited to a few inches
- Ability to move large loads (over 100 tons)

- Simple to assemble and use.

Skidding essentially involves pairs of plates with a low friction surface between them where the top surface carrying a load is pulled across the bottom surface using a hydraulic ram. Figures 15 and 16 provide some generic examples of skidding equipment.

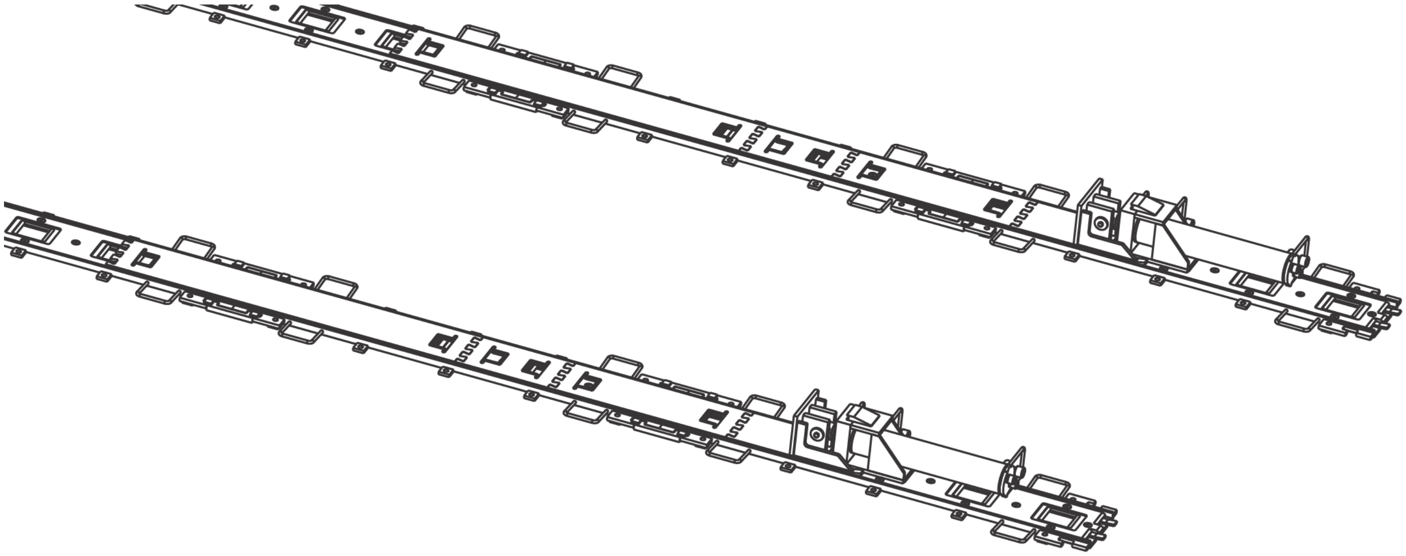


Figure 15. Example of basic skidding equipment.

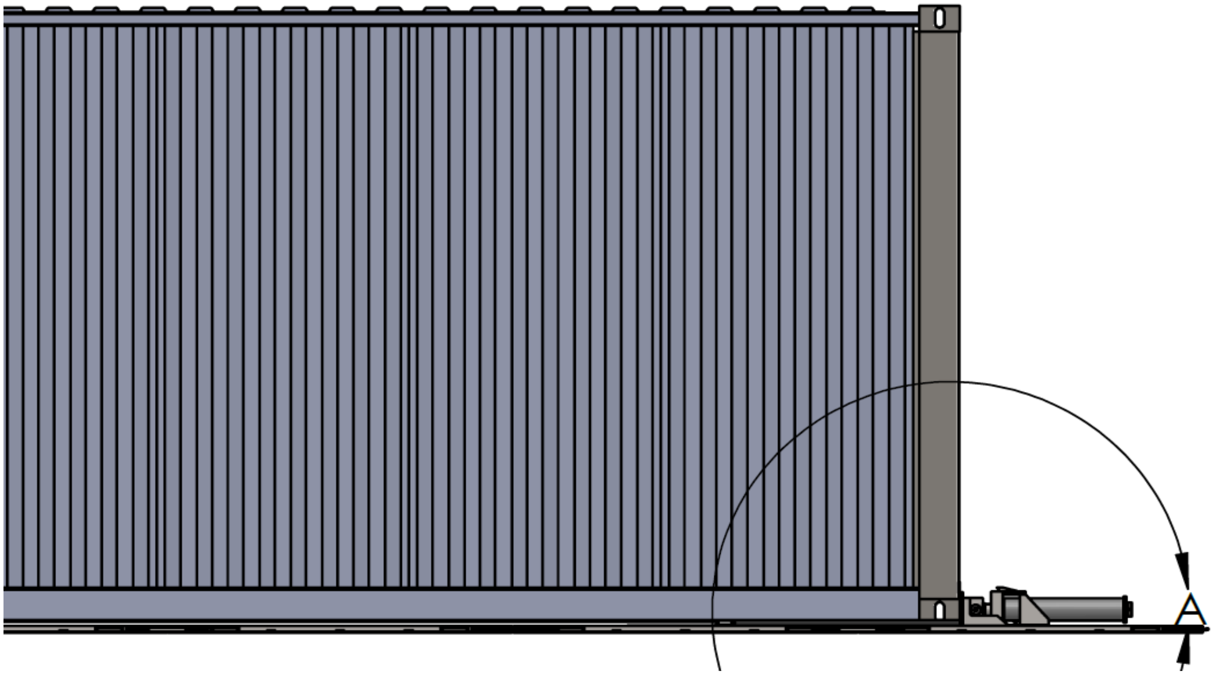


Figure 16. Shipping container on skidding system.

To accomplish a skidding evolution, a flat level surface is required. Removable platforms have been developed that can support the weight of reactor modules and are level with the bottom of the hatch opening, see Figures 17, 18, and 19. There are two platform sizes: 16 × 40 x 5-ft for outside the containment and 16 x 24 x 3-ft for inside containment. The platforms do not make direct contact with the containment and small gaps are acceptable if the manufacturer's guidance is followed. An example of skidding with gaps, see Figure 20, was provided by a potential skidding equipment vendor.

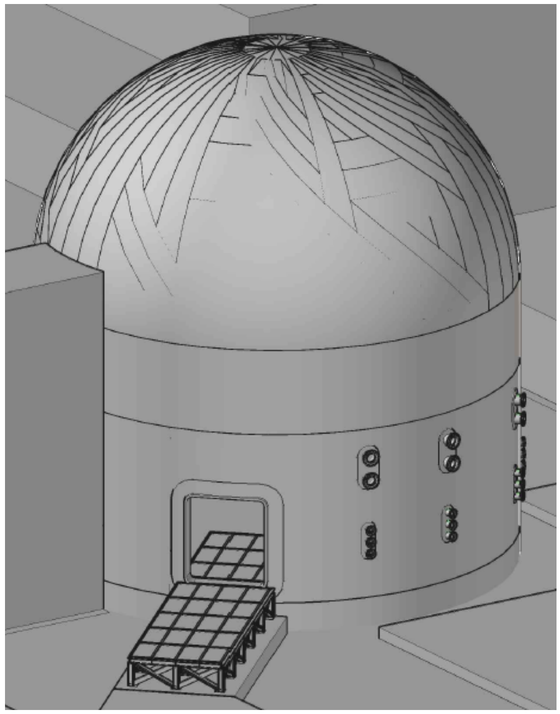


Figure 17. Internal and external platforms to provide flat level surface for skidding through equipment hatch.

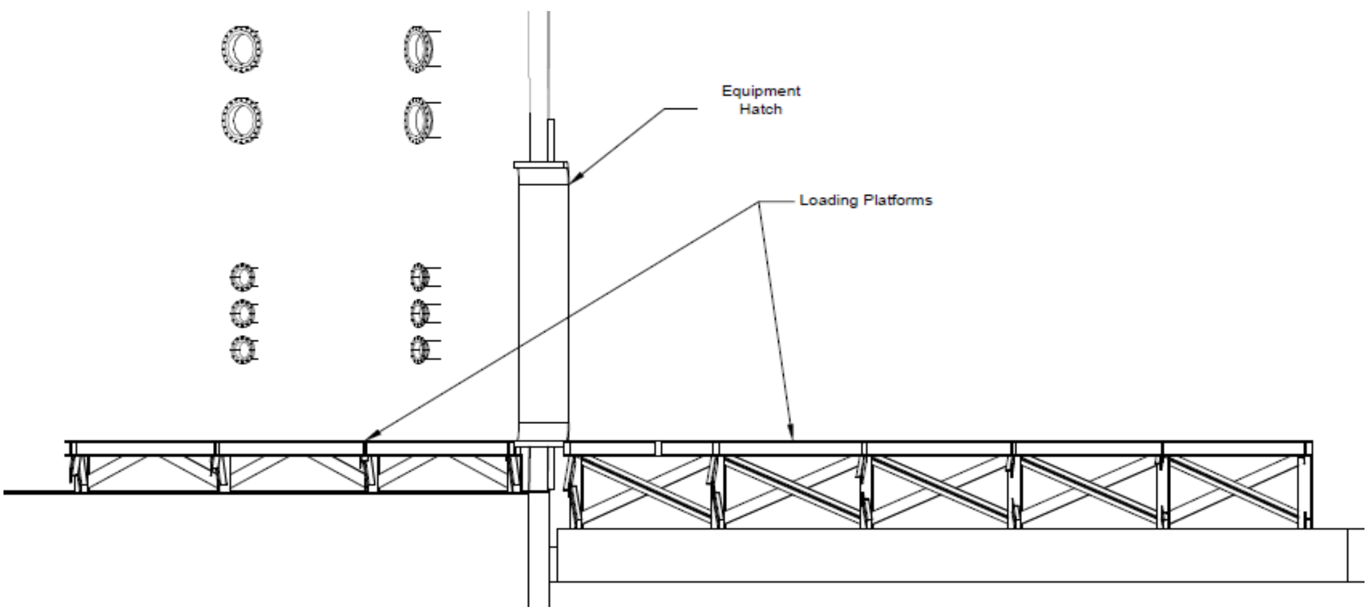


Figure 18. Elevation view of platforms in containment.

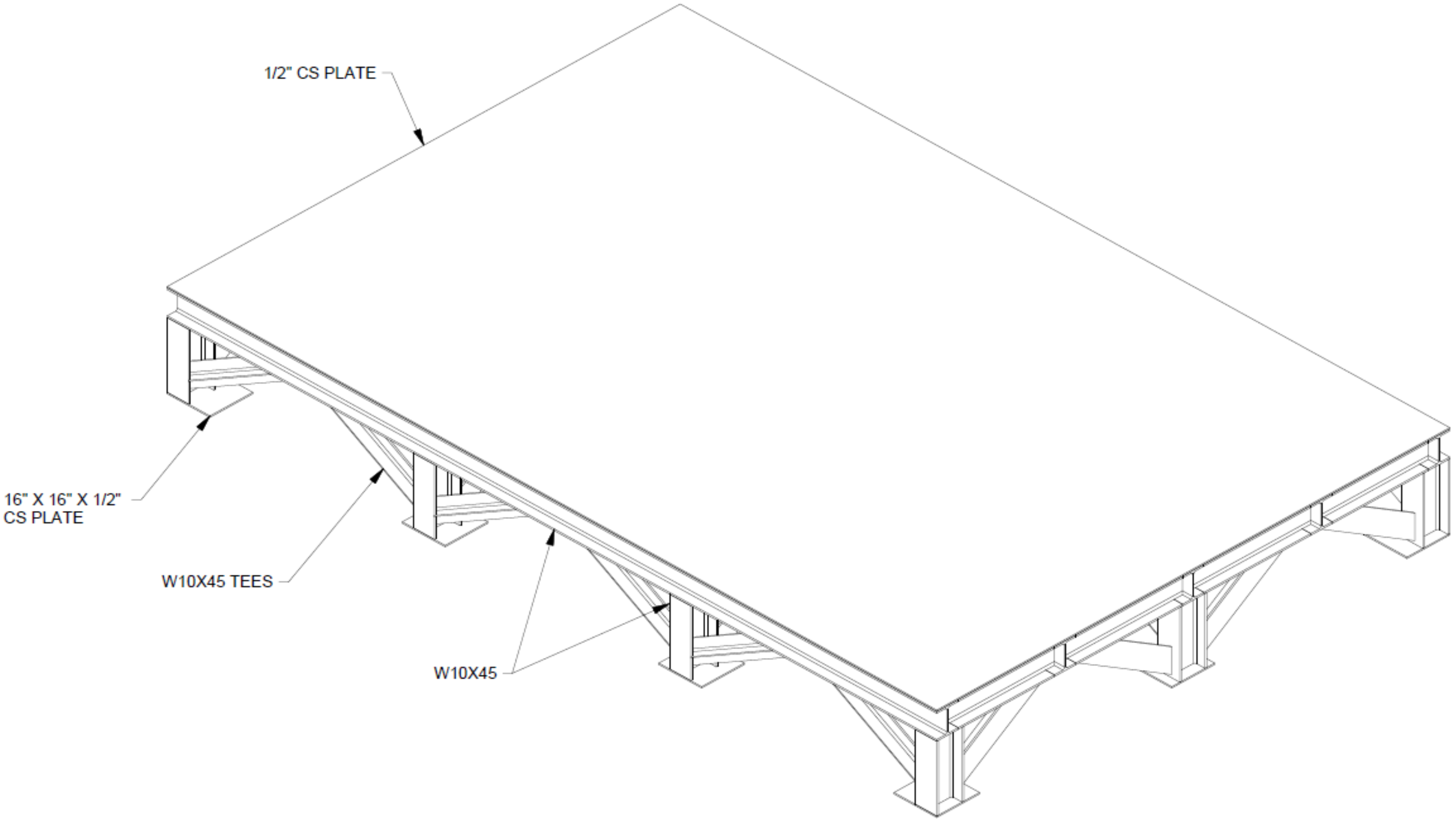


Figure 19. Typical platform.

1. The minimum load length must be at least three times the blocking span.
2. The load is assumed to be sufficiently rigid to support itself over the blocking span.

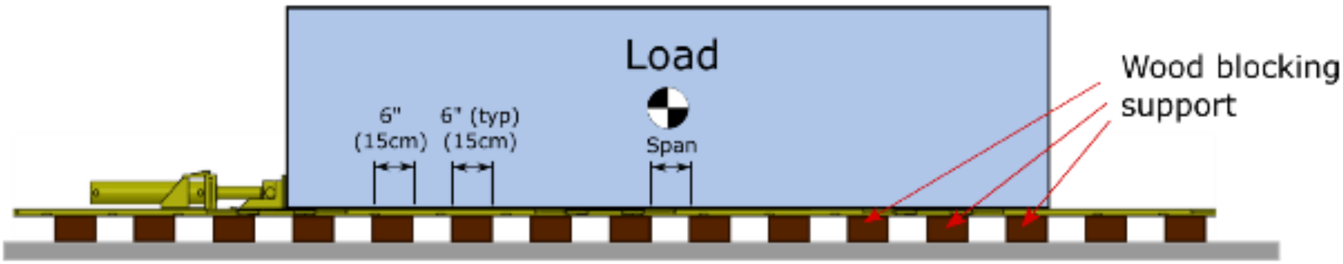


Figure 20. Vendor example of skidding spanning gaps.

The sequence of operations using a skidding system would be as follows:

1. Reactor module arrives on the shipping transport
2. Assemble the skidding system on the loading platform and through to the containment hatch
3. Move the reactor module from transport to the loading platform with a crane or forklift, setting it on the assembled skidding system
4. Skid the reactor module through containment hatch, and onto containment platform
5. Utilize the polar crane to lift the reactor module to its final location.

Removal of the reactor module is essentially the reverse process of installation. However, it may be desirable to place the module in some form of shielding outside of containment with a change in the platform height outside of containment. The platform outside containment would need to be lowered by the thickness of the desired shielding. The skidding system can be set up to allow the module to skid into the shielding. A concept of inserting a container into a shielding system is shown in Figure 21. A portion of the skidding system tracks could be left inside the shielding or high-pressure lifting bags could be used to lift the container for placement onto dunnage and the skidding system could then be pulled out. Lifting bags are available from some of the same vendors as skidding equipment.

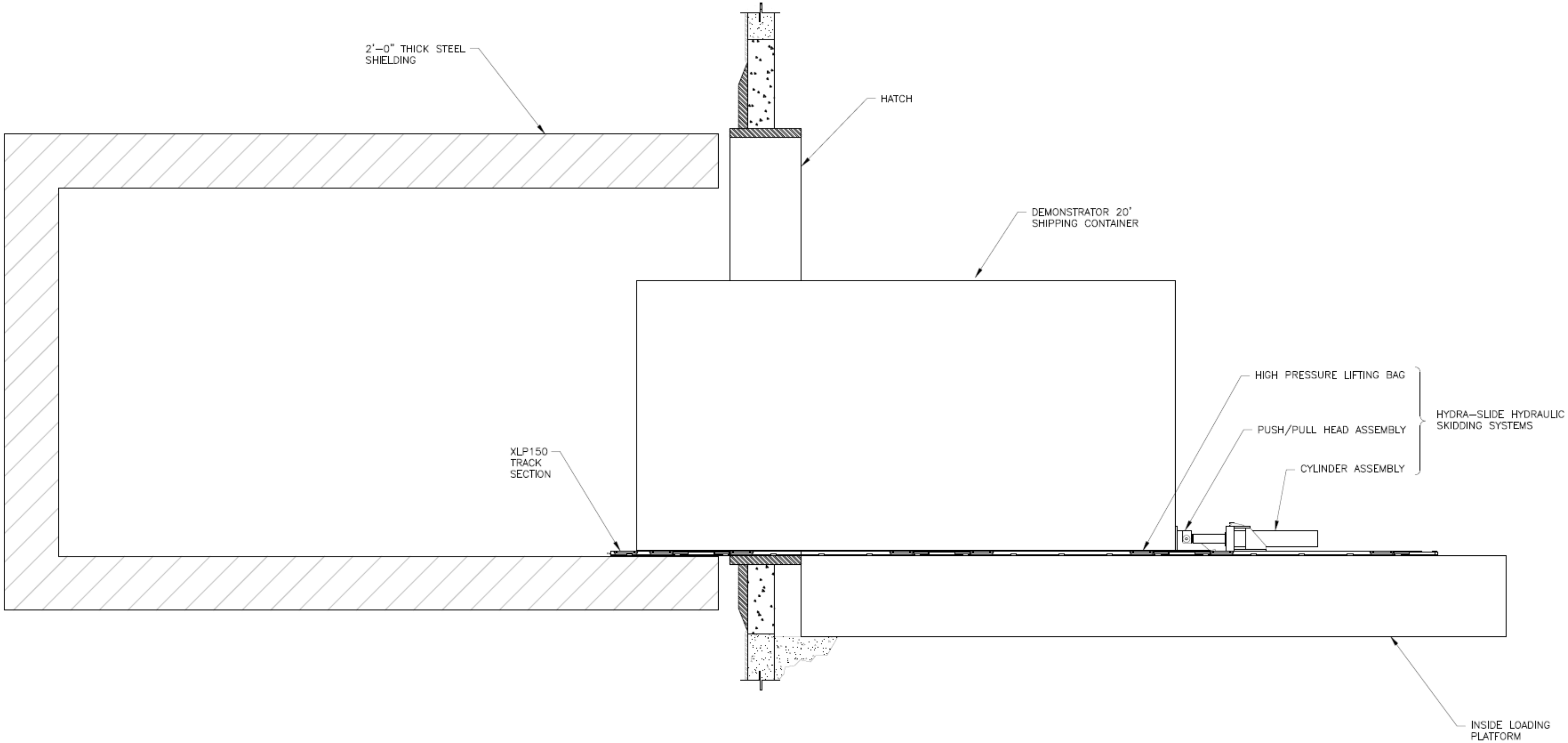


Figure 21. Container being placed into shielding system outside the ETB containment.

2.1.2.5 Yard Area

There are various items/operations that require siting outside the containment dome to support the functionality of the ETB. The major items are: cooling equipment, ventilation equipment, mechanical equipment, safety SSC batteries, reactor loading, demonstrator equipment, and equipment staging. An envisioned layout of the yard area is shown in Figure 22 below.

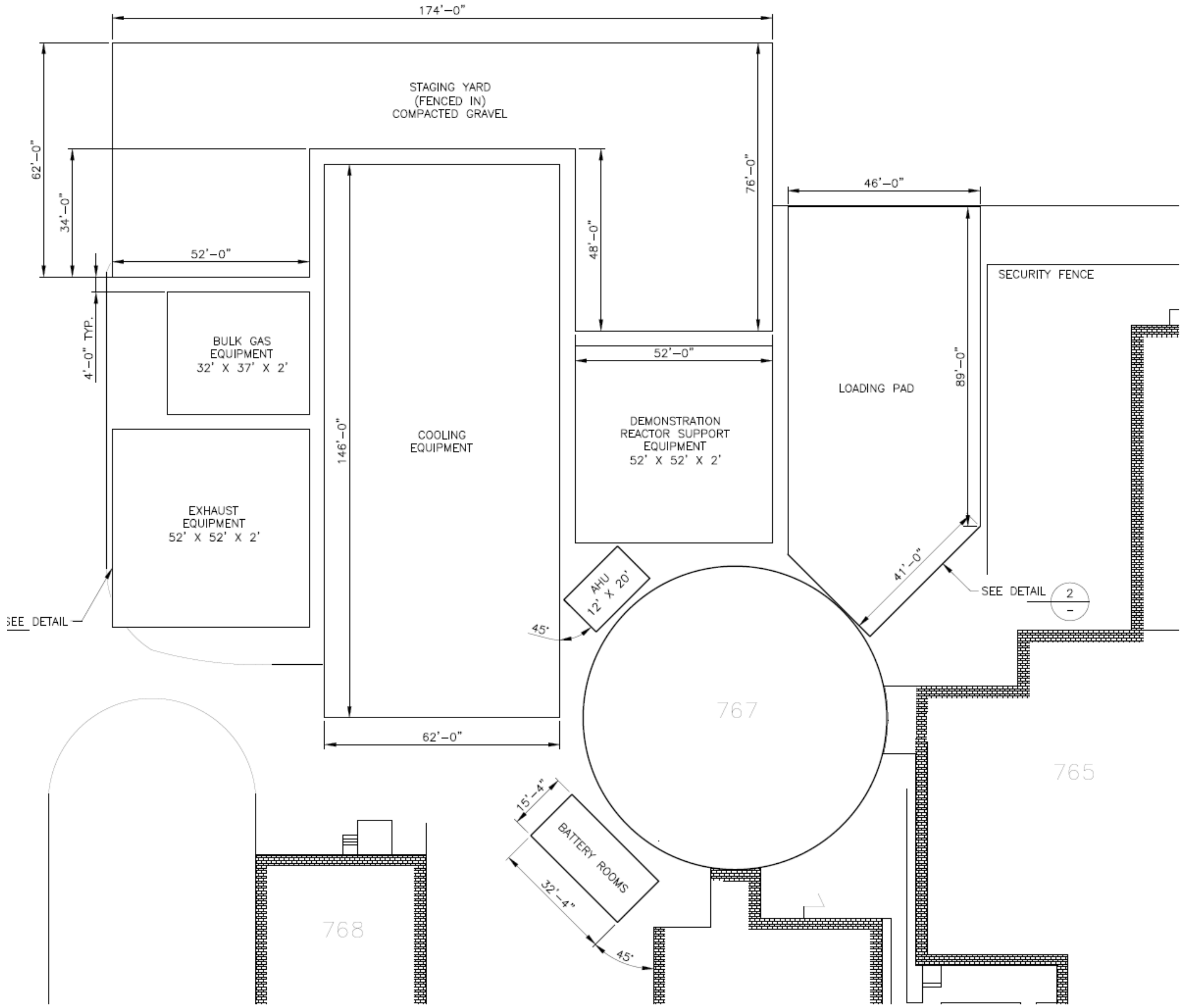


Figure 22. Yard area layout for ETB.

Concrete pads for these areas (excluding equipment staging, which will be gravel) will be provided. The pads will range in thickness from 1.5 ft to 3 ft with reinforcement based only on temperature and shrinkage (no structural reinforcement). The pads are designed based on 3000 psi concrete, ground net bearing capacity of 2500 psf, and the use of ASCE7, ACI 318, and ACI 360. The loads on the pads are based on the weights of major equipment. More detailed analysis in the future may allow for the use of thinner pads.

2.1.2.6 Crane

It is anticipated that lifting and handling operations of demonstrator equipment modules will be required inside the ETB containment dome. Most portions of the existing polar crane were irreparably destroyed during the D&D efforts. However, based on input from vendors, the main girders can be repaired and provide cost savings over complete replacement. A vendor evaluation determined that the crane could be restored to its original load capacity of 75 tons.

The crane is not anticipated to be a safety SSC and therefore ASME NOG-1 will not be applied. The crane will be restored in accordance with the Crane Manufacturing Association of America (CMAA) standard for industrial cranes.

2.1.2.7 Platforms, Ladders, Walks

Ladders, platforms, and catwalks will be installed, if needed, to provide access to regularly accessed equipment mounted to the interior walls of the ETB containment (e.g., air handling units for the dome cooling system).

2.1.3 Mechanical Systems

2.1.3.1 Decay Heat Removal

The ETB cooling systems are not intended to be required for decay heat removal of a demonstration reactor. This was a decision to avoid the need for a very large safety-class backup electrical system. As a result of this decision, analysis of the ETB containment to passively reject decay heat generated by a demonstration reactor was necessary.

Scoping studies to assess the ability of the ETB containment to reject decay heat were performed as part of the pre-conceptual design effort. In total, 9 cases were evaluated to determine whether the structural temperature limits, 100°C (see FOR-554), would be violated. The general model set-up is shown in Figures 23 and 24. The thermal analysis was run over 72 hours. In all cases the temperature in the containment decreased due to the reduction of decay heat produced at the 72-hour period. It was judged that longer analysis time periods were not necessary.

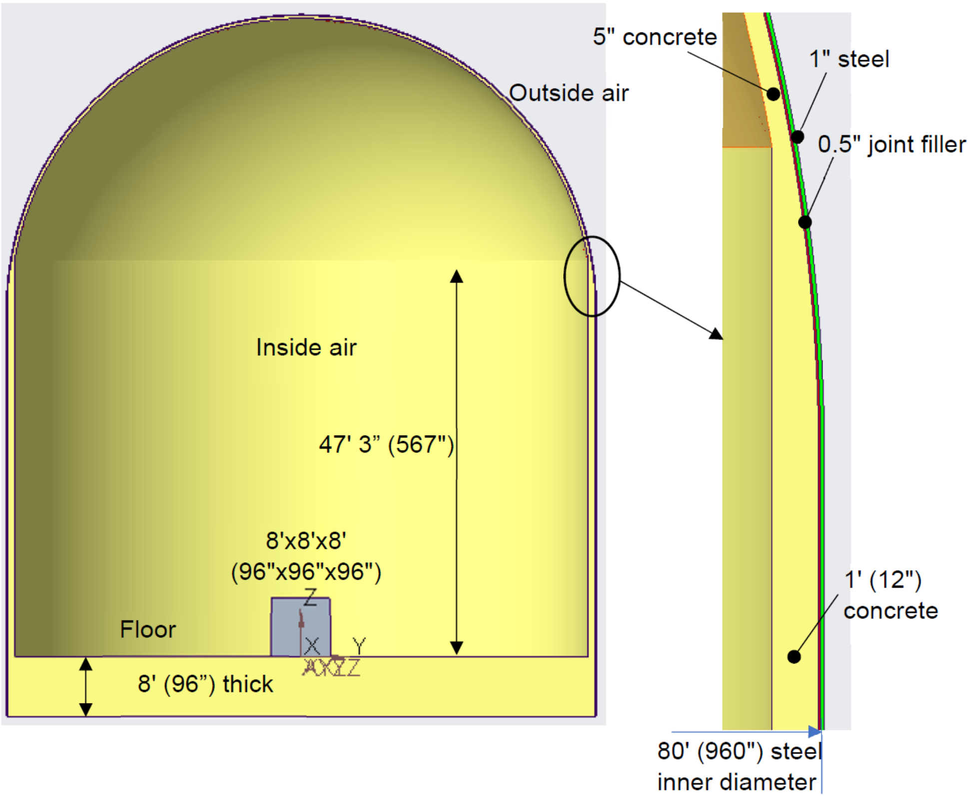


Figure 23. ETB containment structure as modeled in decay heat evaluations.

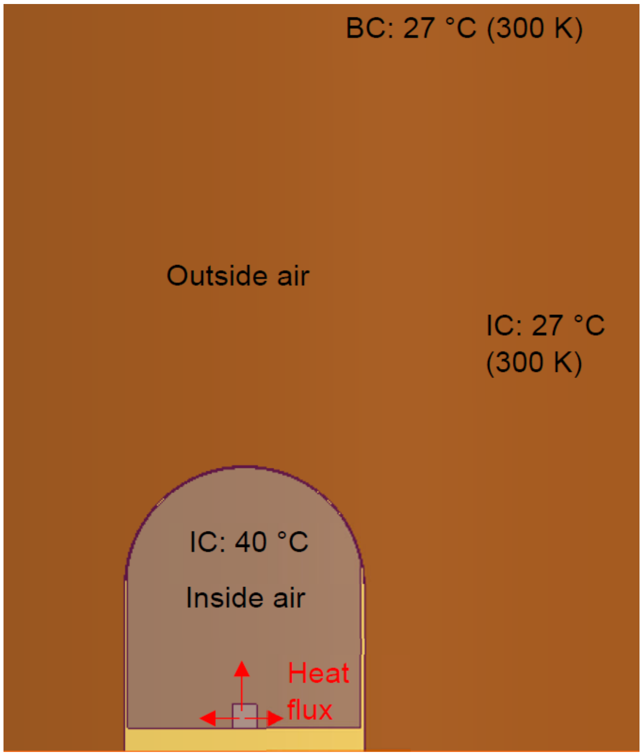


Figure 24. ETB containment decay evaluation boundary conditions and initial conditions.

The material properties of the joint filler are not known. Thermal conductivity of the joint filler was based on assumed upper- and lower-limits of potentially similar materials. Specifically, 10 W/mK to 0.1 W/mK were used in several of the initial cases (for reference, concrete thermal conductivity is 2.1 W/mK). When using a conservative linear decay heat reduction over time, the first three cases evaluated in the scoping calculations resulted in violation of the structural temperature limits. For the remaining six cases, the decay heat was non-linear based on the simplified Wigner-Way equation (see Table 1, 7% power assumed at t=0), and all six cases demonstrated that the decay heat from a 10 MWt reactor could be passively rejected. Since the equation for decay heat used was a simplified method, two of the six cases were evaluated with double the decay heat and passed. Selected concrete temperature plots are shown from the cases analyzed in Figures 25 through 28.

Table 1. Decay Heat Values Used for Analysis.

Time (s)	Power (kW)
10	392.38
100	238.70
1,000	141.73
3,600	104.26
10,000	80.55
100,000	41.98
259,200	30.58
Note: Assumes 6-month reactor run time.	

A brief description of the successful cases evaluated is listed below. The lower bound of thermal conductivity was used for cases 4 through 6.

- Case 4 – Boundary conditions as shown with decay heat as shown, reactor module 8 × 8 × 8-ft cube
- Case 5 – Boundary conditions as shown with decay heat as shown, reactor module 8 × 8 × 16-ft cube
- Case 6 – Same as Case 4, but with decay heat doubled
- Case 7 – Same as Case 5, but with decay heat doubled
- Case 8 – Same as Case 4, but with outside air set at 40°C
- Case 9 – Same as Case 5, but with outside air temperature at 40°C.

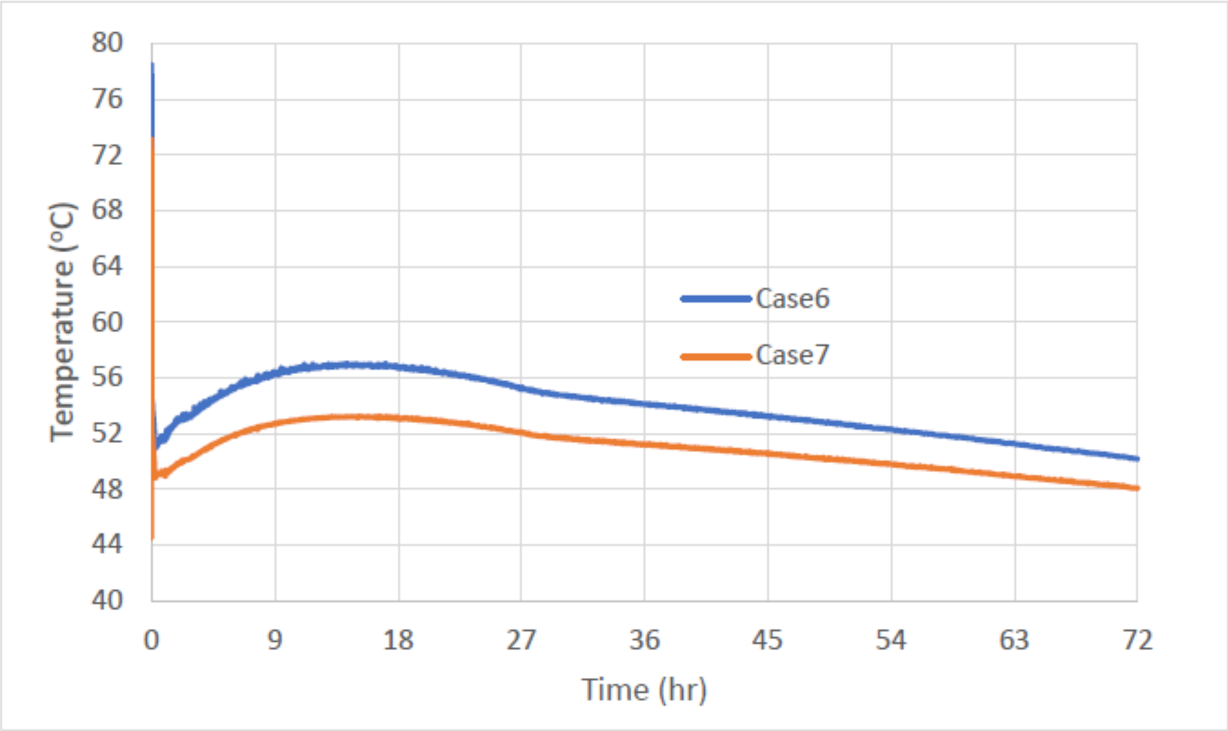


Figure 25. Cases 6 and 7 maximum lateral concrete temperature.

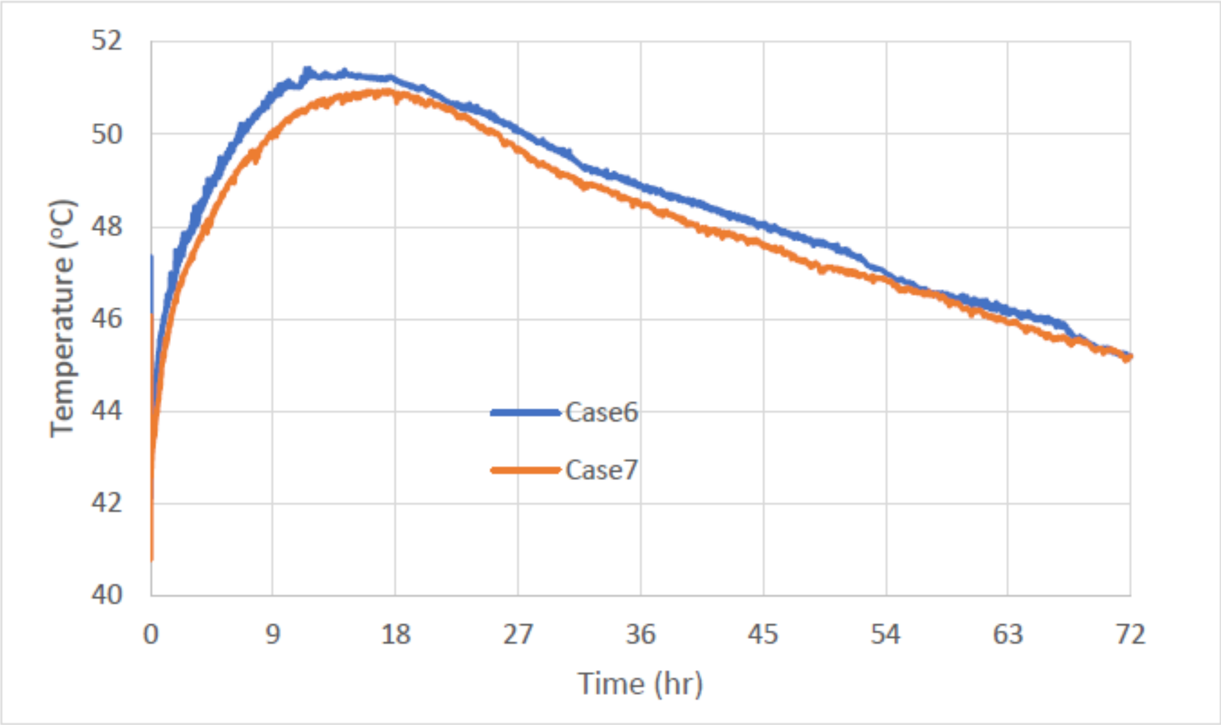


Figure 26. Cases 6 and 7 – maximum roof temperature.

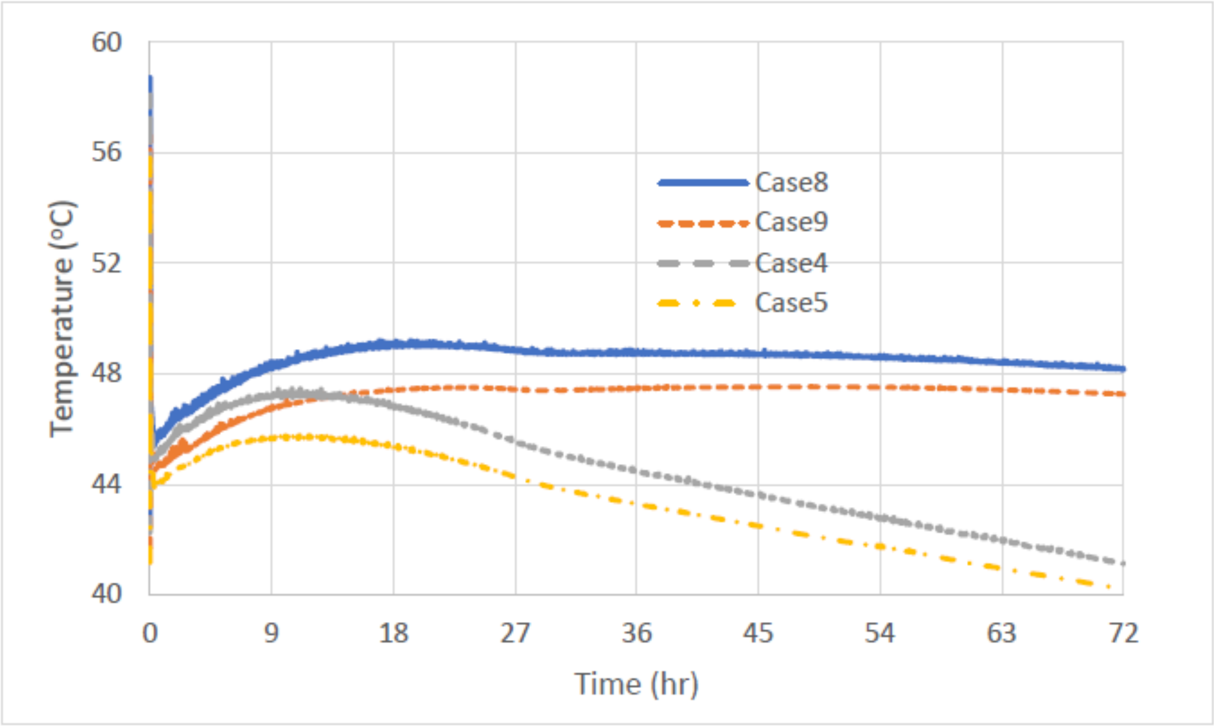


Figure 27. Cases 4,5,8,9 – maximum lateral concrete temperature.

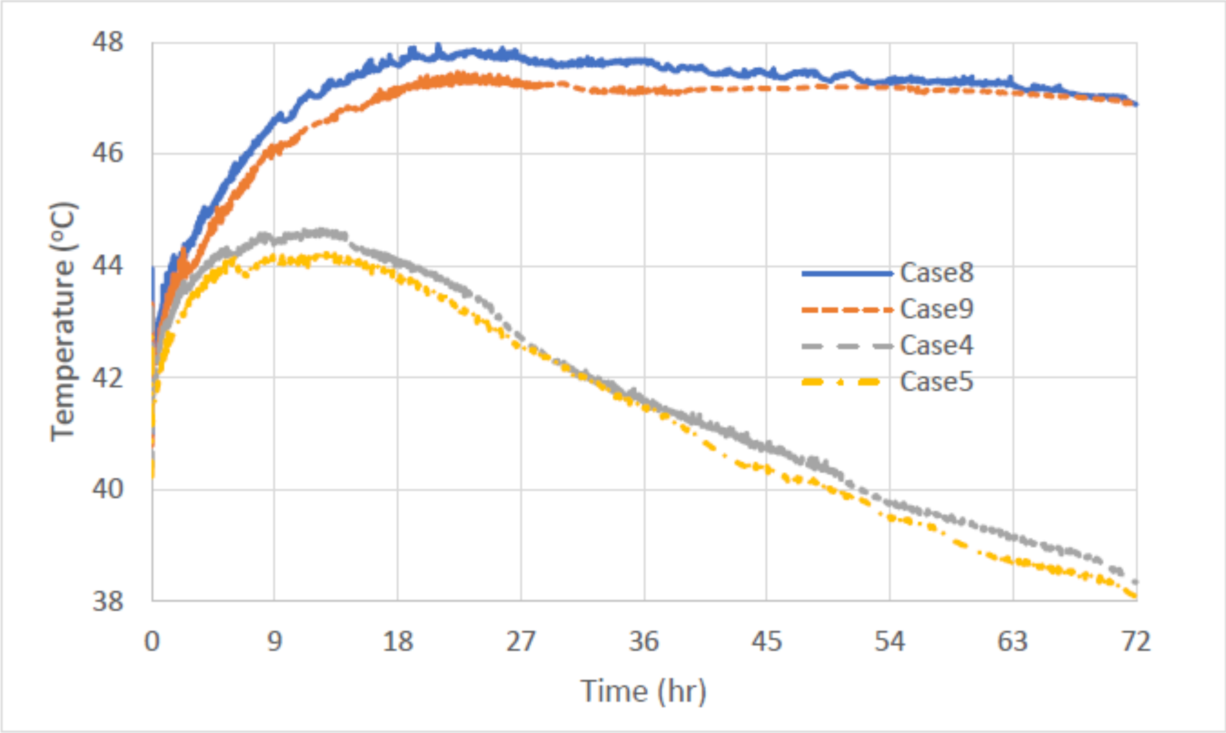


Figure 28. Cases 4,5,8,9 – Maximum roof temperature.

The decay heat scoping calculations are being formalized in accordance with INL engineering processes which will soon be released. It should be noted that while the ETB containment can handle the anticipated decay heat produced by a demonstration reactor, the calculation does not make any assessment of the reactor/reactor module's ability to survive its own decay heat.

2.1.3.2 Cooling Systems

Several variants of cooling systems were considered. A 10 MW chilled water system that only cooled the containment air was considered first. This type of system was not selected for further development since it was unlikely to be able to provide the desired type of dynamic response for reactor cooling that may be desired by demonstrators.

After the air cooling only option was abandoned, a decision was made to split the system into two types, one air cooling and one that would provide a more direct reactor cooling capability. A 2 MW chilled water system was used for containment air cooling, and a 10 MW Dowtherm Q system was used for the more direct reactor cooling option. Dowtherm Q was selected during pre-conceptual design based on its high operating temperature (up to 330°C), and low freezing temperature (-35°C). Three options were considered for the Dowtherm cooling system: dry coolers, adiabatic coolers, and evaporative fluid coolers. The dry cooling Dowtherm system was rejected based on its much larger size (approximately twice as big as the next largest option) and its greater than 50% higher cost. The adiabatic coolers were chosen over the evaporative fluid coolers since the adiabatic coolers would avoid the need for water treatment, drainage systems, and additional pump maintenance; even though the adiabatic coolers have between a 15-20% larger footprint over the evaporative fluid coolers. The system costs are within approximately 1% of each other for the adiabatic and evaporative fluid coolers.

The final heat rejection/cooling system consists of a central plant comprised of two separate systems, a 2 MW chilled water/glycol system and a 10 MW Dowtherm heat transfer fluid system. The 2 MW (600-ton) chilled water/glycol system will provide dome air cooling designed to maintain the space below the specified maximum air temperature of 40°C. The 40°C temperature limit will ensure equipment inside containment is not overheated, provides margin to the structural temperature limits, and ensures the initial conditions of the decay heat calculations are met. This system will reject heat generated within the dome that is not carried by the direct cooling system. The 10 MW Dowtherm heat transfer fluid system will provide a more direct cooling for the demonstration reactor, although not as the reactor primary coolant. This system will supply Dowtherm fluid at a specific flow rate and temperature to the demonstration reactor heat rejection equipment. Model images of the cooling system are shown in Figures 29 through 34.

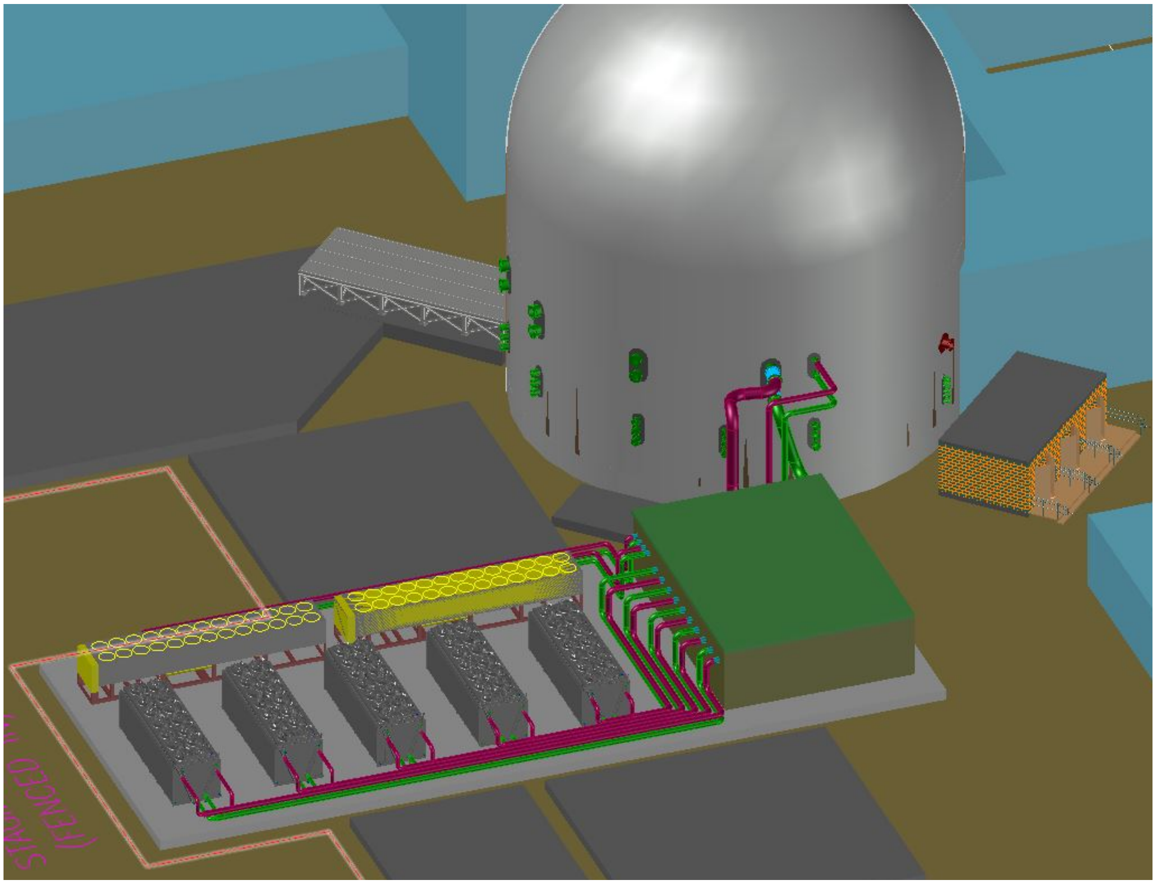


Figure 29. Cooling system in the yard.

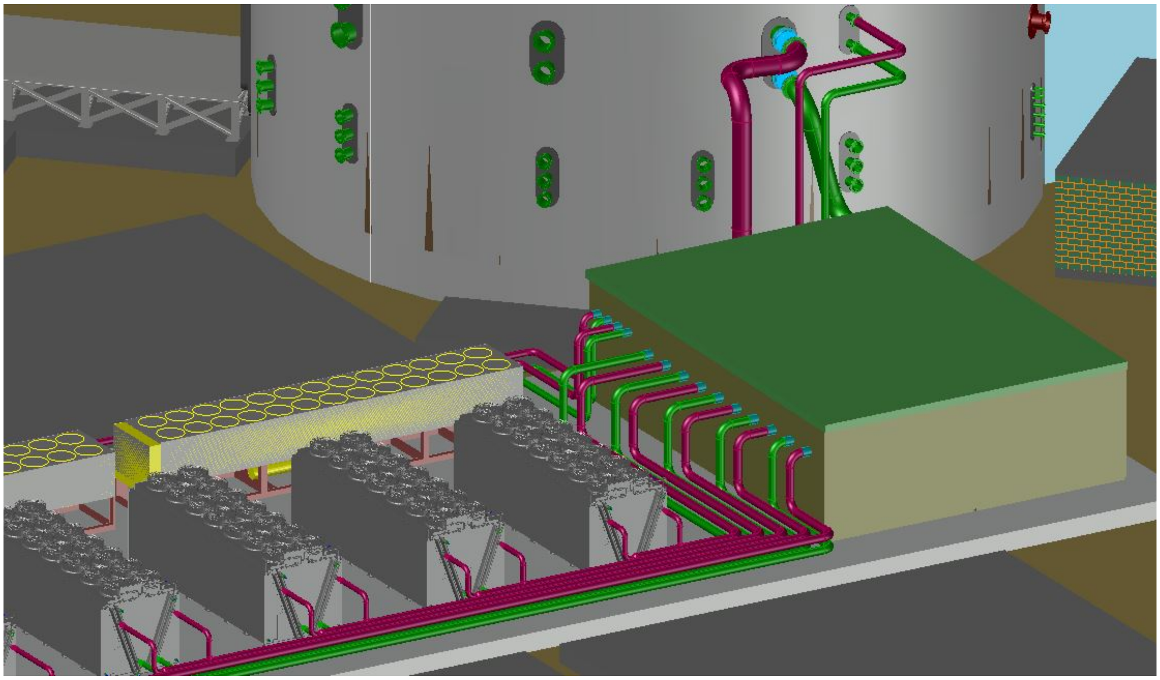


Figure 30. Cooling system pump house and containment penetrations.

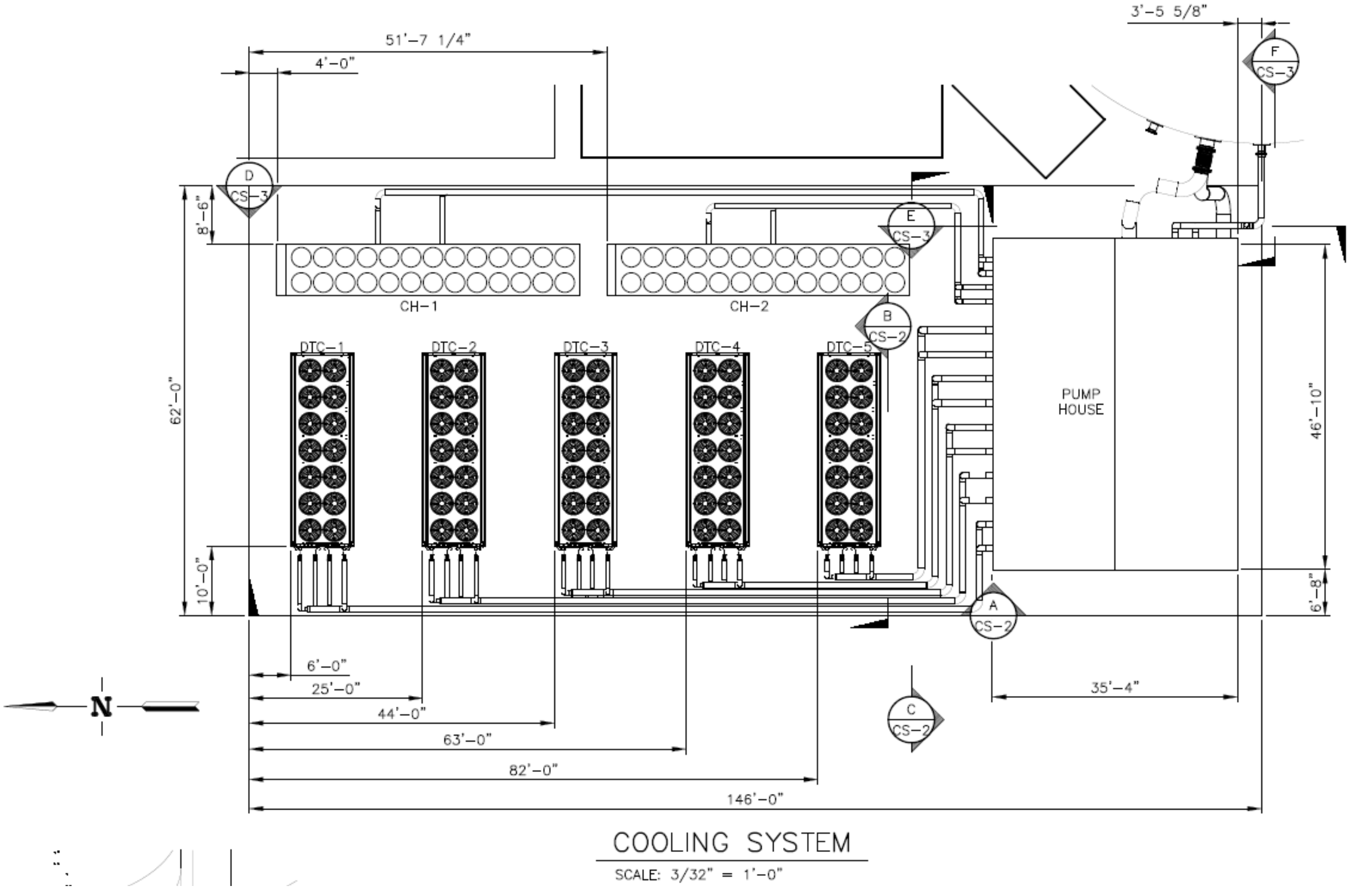


Figure 31. Plan view of cooling system in the yard.

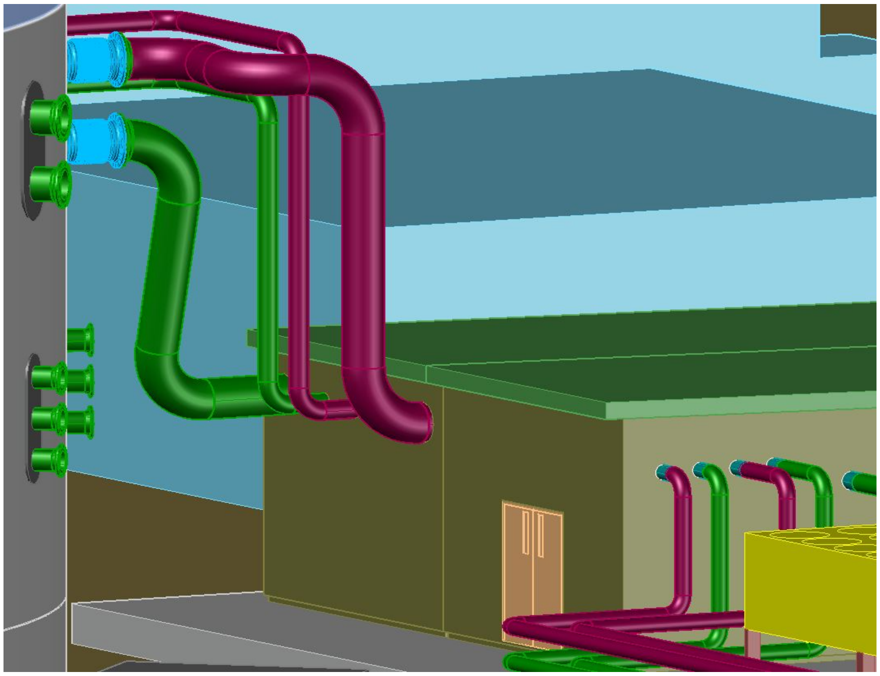


Figure 32. Cooling system piping from pump house to containment penetrations.

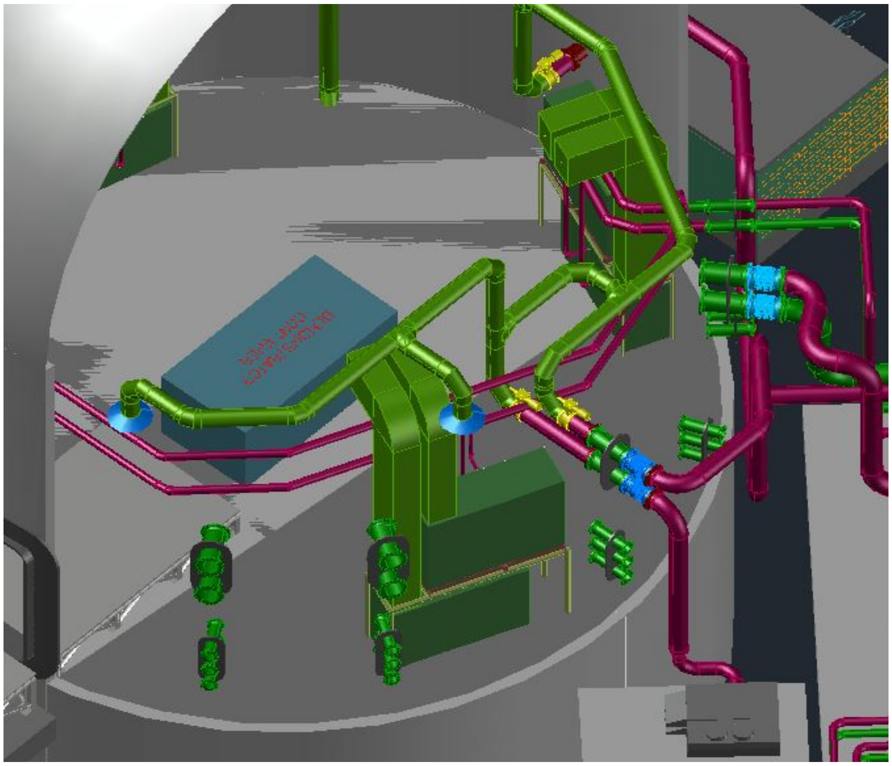


Figure 33. Portion of cooling system with containment cut away.

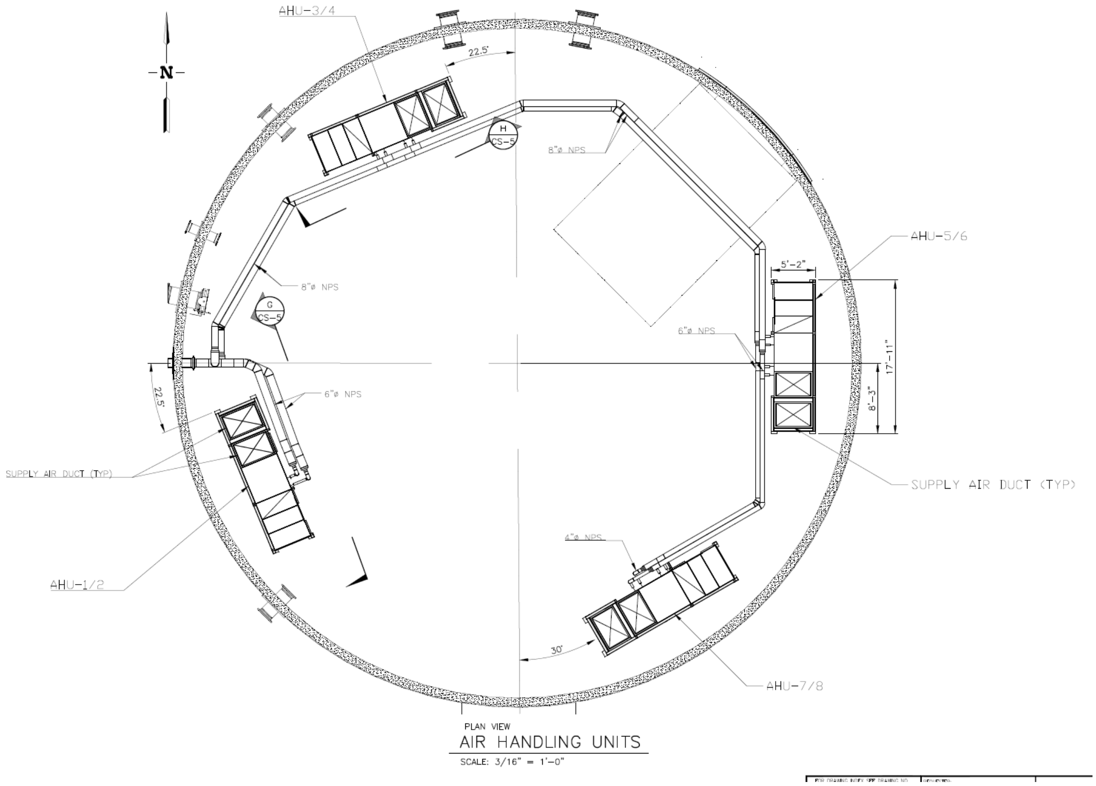


Figure 34. Plan view of cooling system inside containment.

2.1.3.2.1 Containment Air Cooling

The containment air cooling system consists of two 300-ton air-cooled chillers operating and piped in parallel, with each chiller having a dedicated constant speed primary pump to circulate chilled water/glycol in a primary piping loop. There are two pumps for each chiller for a total of four primary pumps. One pump for each chiller is for stand-by service and the two pumps for each chiller will alternate operation in a lead/lag control configuration. Three secondary variable speed pumps (one pump is for stand-by service) in a secondary piping loop shall receive chilled water/glycol from the primary piping loop via a common pipe, and each pump shall operate in parallel at 50% of the total design flow rate. The secondary pumps shall deliver 1610 GPM (2 pumps @ 805 GPM each) of 38°F chilled water/glycol to eight cooling coils contained inside eight air handling units with four fans each. Each of these air handling units shall supply 16,000 CFM of 42°F supply air to the dome to maintain a maximum space temperature of 104°F. It should be noted that the air-cooled chillers can operate down to an ambient 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. A system Piping and Instrumentation Diagram (P&ID) is shown in Figure 35.

The 2 MW value for the air cooling system was picked early in the design cycle as a conservatively high value that would be greater than the amount of heat lost from a reactor that was dissipating heat to its own specialized equipment outside of containment, or through the Dowtherm reactor cooling system. It is possible that the size of the air-cooling system can be substantially reduced in the next design phase with more detailed evaluations of potential reactors.

2.1.3.2.2 Reactor Cooling – Dowtherm

This system consists of five 7,200,000 BTUH (5 units @ 2 MW each) adiabatic coolers operating and piped in parallel with each cooler having a dedicated variable speed primary pump to circulate Dowtherm Q heat transfer fluid in a primary piping loop. An adiabatic cooler is an induced draft fluid cooler utilizing an air precooling system to depress the ambient dry-bulb temperature using wetted fibrous pads. A water supply is provided to each cooler to wet the pads. There are two pumps for each cooler for a total of ten primary pumps. One pump is for stand-by service and the other pumps shall alternate operation in a lead/lag control configuration. Five secondary variable speed pumps (one pump is for stand-by service) in a secondary piping loop shall receive heat transfer fluid from the primary piping loop via a common pipe and each pump shall operate in parallel at 25% of the total design flow rate. The secondary pumps shall supply a total of 9200 GPM (4 pumps @ 2300 GPM each) of 110°F Dowtherm Q fluid to a heat rejection device provided by the demonstration reactor, that is yet to be determined. The system piping inside the ETB containment will be installed when a given reactor requiring its use is installed. A system P&ID is shown in Figure 36.

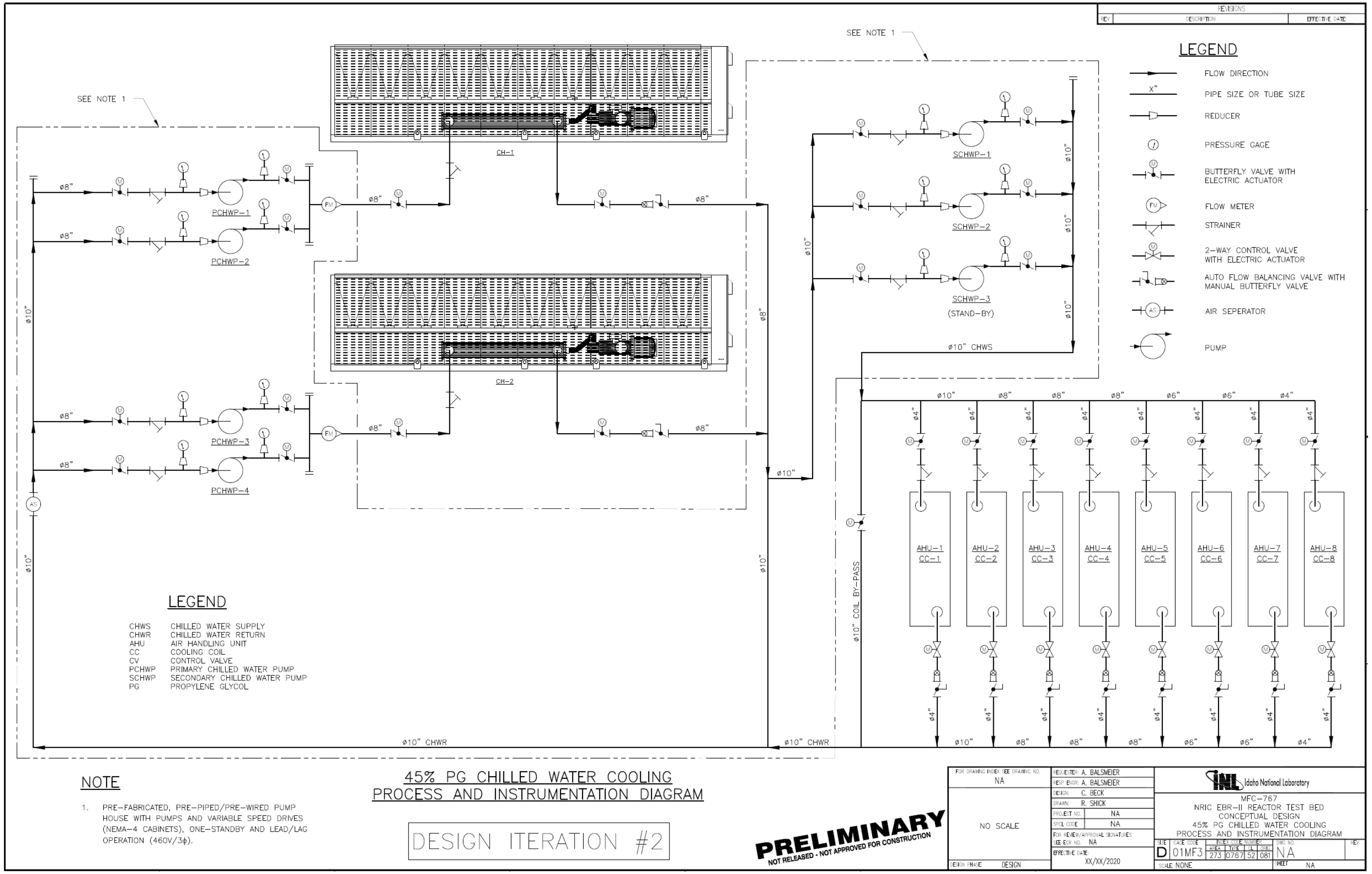


Figure 35. Containment air cooling system P&ID.

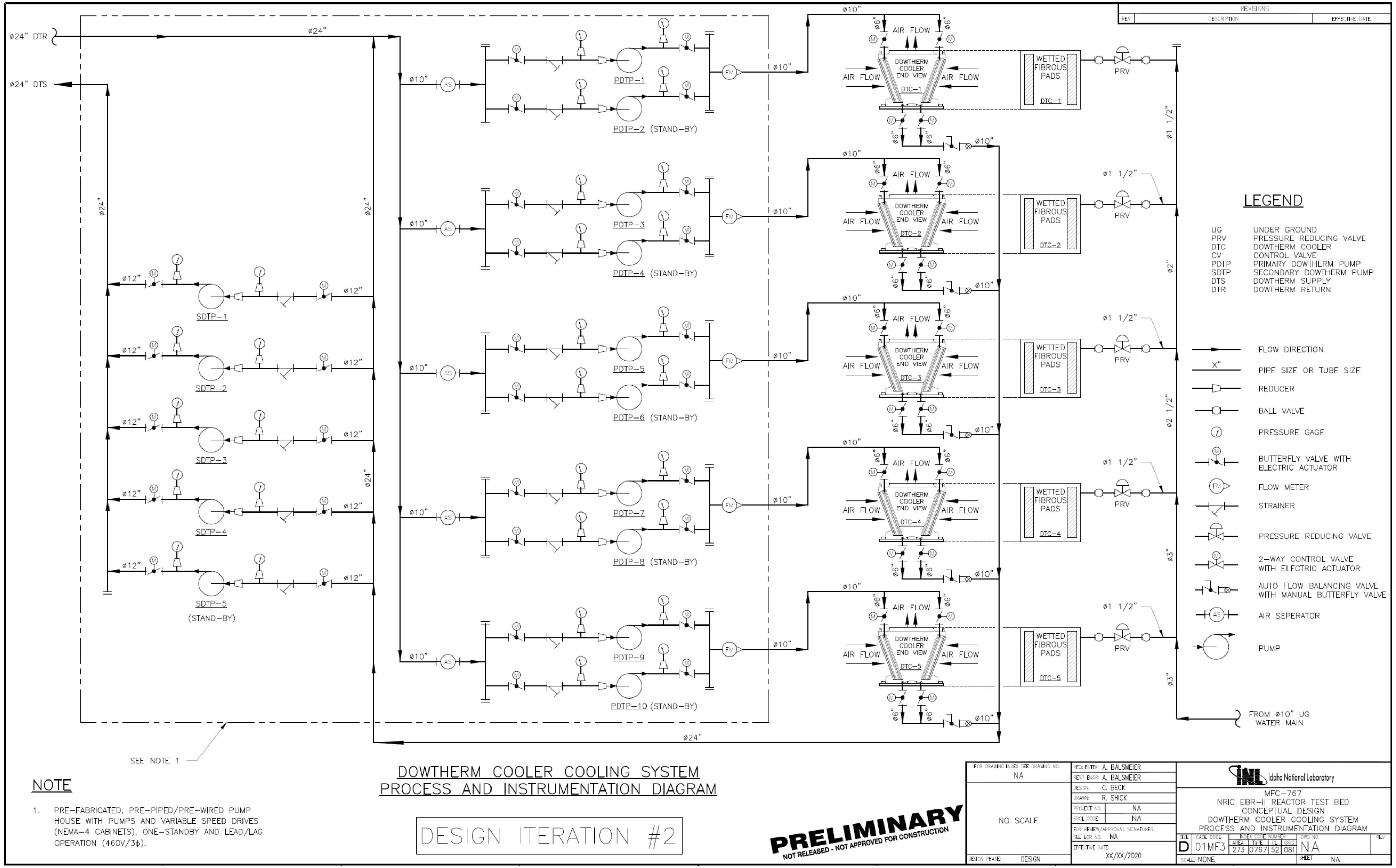


Figure 36. Direct reactor cooling system P&ID.

2.1.3.2.3 Pump House

The pump house is a modular, prefabricated building comprised of two modules that have overall dimensions of 42 × 35 x × 14 ft and contain the primary and secondary pumps for the chilled water/glycol and Dowtherm cooling systems. All pumps are piped and wired at the manufacturer with all necessary piping, valves, fittings, supports and hydronic specialties, and electrical power connections to variable speed drives and pump motor controls. Located on the outside wall external to each pump house module (A & B) is an electrical power switchgear panel ready to accept a single-point power connection. There are three chilled water fan coil units with electric heaters to provide a conditioned environment inside the pump house.

2.1.3.2.4 Turndown Capability

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

2.1.3.2.5 Water Supply

Water supply to the cooling system will be provide by tapping off a nearby existing water main. The water line to the cooling equipment is anticipated to be a 3 in. pipe. A sketch of the water supply is shown in Figure 37.

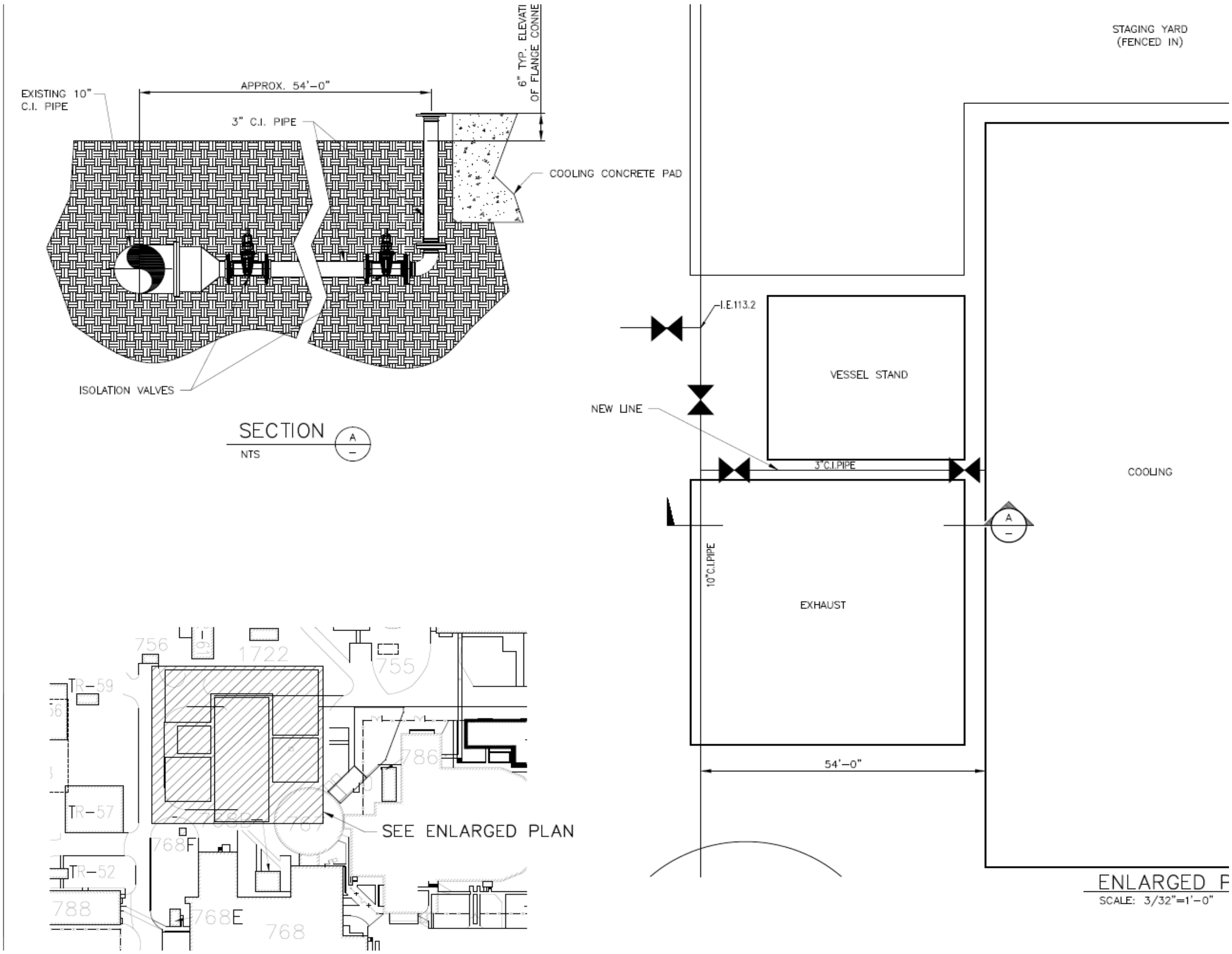


Figure 37. Cooling equipment water connection.

2.1.3.3 Ventilation

The ventilation system differs from the cooling system in that the cooling system is dedicated solely to removing heat generated by the demonstration reactors. The ventilation system provides the other necessary functions for maintaining the containment atmosphere during the various operations that will be done. For example, the ventilation system will maintain a negative pressure inside containment, provide fresh air supply (heated or cooled as necessary when occupied), route exhaust through a filter and out a stack, provide stack monitoring, and provide over/under pressure protection. A general flow diagram of the proposed system is shown in Figure 38 and system layout is shown in Figures 39 through 41. Detailed discussion of various key portions of the system are provided in the section that follows.

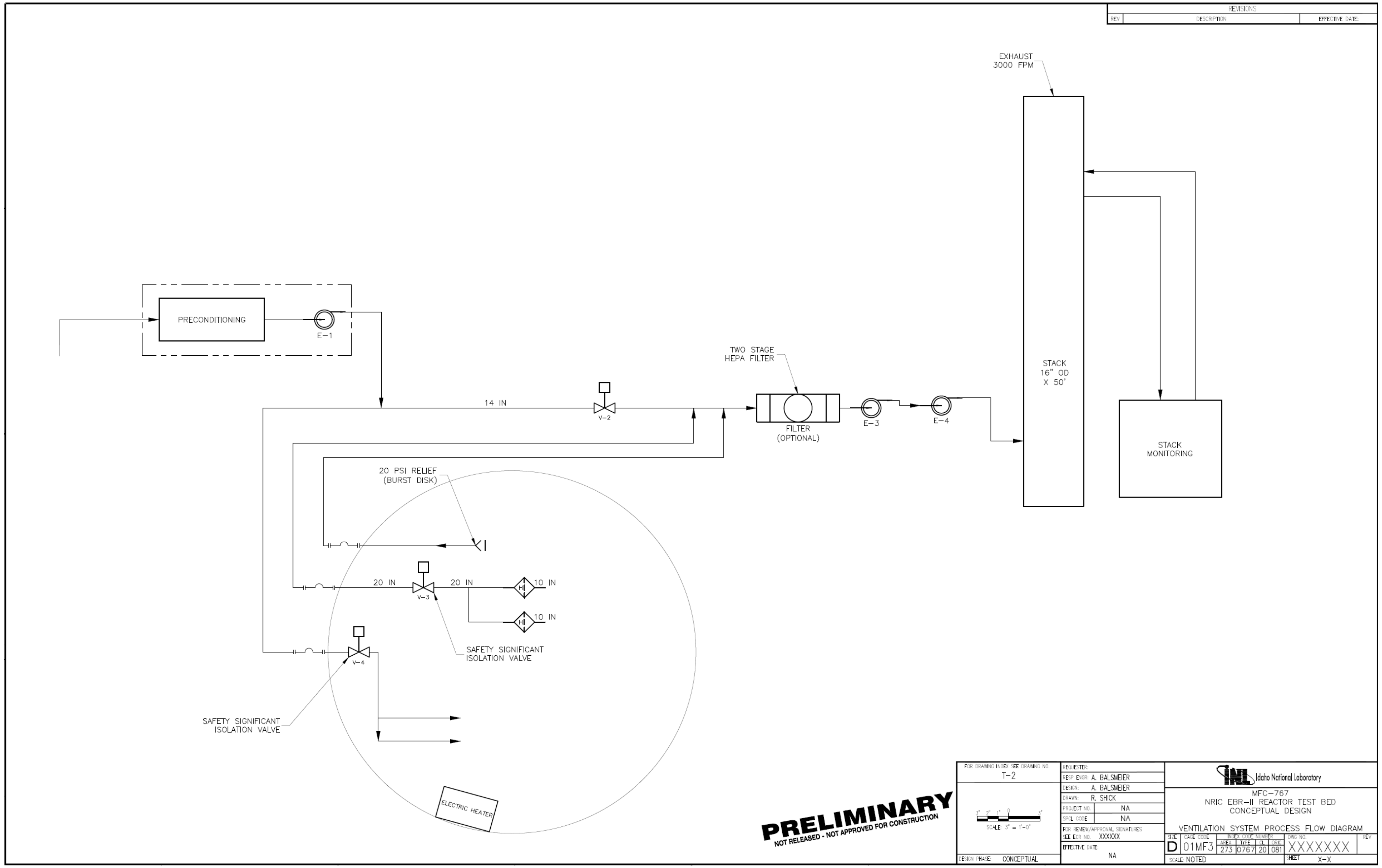


Figure 38. General Flow Diagram for the ETB Ventilation System.

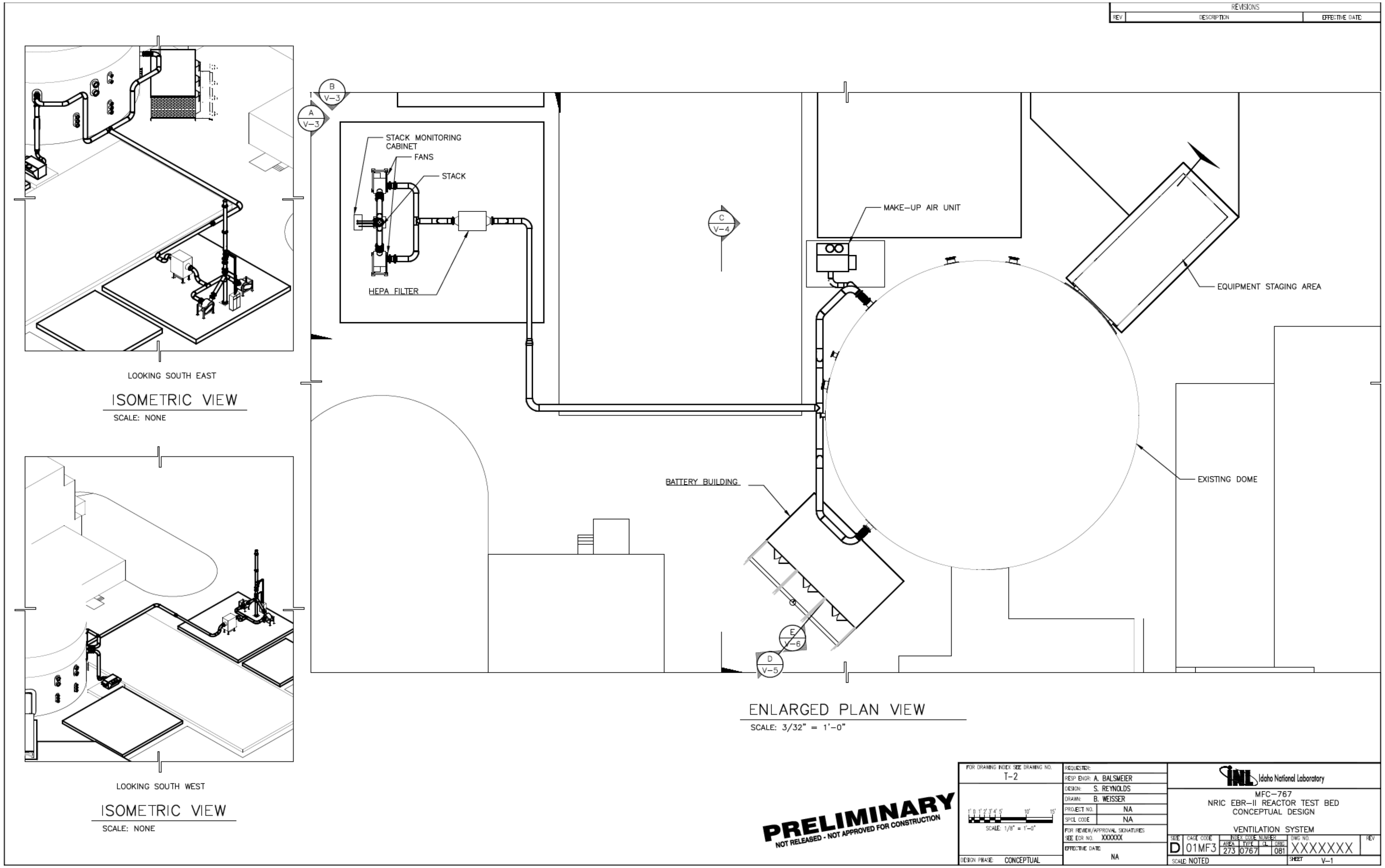


Figure 39. System layout.

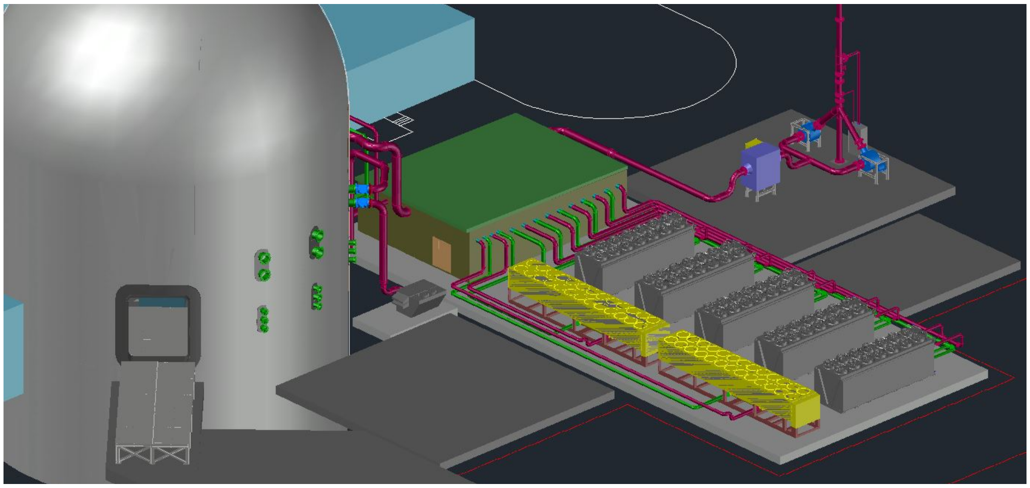


Figure 40. Ventilation system shown in the yard area.

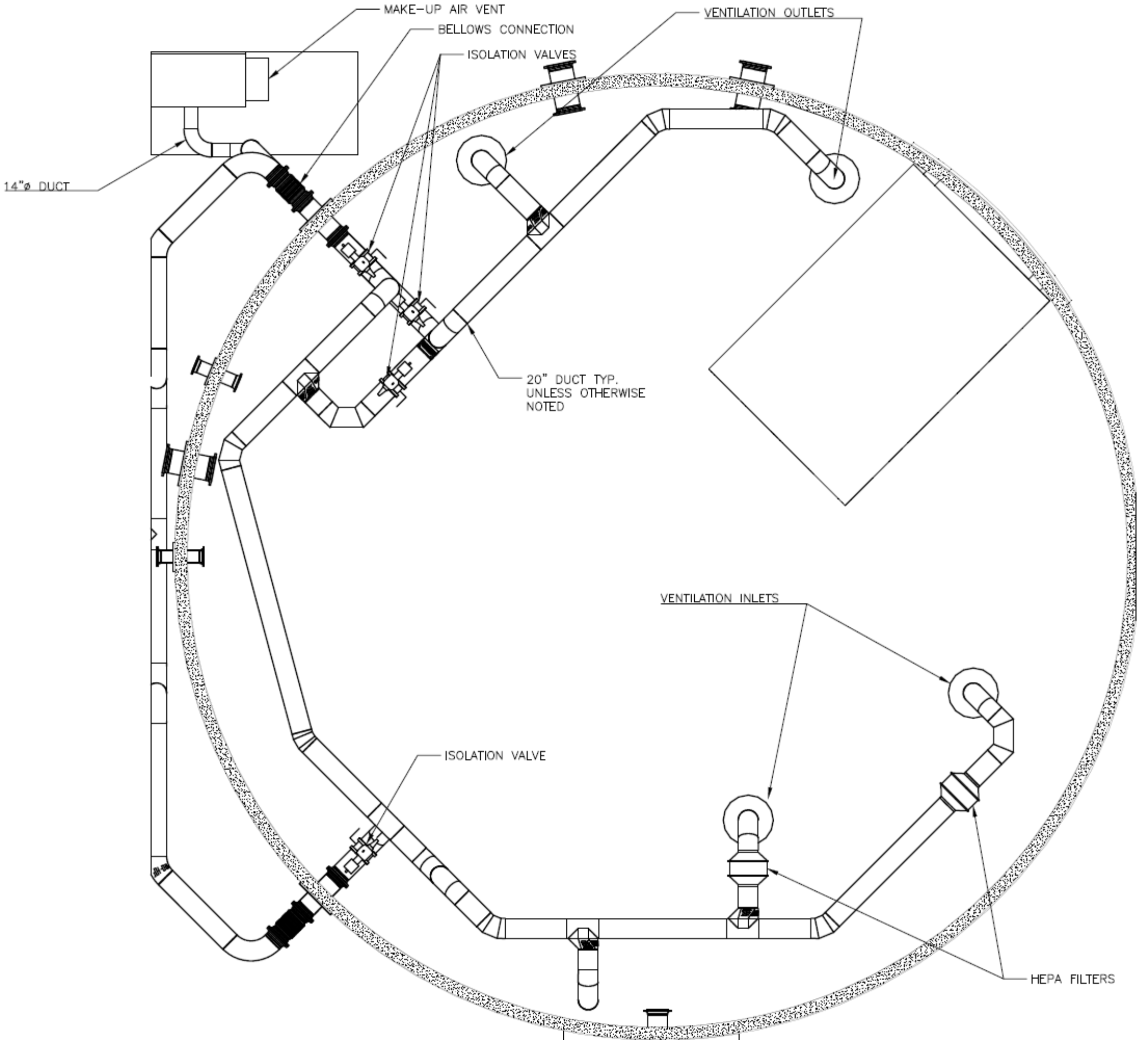


Figure 41. Ventilation system plan view inside containment.

2.1.3.3.1 Supply

Outside air will be provided to the ETB by a typical industrial make up air unit, see Figure 42. This type of unit provides heating, cooling, and filtration for incoming air.

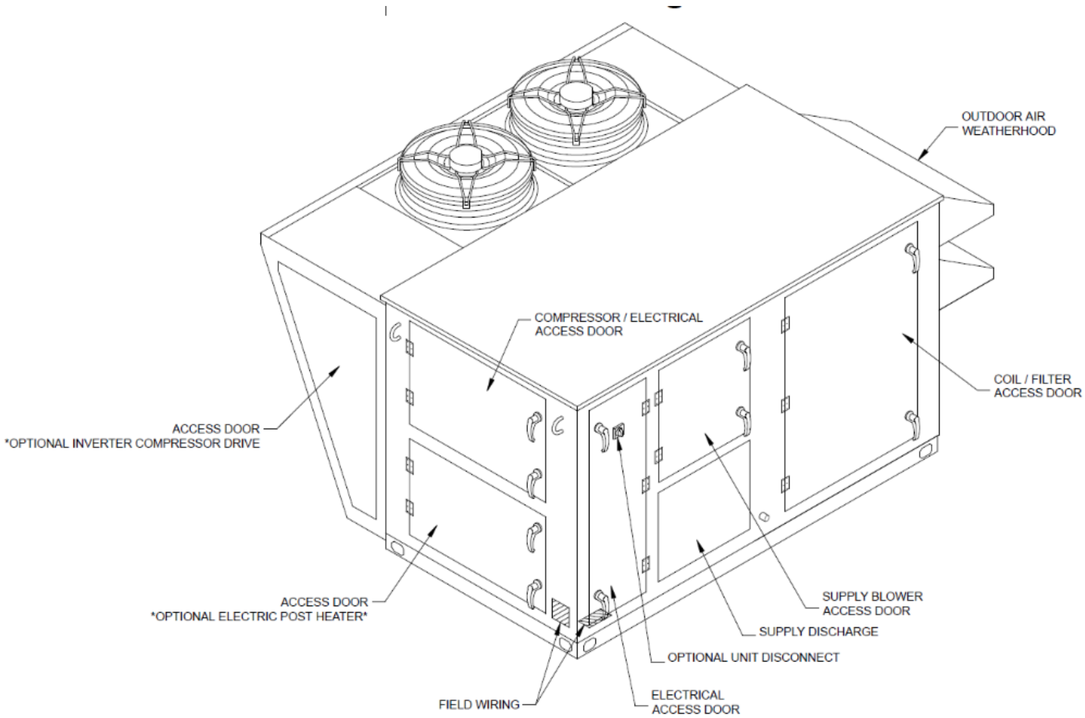


Figure 42. Standard industrial make-up air unit.

The air supply required for the ETB was determined using ASHRAE 62.1, Section 6.2 Ventilation Rate Procedures [5]. The outdoor air intake flow was calculated based on an area of 5000 ft2 with an occupancy of up to 40 people. Using the reference procedure, the required air flow was calculated to be 1300 CFM. A system that can supply 2000 CFM should be installed as it will provide flexibility to increase flow rates, as necessary, for certain construction/installation activities.

Supply will enter the make-up air handing unit (AHU) on the northwest side of the containment. Insulated ducting will connect the AHU to a 20-in. penetration located roughly above the unit. Inside the dome the air will be distributed in a plenum, setting up for a cross-flow pattern across the containment towards the exhaust.

2.1.3.3.2 Control Scheme

During reactor operations the containment will need to be maintained at a slightly negative pressure relative to the exterior ambient pressure. The ventilation control system will monitor differential pressure, flow rates, and radiation levels in the exhaust stack, and take actions to modulate valves/dampers, as necessary. For high radiation levels, it is anticipated that the system will isolate containment, and provide signals to initiate reactor shutdown (either manual or automatic reactor shutdown would be possible).

Supply and exhaust fans with variable speed control (using variable frequency drives) will be provided to deliver a more refined control of the containment differential pressure than can be achieved solely through the use of valves/dampers and bypass. Volumetric flow probes will be installed in strategic locations throughout the system ducting and will be the primary control instrument for the system. It is anticipated that airflows to and from the containment zones will be established during initial system testing and will define the relationship between flow and differential pressure. The system can then use the differential pressure/flow relationships to maintain the containment pressure.

It is envisioned that the control system will maintain constant flow regardless of the potential filter loading and differential pressure across the filters.

2.1.3.3.3 Containment Function

As previously stated, the ETB containment is anticipated to be a safety-class SSC to maintain structure leakage below the defined requirement (1000 ft3/day). To support this function, fast acting, fail-closed valves must be installed at or near the containment penetrations used for supply and exhaust. Both motor-operated and pneumatic valves can satisfy the fail-closed requirement, but pneumatic valves are preferred, all else being equal.

2.1.3.3.4 Exhaust Duct

Ductwork will be in accordance with the Nuclear Air Cleaning Manual, and applicable standards of the Sheet Metal and Air Conditioning Contractors National Association (SMACNA). It is noted that, the Nuclear Air Cleaning manual does not allow use of lock seam or button punch construction even for supply ducting. Use of welded aluminum with bolted flange joints is assumed.

2.1.3.3.5 Stack and Monitor

The use of the ETB as a demonstration reactor test bed creates the potential to emit radionuclides into the environment. Due to this possibility, an air monitoring system will be required. Emissions monitoring requirements are established in 40 CFR 61, subpart H [6].

Subpart H of the National Emissions Standards for Hazardous Air Pollutants requires that a sampling probe be located in the exhaust stack in accordance with criteria established by the American National Standards Institute/Health Physics Society Standard N13.1-2011 [7]. The standard requires that the transport of aerosol particles from a sampling nozzle to a collector or analyzer shall take place in such a manner that changes in concentration and size distribution of airborne radioactive materials are minimized within the constraints of current technology. The monitoring system should be placed in close vicinity to the stack to minimize losses in the transport lines.

Air monitoring probes must be tested to verify that the qualification criteria is met or it must be demonstrated that the monitoring equipment/configuration is comparable to an existing qualified monitoring setup. Qualifying air monitoring probes by using the design of an existing qualified monitoring setup is the preferred approach if possible since it is anticipated to reduce costs. The ETB stack can be similar to Pacific Northwest National Laboratory (PNNL) Stack 296-z-7, as described in PNNL-13687 [8]. This previously qualified stack has typical flow rates of emergency and normal stack flow rates of about 300 and 1550-1800 cfm. Detailed design will ensure that the criteria of ANSI/HPS 13.1-2001 5.2.2.2 [7] are met. A similar strategy (using a different qualified stack) was used for stacks at other MFC nuclear facilities.

For the pre-conceptual design, exhaust enters the fans after passing through a high-efficiency particulate air (HEPA) filtration with a minimum efficiency of 99.95% for particles with a medium diameter of 0.3 μ. The expected flow rate is between 1500 and 2000 cfm with one duty fan and one standby fan. The stack/emission sampling will consist of a continuous record air sampler for particulate radionuclides, a flow monitor, and a continuous alpha monitor device with alarm functions.

The stack has an internal diameter of 15.25 in. and is about 50-ft tall. The approximate number of stack diameters from the top of the stack breach to the sampling nozzle and the test ports is 12.4. The layout of the stack, fans, monitoring cabinet, and HEPA filter is shown in Figures 43 and 44.

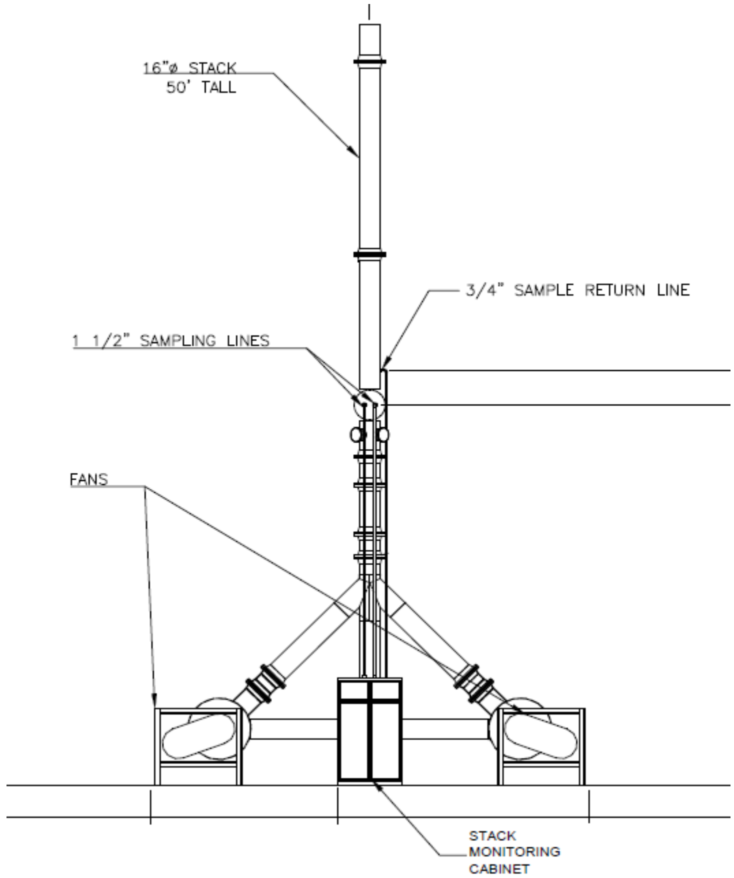


Figure 43. Ventilation system in yard area – view from west.

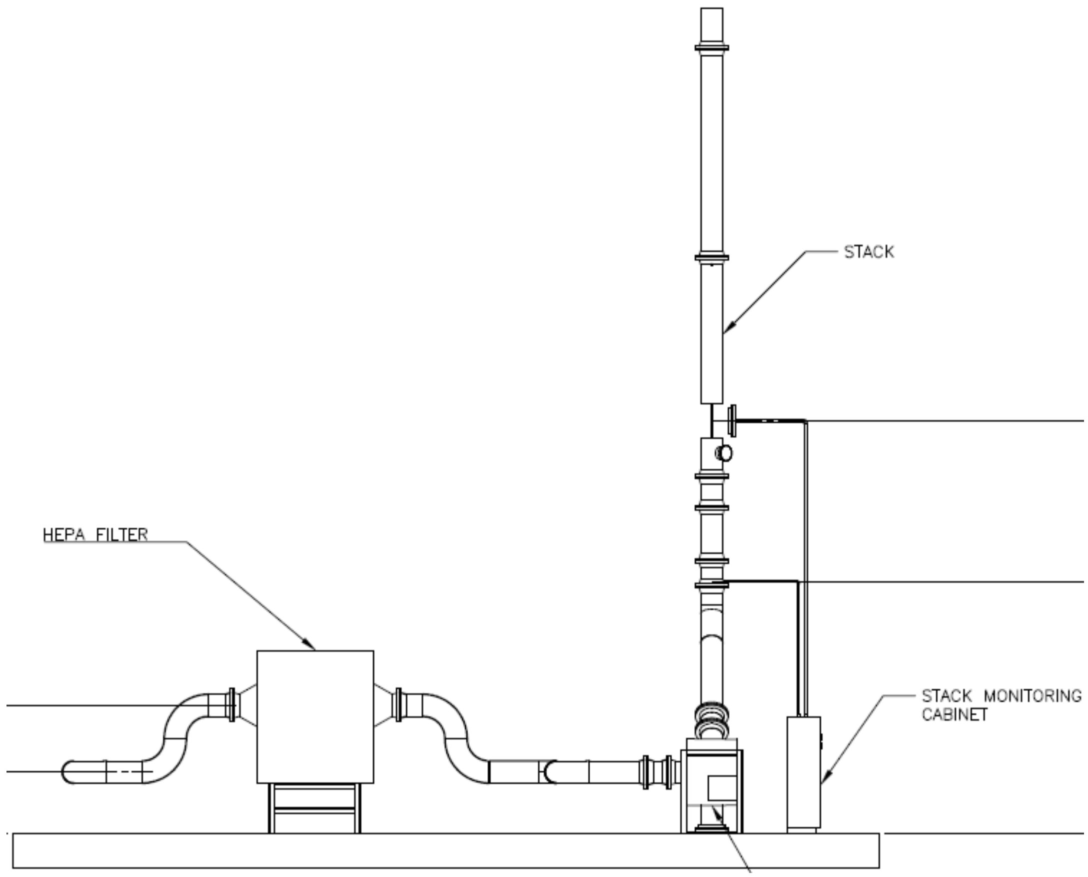


Figure 44: Ventilation system in yard area – view from north.

The new stack will be designed in accordance with the Nuclear Air Cleaning Handbook and applicable SMACNA standards. Stack exit velocity of at least 3000 ft/min is recommended by the Nuclear Air Cleaning handbook to avoid downdraft from winds up to 22 mph, to keep rain out, and to keep condensation from draining down the stack.

2.1.3.3.6 HEPA Filters

It is anticipated that the ventilation exhaust system will be a safety-class SSC for passive filtering of any exhaust during an accident scenario (valve leakage or actuation of the over/under pressure system).

A basic assumption is that only a single stage of HEPA filtration will be required for the basic building ventilation system. If it is determined that further filtration is required that filtration shall be included in the system design. There is also the option to include a second stage of HEPA filters upstream of the exhaust fans on an outdoor skid. Some operations within the facility may require additional filtration due to their nature, but it is assumed that this additional filtration would be provided at or near the point of use. HEPA filtration systems and testing of the final HEPA stage shall be in accordance with the Nuclear Air Cleaning Handbook, ASME AG123, ASME N-50924 and ASME N-51025. HEPA filters will meet DOE-STD-302026. It is noted that ASME N-509 is specifically applicable to nuclear power plants and is therefore considered a "best practices" document rather than a design requirements document, except where INL requirements specify compliance.

The pre-conceptual design utilizes two Flanders G-series HEPA filters in parallel located within the ETB. These filters are rated for 1000 CFM each. In parallel they can support the planned flow through the system. Flanders G-series filters are used in multiple locations at MFC facilities.

G-Series bag-in/bag-out filter housing allows a single filter element (prefilter, HEPA filter, or gas adsorber) to be installed in a low CFM ventilation system. These filter housings are designed for particulate filtration and gas filtration. The G-Series design is built so that the housing can be tested in place, and is flexible, accommodating various arrangements of inlet and outlet ports to fit particular applications.

One of the primary uses of HEPA filters is to contain toxic materials. When filters become contaminated with these materials, it is important that there is a method for the filters' removal without direct operator contact. The bag-in/bag-out feature of the G-Series filter housing allows an operator to change filters without coming into direct contact with the collected toxic materials, including viable organisms, radioactive dust, and carcinogens. Air is supplied to and exhausted from the G-Series filter housing through round inlets and outlets that are connected to the operator's pipe or ducting.

The G-Series filter housing is designed for single filter replacement from the top of the unit. This filter housing can be installed through side access, but it is not recommended that the unit be supported by inlet and outlet connections. Instead, a mounting stand, or some other means of support should be used.

There is no specific diameter for the inlet and outlet connections on the G-Series filter housing since requirements vary considerably. The purchaser or system designer can simply specify the required pipe (or tubing) sizes and lengths. The G-Series inlet and outlet connections can be a standard rolled stainless-steel sheet metal nipple, or optional stainless-steel piping.

The filter-to-housing fluid seal is created between the housing and the filter by means of a continuous knife-edge in the housing. This knife-edge mates into a channel on the upstream (air entering) side of the filter, which is filled with a highly viscous, non-drying, sealing compound. The knife edge seal is guaranteed to pass an in-place DOP test.

2.1.3.3.7 Exhaust Fans

ANSI/AIHA-Z9.5 requires that exhaust fans for laboratory ventilation be located outside the building, preferably on the highest-level roof of the building served. While this standard is not mandatory at INL, it is considered as a set of "best practices." This requirement is based on discharge of chemical fumes and gasses from a chemistry laboratory. The fact that the principal contaminants in the ETB would be particulate, and would be filtered prior to reaching the fans, this requirement can be offset. Location of the fans outside the facility would still be beneficial. Due to the configuration of the facility, the "highest level roof of the building served" is not a practical location. Fans will be located just below the stack, on a pad west of the ETB. The fans will be controlled by a Variable Frequency Drive (VFD) and supply 1000 to 2000 CFM out of the stack.

2.1.3.3.8 Over/Under Pressure Protection

There are several penetrations within the ETB containment that can be used for piping over/under pressure protection. Since the containment is safety-class, pressure relief valves or burst disks will have to comply with NQA-1 requirements and should also conform to the ASME BPVC. Over pressure protection is currently planned to be piped into the ventilation exhaust system. However, further evaluation will need to be performed with specific reactors to determine if further filtration or ducting will be required, prior to venting out the exhaust stack.

The pre-conceptual design for the over/under pressure protection system is a dual acting rupture disk on an existing 20 in. penetration. At this size, the rupture disk can have overpressure ranges above the needed set-point of 24 psig and under pressure burst ranges as low as 0.25 psig (~7 iwc).

Scoping calculations indicate that for a temperature increase of 5°F/min or a pressure increase of 0.1 psig/min a flow rate of between 2500 and 3500 CFM would be needed to relieve the building pressure. A 20 in. pipe can easily support this flow.

2.1.3.4 Containment Sealing and Testing

2.1.3.4.1 Doors

The personnel door into the containment will need to have a re-designed sealing system installed. The previous system/hardware has been removed. Closure and securing mechanisms will also need to be designed that can maintain a positive closure of the door.

The original equipment hatch door has been destroyed, along with the mounting hardware, and the sealing surface integral to the containment steel shell. A concept for a new hatch door and integral missile shield has been developed along with a mounting and opening method. The door concept is shown in Figures 45 and 46. Static seals will be set in grooves on the door side, and the door will be bolted (not shown in the figures) to a flat sealing surface that is an integral part of the hatch opening reinforcement. The bolting will achieve the necessary compression on the seals to maintain leak-tight integrity.

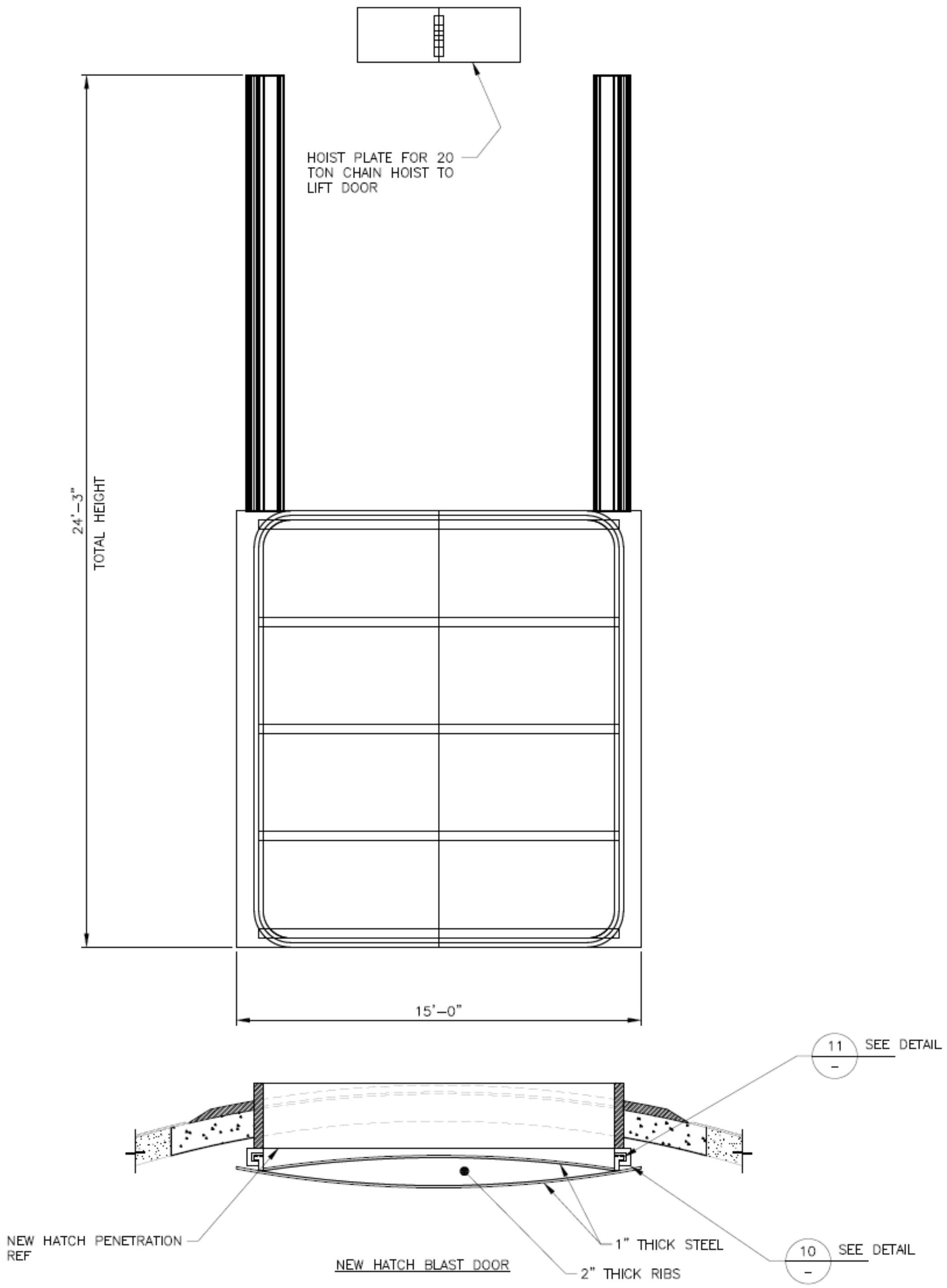


Figure 45. Equipment hatch door concept.

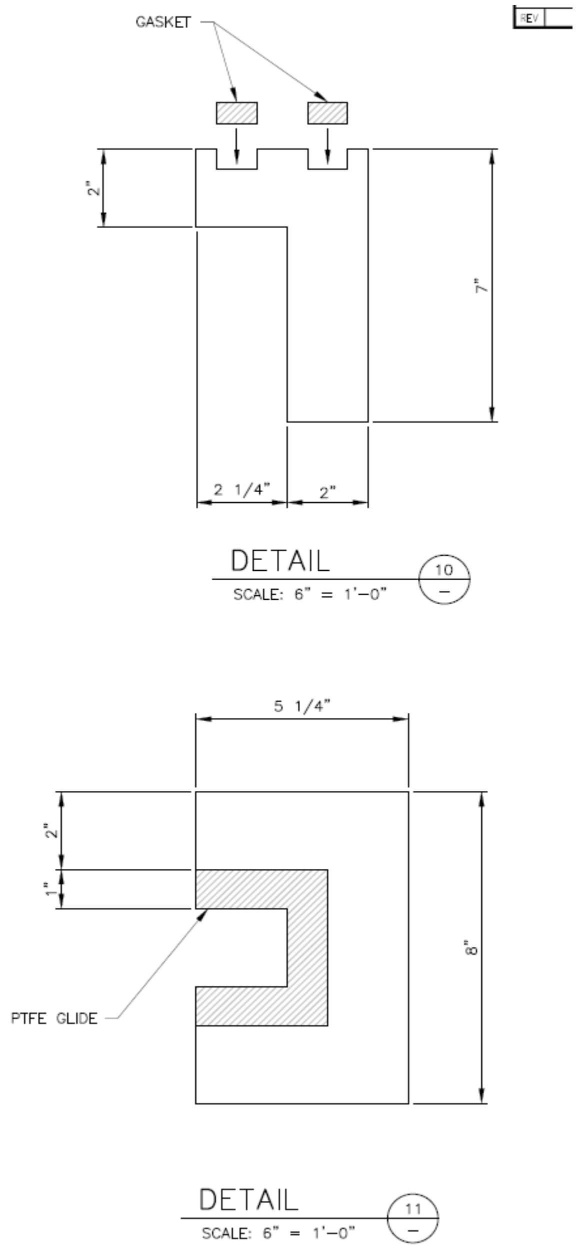


Figure 46. Equipment hatch door – details.

The seal design for both doors should focus on static seals that do not require pneumatics to achieve an acceptable seal. If pneumatics are used, it may result in at least a portion of the pneumatic supply system being a safety-class SSC.

2.1.3.4.2 Leak Test/Pressure Test Accommodations

After modification of the ETB containment, leak testing and pressure testing will be required. Both of these tests will require pneumatically pressurizing the ETB containment vessel with all isolations and doors in place.

As stated in FOR-554, the ETB containment will be restored to the original design requirements; modern code requirements will be used where practical. The original pressure test of the ETB containment was performed at 30 psig and initial leak testing was performed at 20 psig, a leak rate of less than 1,000 ft3 per day.

Post modification pressure and leak tests will be required, but the test pressure needs to be determined. Regularly pressurizing the containment is not recommended due to the large stored energy during the test and the consequences of failure. However, a test program should be developed for the ETB containment to quantify and track both leakage and pressure retaining capability. Consideration should be given to ANSI/ANS-56.8 when developing a testing program.

The original design incorporated features into containment penetrations to allow individual components to be pressure and leak tested, independent of the remainder of the structure. The stated reason for this approach was to avoid pressure tests of the entire vessel. The penetrations designed for mechanical and electrical penetrations have flanges on both ends and would allow for independent pressure testing.

Following this same approach, the personnel door and equipment hatch door should implement features that allow isolated leak testing to be performed. Currently, this is conceived as using a double seal system with a leak test port between the two seals. The space between the two seals can be pressurized for a leak test (helium leak testing or pressure decay testing depending on the sensitivity needed), this is commonly done for various penetrations into hot cell systems at MFC and should be the primary focus for the door seals.

It should be noted that the existing MFC compressed air system does not have sufficient capacity to perform the pressure tests/leak tests of the ETB containment in a reasonable amount of time. Scoping calculations indicate that using the current MFC compressed air system would take between 1.5 and 2 days of continuous usage to reach test pressures. Portable industrial air compressors are recommended for use, to reduce the time needed to pressurize to 6 hours or less.

2.1.3.5 Gas Supplies

2.1.3.5.1 Compressed Air

Compressed air is available for use in MFC-768, located adjacent to the ETB. An NPS 1 line will be tapped off the existing system just downstream of the system dryers and accumulators and will be piped into one of the planned NPS 1 penetrations. The system will be branched from there, as necessary, to support the demonstration reactor and the ETB facility equipment.

Based on discussions with potential demonstrators, the initial use of the compressed air system will only be ETB equipment such as valve/damper operations. A potential installation plan for the compressed air from the existing system to the ETB containment is shown in Figure 47. The exact routing may be different, but the extent of the work is applicable.

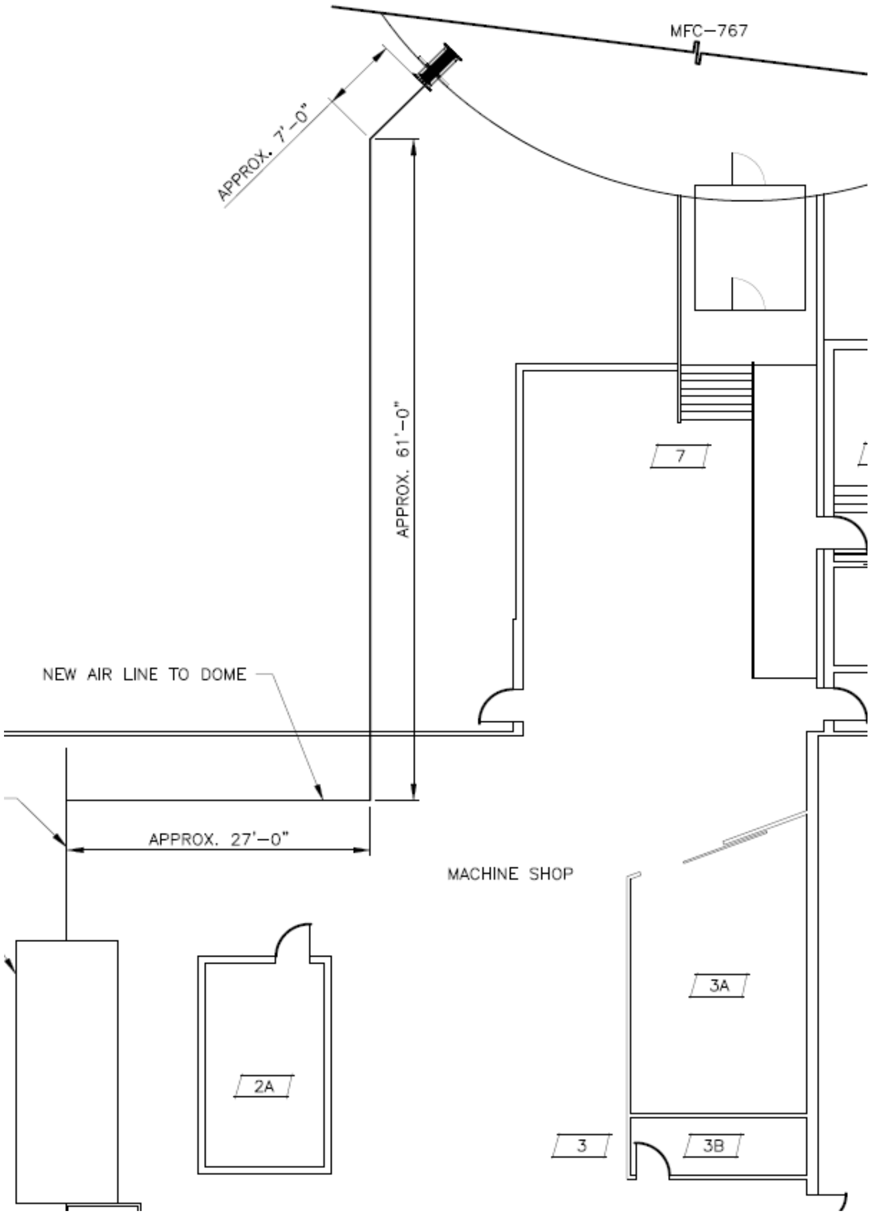


Figure 47. Compressed air installation plan.

2.1.3.5.2 Other (Future Use)

It is anticipated that over the life of the ETB, demonstrators may have a need for other bulk compressed gases such as nitrogen or argon. Provisions have been made for bulk gas use as part of the ETB. The provisions include three NPS 1 penetrations into the dome, and a concrete pad in the yard area that is 32 x 37-ft. This pad is over twice as large as a recently installed pad at MFC for a 6000-gal cryogenic tank and vaporizers.

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

2.1.4 Electrical and I&C Systems

2.1.4.1 Normal Power

Scoping of the ETB cooling system indicated that between 2000 - 2500 amps at 480 V would be required to operate the equipment. The ETB electrical supply was sized to account for this demand. A substation will be installed in the yard area, approximately between the cooling equipment pad and the ventilation equipment pad, but may be located on the ventilation pad.

The supply for the substation will be from the medium voltage switch gear (13.8 kV) on the turbine deck of MFC-768. The 13.8 kV switch gear has sufficient capacity to provide the necessary service to the ETB substation. To supply the substation 15 kV cables will be routed from the turbine deck in conduit down through the floor, through the mezzanine, penetrating the main floor into the cable tunnel, and into cable trays, see Figure 48.

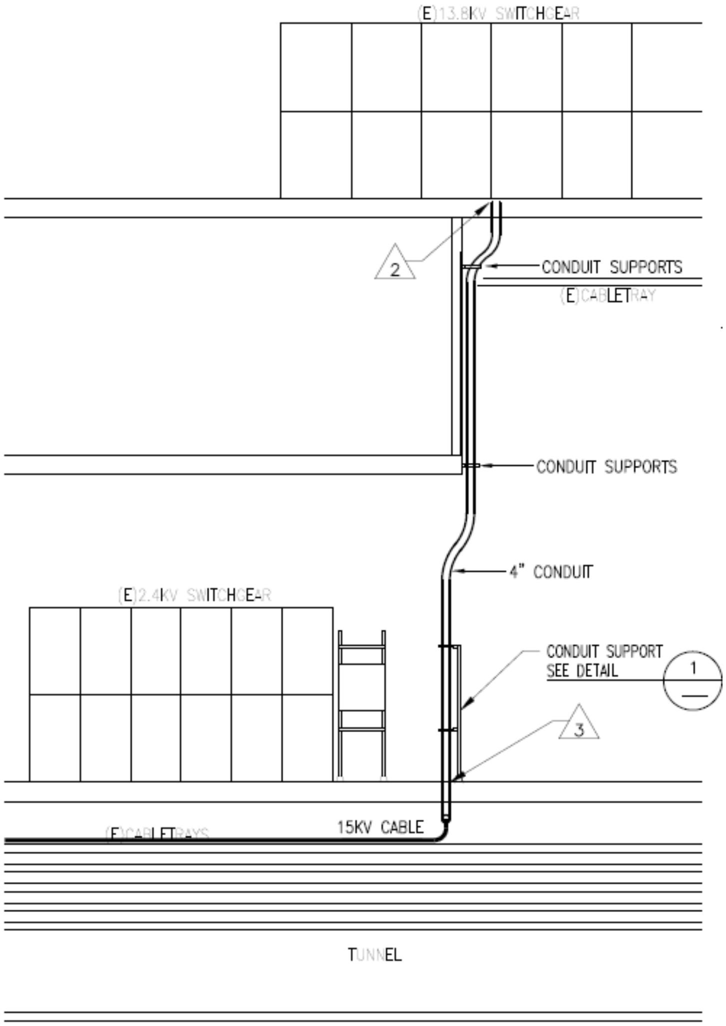


Figure 48. Cable routing from switch gear to tunnel.

The cable will follow existing cable trays until exiting the tunnel into existing duct bank to EM-12. From EM-12 the new duct bank will need to be approximately 20 ft to the west, where the new substation will be installed. From the substation conduit can be routed to the necessary power panels, disconnects, etc. Additional details are in sketches E-1 through E-3, shown in Appendix B. A portion of the one-line diagram is shown in Figure 49.

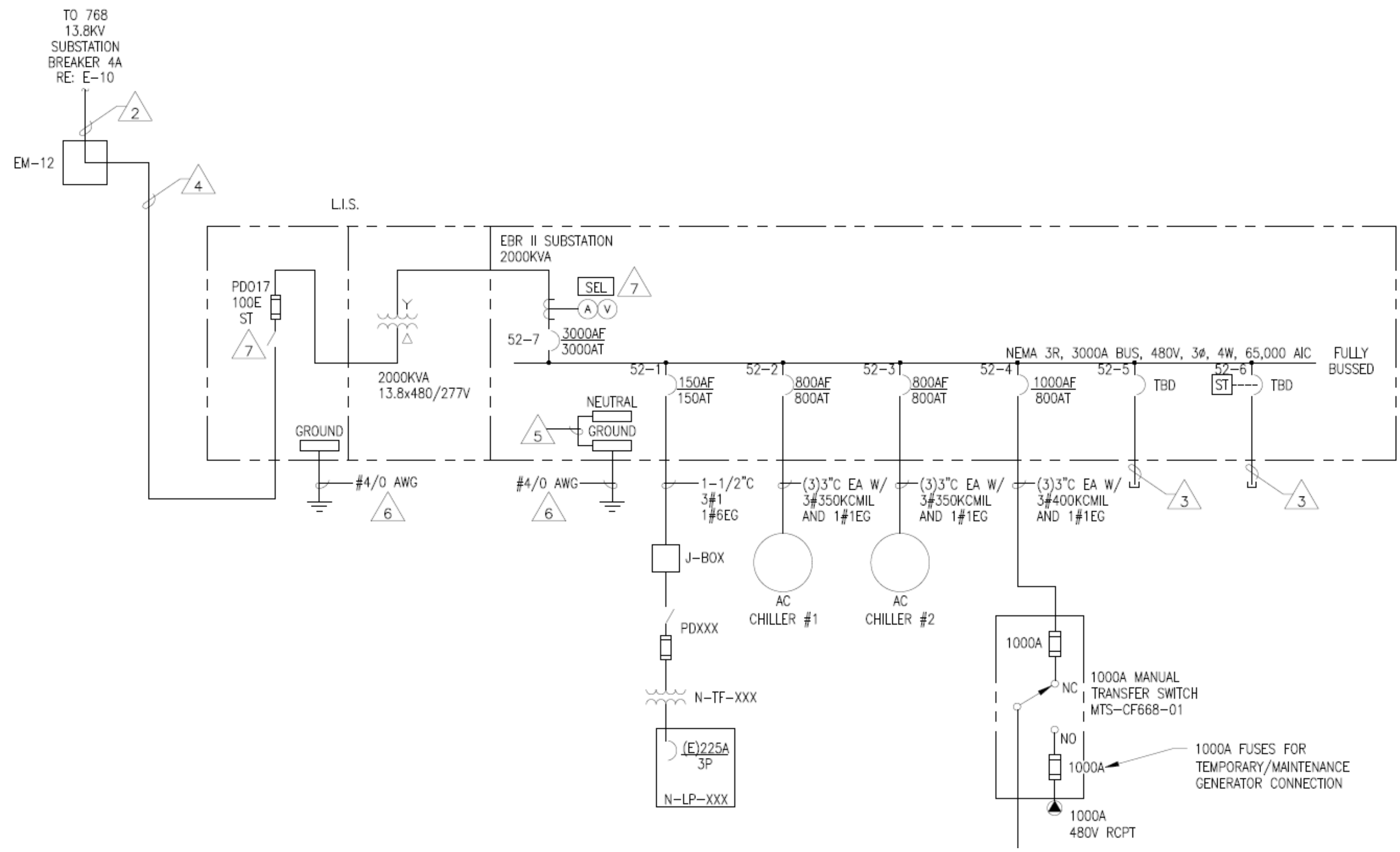


Figure 49. Partial ETB substation one-line diagram.

The largest loads anticipated for the ETB substation are the chillers for the containment air cooling system. There are two chillers that draw 700 amps each totaling 1400 amps. There are five Dowtherm coolers that draw 90 amps each, totaling 450 amps.

Prior to the ETB project, planning was initiated to provide 400 A, 480 V service for base loads inside the containment, install standard lighting, and install electrical outlets. The pre-conceptual design assumes that this electrical service will be provided by others and will be available for powering the designed AHUs for containment air cooling, polar crane, and other miscellaneous equipment needed during reactor installation. There are eight AHUs that each draw 40 amps. The planned electrical service is sufficient since no other loads inside the containment would be running concurrently with the AHUs. Sufficient electrical penetration capacity is planned to support additional power if necessary.

The current temporary power supply to the EBR-II dome is fed from the 2.4 kV switch gear, which has a total ampacity rating of 1200 A. This is insufficient to power the necessary equipment in the ETB yard.

2.1.4.2 Non-Safety Backup Power

Conversations with the anticipated initial demonstrators indicated that a non-safety, backup power supply is not anticipated to be necessary to support reactor operations. Aside from the reactor, the cooling equipment that has been identified in the pre-conceptual design would require large back-up generators (1-2 MW electric based on current equipment sizes) to support operations of all equipment through a loss of off-site power. Rather than design and install back-up generators of the necessary size, a connection to the main cooling system equipment (thermal fluid coolers and pumps) has been included in the design. This decision will likely result in the standard response to loss of off-site power being reactor shut down.

This same concept could be extended or added to other equipment that is part of the ETB. With this design, a demonstrator that desired continuous electrical power, would have the option of supplying a generator, and utilizing the existing connections.

2.1.4.3 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 24 VDC at 50 amperes with a capacity to support up to ten instruments (or equivalent) for up to 72 hours. Each division needs a capacity of 3600 amp-hours. A 72 hr operation span was judged to be sufficient time for any one of several actions to happen, including: 1) restore off-site power, 2) connect an alternate power supply (portable or otherwise) to feed battery chargers, or 3) verify the 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 50.

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

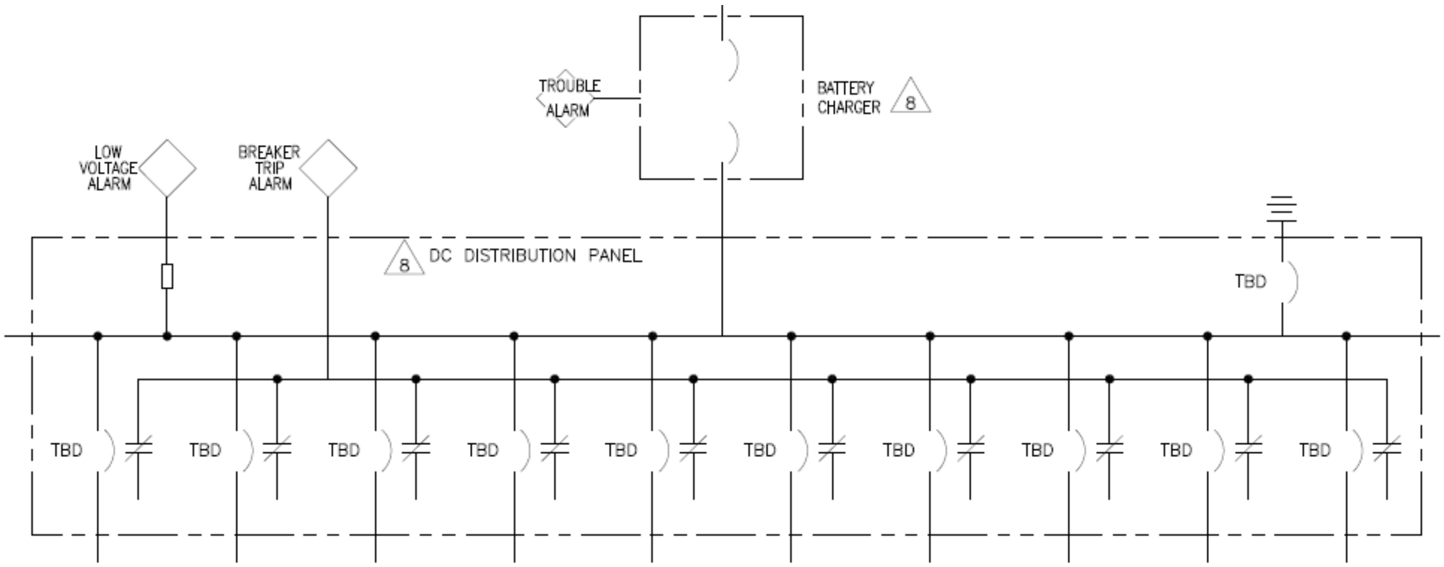


Figure 50. Single division of safety-class batteries.

The first iteration of the battery design included putting the batteries on the mezzanine level of MFC-768 (power plant). However, each cell of batteries weighs about 500 lb, and additional weight will be required for an enclosing structure to ensure independence. Initial scoping calculations by the structural engineer identified that the mezzanine of MFC-768 would not be able to support the weight of the batteries and structures in an SDC-3 event. In addition, it was identified that it is unlikely that the structure without additional weight would be able to survive an SDC-3 without the additional weight.

Consideration was given to putting the batteries on the main floor of MFC-768. The concerns with the surrounding structures ability to survive an SDC-3 event raised additional concerns about demonstrating the battery rooms would be able to survive a potential collapse of the building (2 over 1 event). It was determined that additional engineering effort should not be put into housing the batteries in the MFC-768.

A new battery building was chosen as a solution to the structural issues with MFC-768. A new building seemed to be a reasonable risk reduction for safety-class SSC, and potential cost avoidance by eliminating the need for detailed seismic analysis, the likely design of seismic modifications, and the cost of installing modifications in MFC-768.

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. With the proposed proximity to MFC-768, power will be accessible without much difficulty. The concept for the battery enclosure is shown in the Figure 51 and 52.

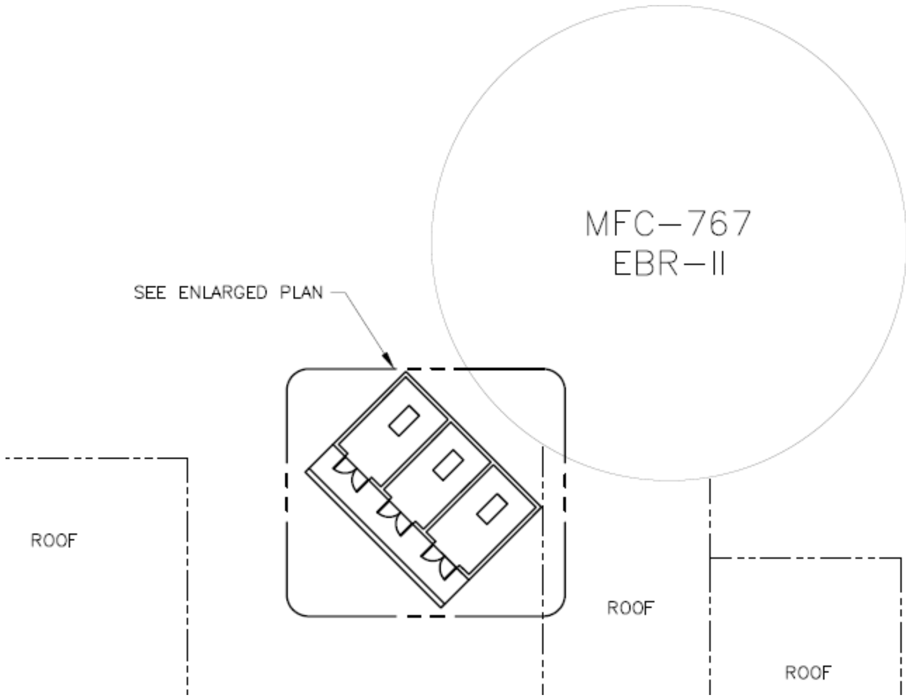


Figure 51. Proposed general location of battery building.

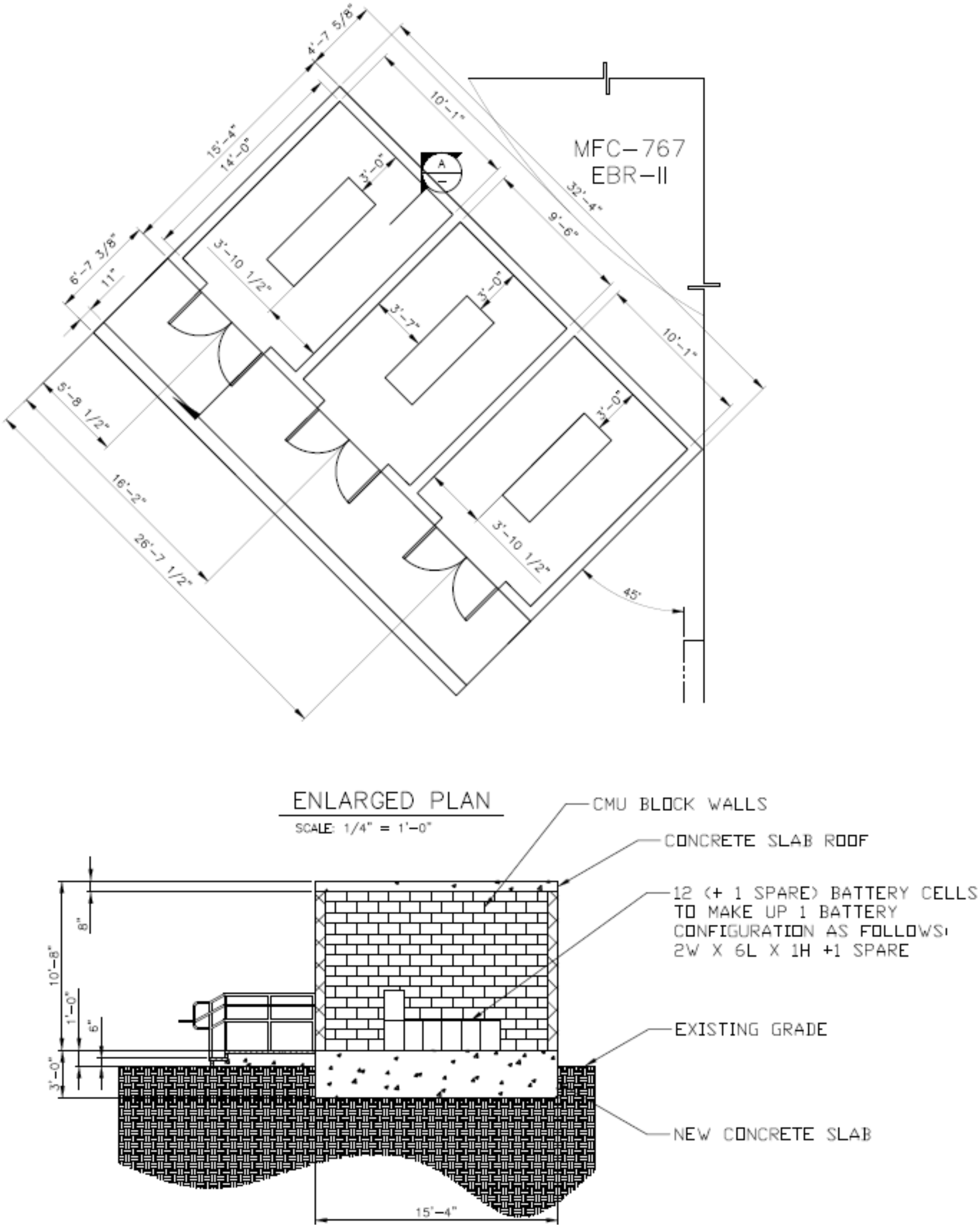


Figure 52. Battery enclosure building details.

2.1.4.4 Cathodic Protection

Prior to D&D efforts commencing, the EBR-II containment had a cathodic protection system. This is a system that protects metal structures from corrosion by making them the cathode of an electrochemical cell. For the EBR-II containment it was an underground system attached to the dome structure.

However, the cathodic protection system for the EBR-II containment has been out of service and not maintained for several years. The current functionality of the remains of the system are not known, and it is unclear whether the system is needed. If the system is needed, it will likely need to be re-built.

The ETB project assumes that the cathodic protection system will be provided by others, if required.

2.1.4.5 Control Room and I&C

Basic ETB control room equipment for controlling systems such as cooling, ventilation, etc. is not a safety-class SSC. Any necessary reactor control and monitoring equipment, safety-class SSC, or otherwise, will be provided by the demonstrator with data integration to the ETB control equipment and the MFC private facility control network (PFCN). The ETB control room will include a programmable logic controller (PLC) that will provide operator interfaces, and control functions of the reactor cooling system and containment ventilation system, along with any necessary isolation valves for containment. The containment 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 has the control room located in MFC-768 just outside the ETB containment, see Figure 53. Currently, this area has out of service equipment installed, is a simple sheet metal structure, and is open to the main floor of the power plant.

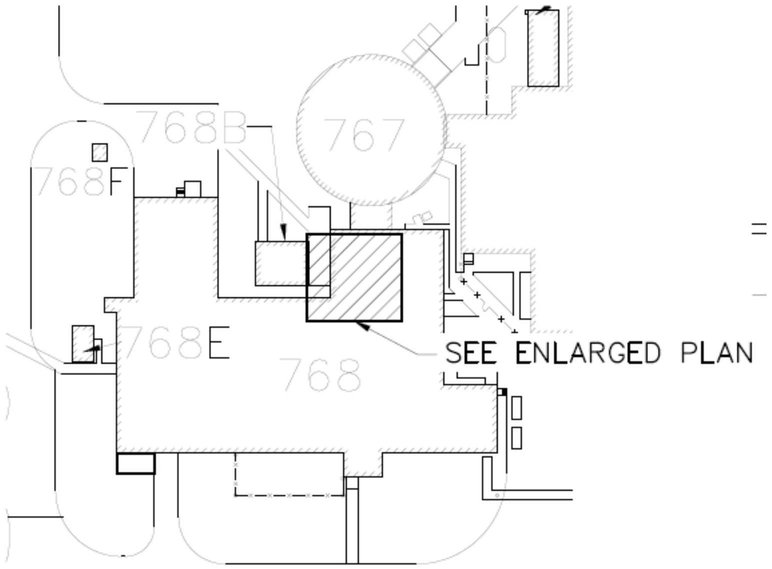


Figure 53. General location of control room.

The area which would be finished and enclosed is shown in Figure 54. To renovate this space into a control room, several actions will be necessary and are listed below.

- Refurbish the roof with insulation and a waterproof membrane
- D&D all remaining equipment in the area
- Level the existing floor to the highest obstruction, or install a false floor
- Frame new walls on the south and east side of the room
- Insulate the exterior walls on the north and west side of the room and cover with sheet rock
- Install flooring, or install false floor
- Route numerous conduits from the control room to the electrical penetrations
- Route conduit and fiber optic cable from the control room to the existing PFCN connections in the power plant
- Provide general telecommunications connections to the room (phone, and INL Intranet)
- Install operator workstations (computers separate from the control system)
- Install furniture (operating consoles, monitor mounts, tables, chairs, etc.)
- Install a service window should be installed to allow communications with the control room personnel without entering.

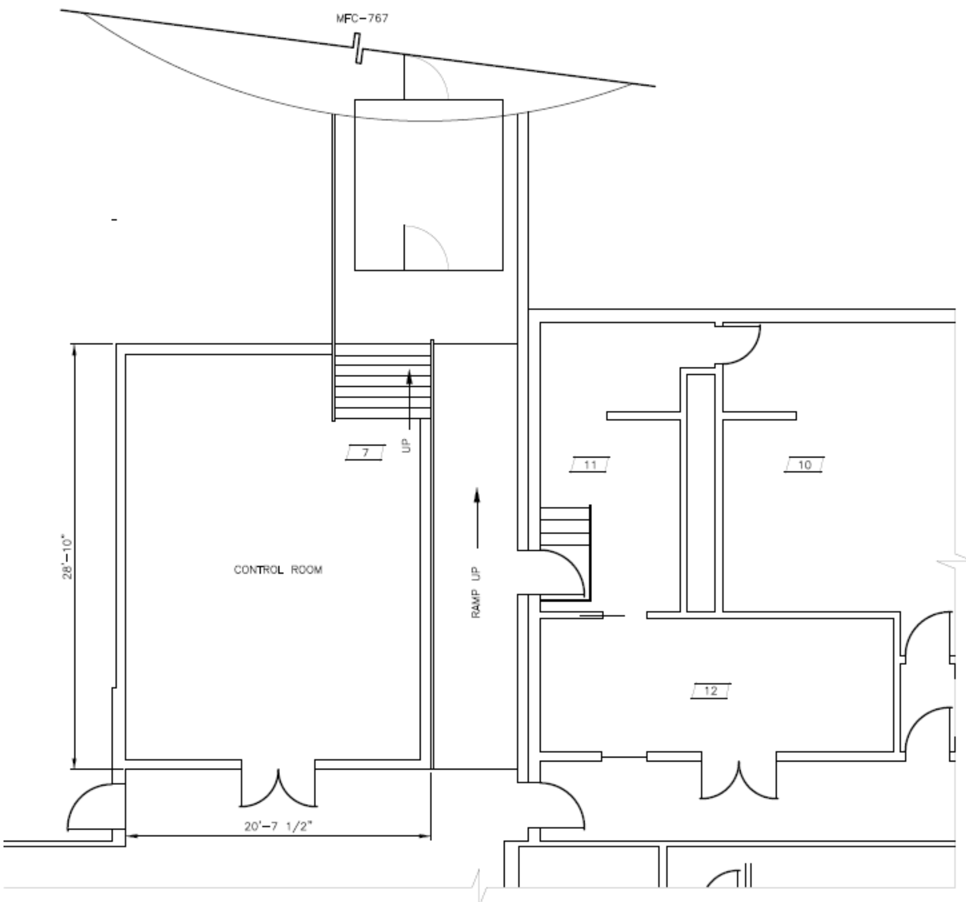


Figure 54. Control Room Location in MFC-768.

The ramp up to the ETB containment should remain open for general access without passing through the control room. The stairs to the containment should be accessible from the control room directly.

In all conceptualized operating scenarios, the reactor operators are outside of the ETB containment and will be available for reactor monitoring since the safety-class containment is anticipated to protect the operators and control room from anticipated accidents. If the applicable data is being sent over and stored on the MFC-PFCN, it could 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.

2.1.4.6 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 ETB.

The system architecture to accomplish the anticipated connection and data transmission are shown in Figures 55 and 56, and a network schematic for the NRIC connection to the MFC-PFCN is shown in Figure 57.

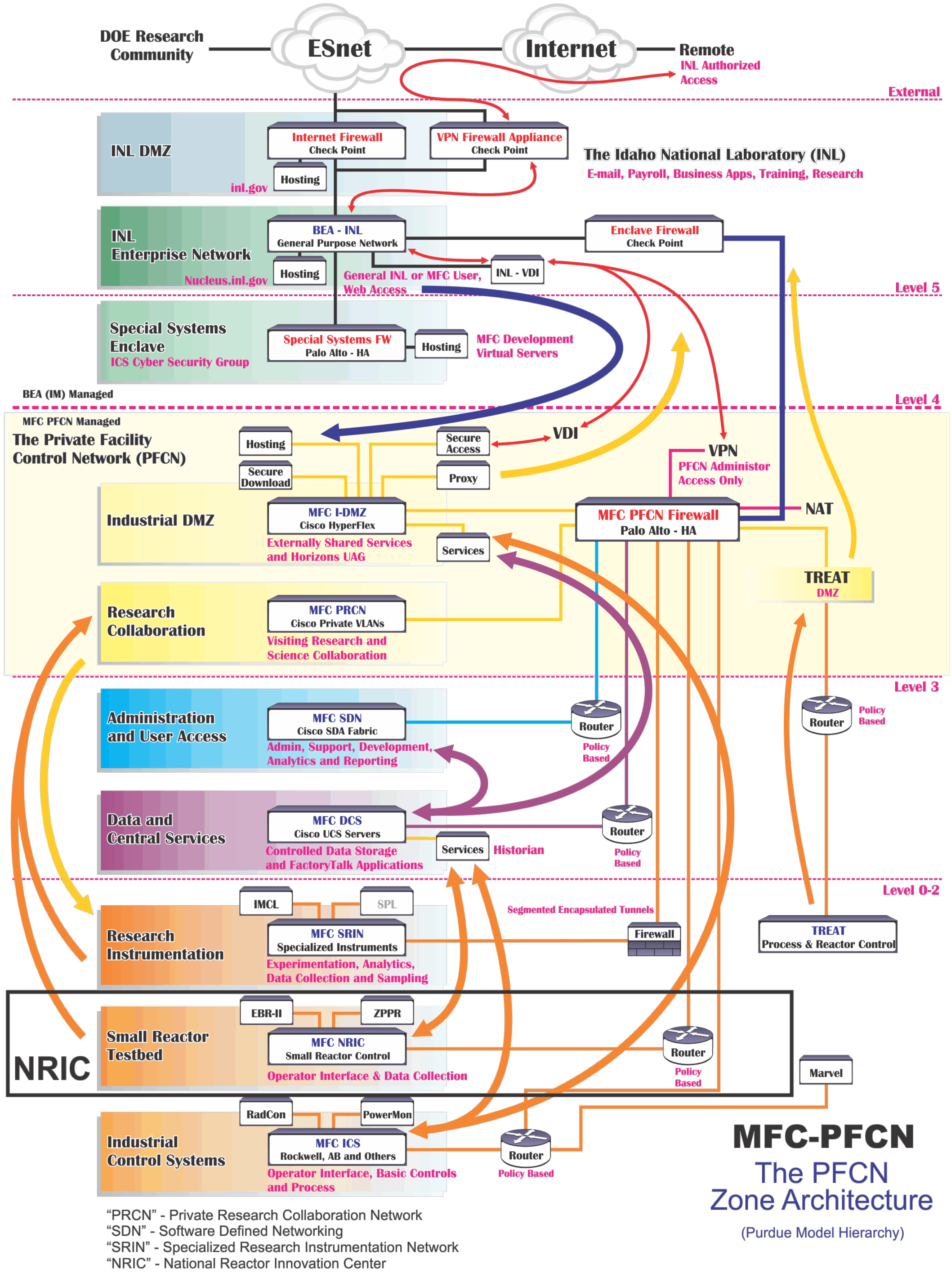


Figure 55. MFC-PFCN zone architecture.

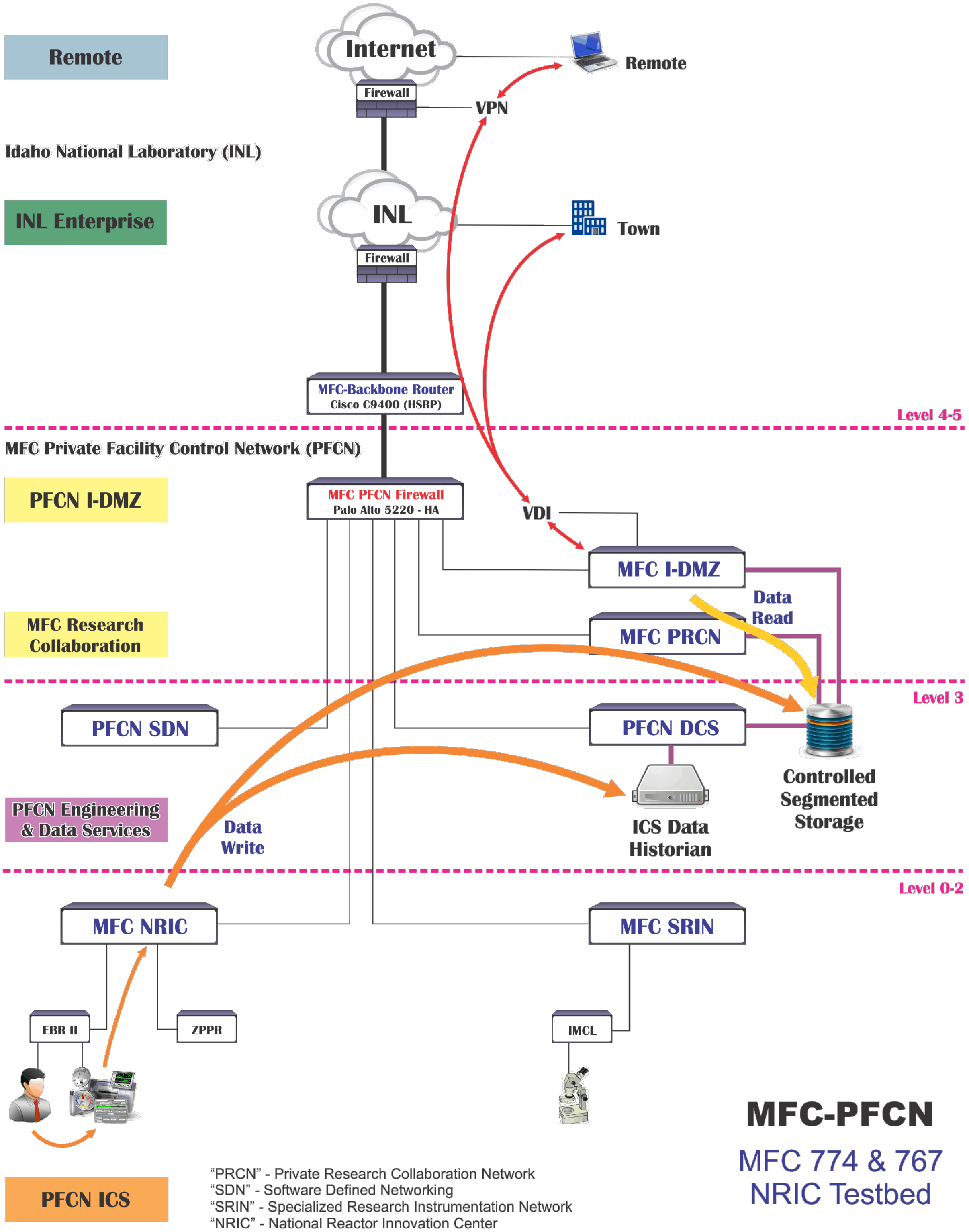


Figure 56. NRIC testbed PFCN architecture.

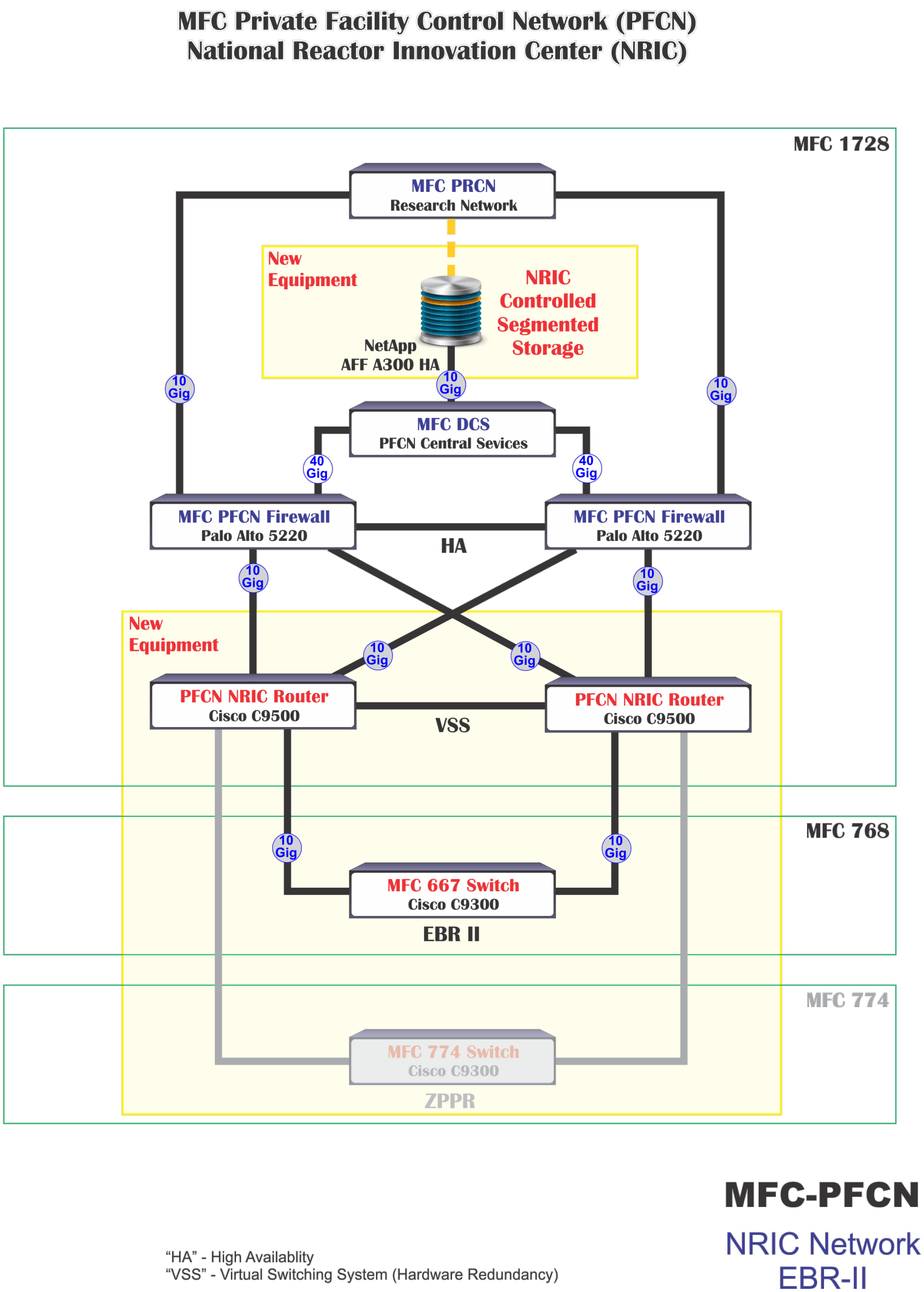


Figure 57. NRIC ETB network.

To accomplish the connection to the MFC-PFCN and data transmission beyond the PFCN, a network cabinet will be required in the ETB control room. In addition, a high availability, controlled storage segment for NRIC and two high availability routers will be required in 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., ZPPR) without duplication of the equipment in the dial room. A draft of the network cabinet needed in the ETB control room is shown in Figure 58.

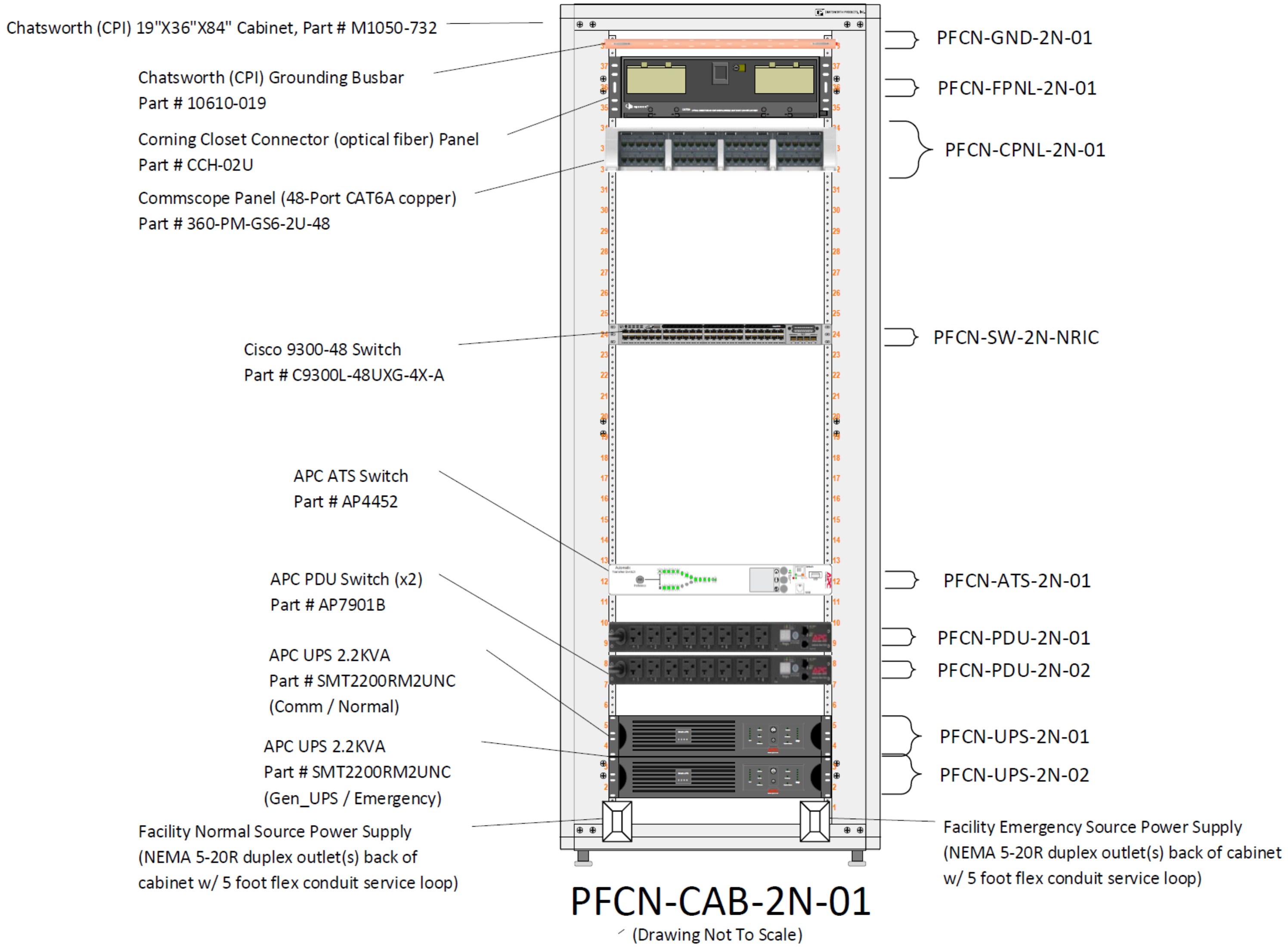


Figure 58. ETB network cabinet.

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

2.1.5 Life Safety

2.1.5.1 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 an "equivalent" means. Several types of active fire suppression systems were considered as part of the ETB 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 as water suppression.
3. Clean Agents (Novec 1230, Halon, Stat-X) – Based on evaluations to date, these systems are ineffective on Class-D fires, such as uranium or sodium.
4. Inerting Systems (CO2/N2) – 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 ETB 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 appears to eliminate options 1-3, above. The ETB containment 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 ETB containment would also 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 for 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 detection systems help provide an equivalent means of protection. Examples of fire detection systems are: smoke detection, heat detection, VESDA, and flame detectors. Each of these fire 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.

2.1.5.2 Oxygen Monitoring

Based on the possibility of having 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 ETB containment is that of MFC-784 (AFF), shown in INL Drawing 815131 [9].

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

2.1.6 Security

A limitation has been set for demonstrators using the ETB that all fuel will be 19.75% enriched uranium or less. With this limitation in place, the ETB will be a safeguards category 4 facility. The requirements are simply to have locked doors, and control access to authorized individuals only. This will be easily accomplished by placing key card access on the personnel doors and placing a simple pad lock on the hatch. A sketch of the access controls for the personnel door is shown in Figure 59. It is envisioned that the access control will be implemented in the breezeway between

MFC-768 (Power Plant) and MFC-767 (Containment Dome). There are already connection points to the MFC security systems in MFC-768, so the conduit runs, and connections will not be extensive.

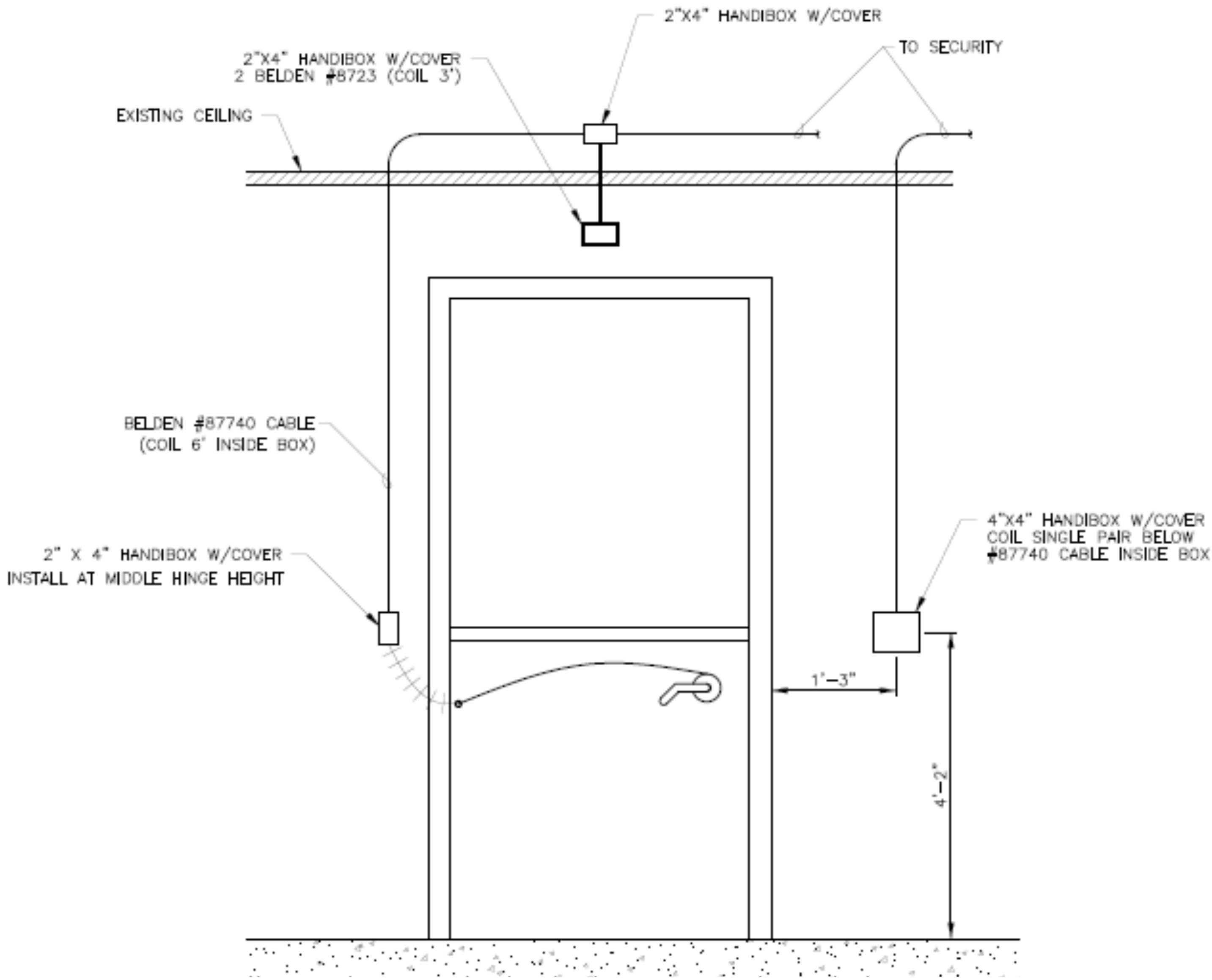


Figure 59. Personnel door access control sketch.

3 Systems Engineering

Systems engineering (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 ETB project 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 60 shows the completed ETB process.

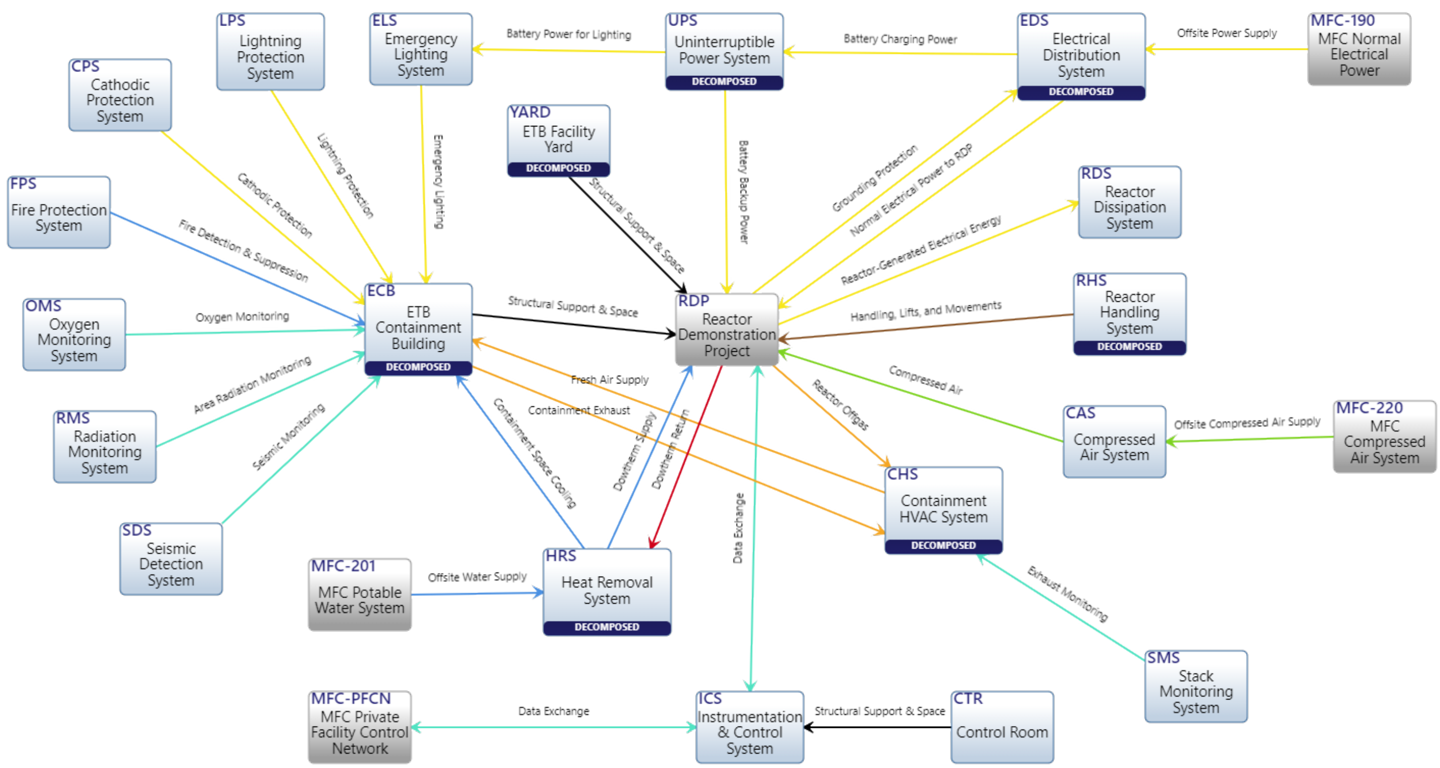


Figure 60. Data architecture for the MBSE process.

4 Cost Estimate

A level 5 cost estimate has been completed to identify expected costs for the renovation of EBR-II and create a test bed for advanced reactor demonstrations. The estimate is based on the pre-conceptual design outlined in this report.

4.1 Work Breakdown Structure

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 better track design documents and costs. 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 C.

4.2 Major Cost Drivers

The major cost drivers are the cooling system, electrical system, and the repair of the polar crane. The design intent was to develop a test bed that was flexible and would accommodate a wide range of advanced reactor concepts. This flexibility comes at a cost. Cost savings could be realized if requirements are relaxed and flexibility reduced. The design meets the identified functional and operational requirements.

The largest single cost is the cooling system. Cooling systems are described in detail in Section 2.1.3. Due to the size of the reactors anticipated to be tested at the ETB, the cooling system is being designed to remove 10 MWt from the reactor and 2MWt from the containment area. As demonstrator designs progress and more detailed information becomes available the size of the systems will be refined and the cost savings may be realized.

The electrical system is another a major cost driver. A primary contributor in the design of the electrical system is the cooling system, the main use of electrical power at the ETB.

Another major cost driver is the requirement for the containment to hold pressure at the design leak rate. The exact cost of this is difficult to identify as it is integral in other aspects of the design such as the penetrations and the hatch door. Installation of the door is not only costly but has significant construction risk as well.

Prior to the EBR-II facility being identified for use as a reactor demonstration test bed the facility was being prepared for D&D. The polar crane was part of this process. To add flexibility and capability to the test bed it is desirable to refurbish the polar crane.

5 Risks and Design Issues in Implementing the EBR-II Test Bed Program

An important part of the ETB will be identifying and managing risks. Identifying and managing risks is an iterative process and will be managed according to DOE and INL procedures. Risks can result in increased design/construction costs or changes in strategy. The risks identified vary in probability and consequence. Risks have been divided into two categories, project risk and design issues. Both risks and design issues will be tracked and managed by the project. The primary difference is an issue has already been realized and work has begun to find a resolution and a risk is a potential issue that may or may not happen and can have a positive or negative impact on the project.

5.1 Project Risks

During the pre-conceptual design risks have been uncovered that could impact the design moving forward. Preliminary probability and consequences have been assigned to the risks and as the project progresses a more detailed and thorough review of the risks and the associated consequences will be completed. The risk matrix, Figure 61, summarizes the qualitative assessment of the identified risks and the probability and consequence rating for each. The risk register in Appendix A shows all the risks identified for the project.

Project risks were analyzed using five categories for each consequence and probability. Definitions of those categories are provided in Table 1 (Consequence) and Table 2 (Probability).

Table 1. 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 2. Probability Category Definitions.

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

	Negligible	Marginal	Significant	Critical	Crisis
Very Likely > 80%					
Likely 60% - 80%		• Risk-021 System Inspection/testing delays	• Risk-014 Demonstrator changes design inputs • Risk-032 Subcontracting delays	• Risk-030 Long lead items delayed	
Somewhat Likely 40% - 60%		• Risk-015 Inadequate INL support staff • Risk-029 RDP uses inappropriate interface	• Risk-003 Inadequate remote handling/tool capability • Risk-016 Cost overrun on test bed system(s) • Risk-019 Installed system components do not meet • Risk-026 Contractor unable to meet requirements • Risk-027 Inclement weather delays construction • Risk-028 Requirements are not properly identified or are		• Risk-023 Funding lapse or delay
Unlikely 20% - 40%		• Risk-017 Emergent issues affect design documents • Risk-025 Inadequate subcontract staff	• Risk-012 Not allowed to use original construction specifications • Risk-013 Delay in crucial component supply chain • Risk-020 Readiness assessment is longer than	• Risk-001 Cell leak rate not met • Risk-007 Fire suppression exemption request not • Risk-018 Quality Components Unavailable • Risk-022 Accident during system installation	• Risk-031 NEPA approval delayed
Very Unlikely < 20%		• Risk-008 Safety class electrical sized incorrectly	• Risk-006 Permit to construct is required	• Risk-002 Seismic design not satified • Risk-004 Reactor module removal not possible • Risk-024 Delay in DSA approval	• Risk-005 Release of volatile fission products

Figure 61. ETB risk matrix.

5.2 Project Issues

A number of project issues have been identified and work has begun in resolving these issues. Some of these issues are detailed below. A complete list of design issues is listed in Appendix D.

5.2.1 Structural

1. If foregoing PWHT is not demonstrated to be acceptable, there are potentially significant cost increases for the installation effort. Contributors to the cost increase are actual performance of the PWHT and the potential to have to replace large portions of rebar and concrete, subject to structural analysis.
2. Since the cathodic protection system has been out of service for several years, the potential for degradation of the subsurface structure exists. If the structure has degraded it could impact the structural integrity of the ETB containment and either reduce or eliminate the structure's ability maintain pressure and/or survive a seismic event.
3. The current capability of the ETB containment structure to meet the leak rate criteria is not known. If leaks exist, especially in inaccessible areas, the criteria may need to be relaxed. This has the potential to impact the safety strategy and/or require imposing additional requirements onto the demonstration reactors to ensure the necessary nuclear safety posture can be met.
4. The joint filler between the containment steel vessel and inner concrete structure has unknown mechanical properties. These properties have to potential to negatively impact the structural analysis. The mechanical property tests need to be performed.

5.2.2 Mechanical Systems

1. The large piping systems include bellows expansion joints attached to the applicable penetration outside containment to isolate piping movement from the containment movement. If in-line expansion joints are not acceptable, larger piping penetrations will need to be used to allow the pipes to pass into containment and still provide the same isolation and sealing capability.
2. The cooling systems pre-conceptual design did not include safety-class isolation valves. This may result in piping inside containment being safety-class. An evaluation between safety-class valves and safety-class piping should be performed and include the potential impact to the safety posture of isolating cooling systems.
3. The most likely areas for leakage to occur are at the existing personnel access door and the new equipment hatch door. The baseline assumption in pre-conceptual design is that basic dual static seals will be sufficient and straight forward to implement. If more complicated sealing systems are required, there will be cost impacts due to the additional equipment and the potential for increased number of safety-class SSC.

4. The joint filler between the containment steel vessel and inner concrete structure has unknown thermal properties. These properties have to potential to negatively impact the decay heat analysis. Thermal conductivity measurements need to be performed.

5.2.3 Electrical

1. The safety-class battery backup was designed to serve a small electrical load 3 days. If a need arises to expand this system to have increased functionality or capacity (longer run time), there may be significant cost increases and increased need for footprint.

5.2.4 I&C

1. 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 ETB (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.

6 System Design Recommendations and Trade Studies

6.1 Design Recommendations

Based on the output of the pre-conceptual design, the following system design recommendations should be considered in the next phase of design.

- There are two aspects of penetration location that should be evaluated in more detail based on the structural analysis. The first is the spacing of penetrations within a group may need to be spaced further apart to reduce stresses. The second is all penetrations should be lowered to the extent possible to allow easier access and reduce the number/complexity of pipe supports.
- Due to the large surface area of concrete pads required, reductions in thickness may result in substantial cost savings relative to the required engineering effort needed to evaluate them. A more detailed analysis of concrete pad thicknesses should be performed.
- Consideration should be given to not replacing concrete removed around new ETB containment penetrations.
- The reinforcement insert for the new equipment hatch is currently pushing the limits (if not beyond) for over road transport and is anticipated to require substantial field assembly. A smaller hatch should be considered to allow shop fabrication and over road transport. This is anticipated to result in lower cost and allow for shop machined sealing surfaces which will reduce the possibility of leakage.
- A detailed evaluation of the amount of air cooling needed inside the ETB containment should be performed. A reduction in the cooling system capacity is likely possible and would result in reduced costs by reducing the size/number of chillers and reducing the

size/number of AHUs inside containment. In addition to cost reduction additional space inside containment will be available with a reduction of system size. If the level of air cooling required can be demonstrated to be low enough, it may be possible to upsize the ventilation system air supply to perform dual functions of cooling the containment air for personnel and to dissipate heat during reactor operations.

- The cooling system piping and ventilation exhaust ducting arrangements need further refinement. The following changes should be made in the next phase of design:
  - The ventilation ducting should conform more to the inner surface of the containment
  - The ventilation exhaust should leave containment through the existing 20 in. penetration on the south side of the containment and one of the 20 in. ventilation penetrations should be eliminated.
  - The chilled water piping inside containment should not be routed through the north-east quadrant of containment since this will be the main travel path for reactor demonstration modules and could interfere with lifting activities with the polar crane.

6.2 Recommended Trade Studies

Along with the design recommendation identified for future work, some trade studies have been identified which will refine the design alternatives and better understand the requirements. Based on the results of the trade studies the functional and operational requirements may be revised and system designs will be refined. The identified trade studies include:

- Module handling system strategy
- Heat removal strategy
- Containment pressurization and access evaluation
- Reactor activation and shielding requirements
- Systems control strategy

7 References

1. Department of Energy. (2016). *Integration of Safety into the Design Process*, DOE-STD-1189-2016. (https://www.standards.doe.gov/standards-documents/1100/1189-astd-2016 : accessed September 24, 2020)
2. American Society of Mechanical Engineers International. (2019). *2019 ASME Boiler and Pressure Vessel Code (ASME BPVC), Section VIII*.
3. Koch, L. J.; Monson, H. O.; Okrent, D.; Levenson, M.; Simmons, W. R.; Humphreys, J. R. et al. Hazard Summary Report Experimental Breeder Reactor II (EBR-II), Volume I, Appendix E, May 1957; (https://digital.library.unt.edu/ark:/67531/metadc11523/ : accessed September 24, 2020)
4. Payne, S. J.; Development of Rock and Soil Design Basis Earthquake (DBE) Parameters for the Materials and Fuels Complex (MFC), April 2006. INL/EXT-05-00925
5. American Society of Heating, Refrigerating and Air-Conditioning Engineers. (1973). ASHRAE standard: standards for natural and mechanical ventilation, Section 6.2 Ventilation Rate Procedures. New York: The Society,1973
6. Code of Federal Regulations. 40 CFR 61, Subpart H—National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities
7. N13.1-2011, "Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stack and Ducts of Nuclear Facilities".
8. J. A. Glissmeyer; A. D. Maughan; Qualification Tests for the Air Sampling System at the 296-Z-7 Stack, October 2001. PNNL-13687
9. INL Drawing No. 815131, "MFC-784 AFF Atmospheric Oxygen Monitoring System Control Cabinet AFF-CP-001 Schematic", Revision 2, May 30, 2019.
10. FOR-554, "EBR-II Dome Modifications to Support Demonstration Reactors", Revision 0. July 9, 2020.

Appendix A

Risk Register

Number	Name	Description	Risk Type	Status	Strategy Method	Risk Owner	Identified Trigger Event	Probability	Consequence	Consequence Description
Risk-001	Cell leak rate not met	The design pressure of the dome is 24 psig with a 1000 ft3/day leak rate. This is a safety design criteria. Leakage could happen through the floor that has been poured on top of the old basement, through penetrations, through the hatch, etc.	Technical	Open	Mitigate	Installation Project Team	Initial testing of ETB (without the reactor) does not meet the specified leak rate.	30	60	
Risk-002	Seismic design not satisfied	The structure might not meet seismic design category (SDC)-3 as required by the F&OR.	Technical	Open	Mitigate	Engineering Design Project Team	Structural analysis concludes that the cell structure does not meet SDC-3	10	70	
Risk-003	Inadequate remote handling/tool capability	Remote handling system not compatible with multiple reactors for fuel removal and maintenance.	Technical	Open	Avoid	INL Technical Leadership	A demonstrator designs a module that exceeds the weight/lifting limitations of the reactor handling system.	50	50	Reactors are not able to be maintained, repaired or defueled.
Risk-004	Reactor module removal not possible	The reactor module has high levels of radiation or the test bed does not support the demonstrator's plan to remove the reactor.	Technical	Open	Mitigate	INL Technical Leadership	Demonstrators communicate specific requirements for reactor removal operations that require significant design changes.	10	70	Due to the high levels of radiation personnel are not able to enter the containment area and remove the reactor, impacting the ability of the test bed to meet its target of one demonstration per year.
Risk-005	Release of volatile fission products	Release of volatile fission products as a result of a major accident.	Technical	Open	Mitigate	INL Technical Leadership	Off-normal reactor event	5	100	ETB containment is contaminated and contamination is released to the environment and surrounding area.
Risk-006	Permit to construct is required	A permit to construct might be required if expected radionuclide emissions exceed certain standards.	Technical	Open	Accept	INL Technical Leadership	Preliminary work with potential demonstrators yields the expectation that a permit to construct will be required	10	50	Delay in schedule for permit application process and approval.

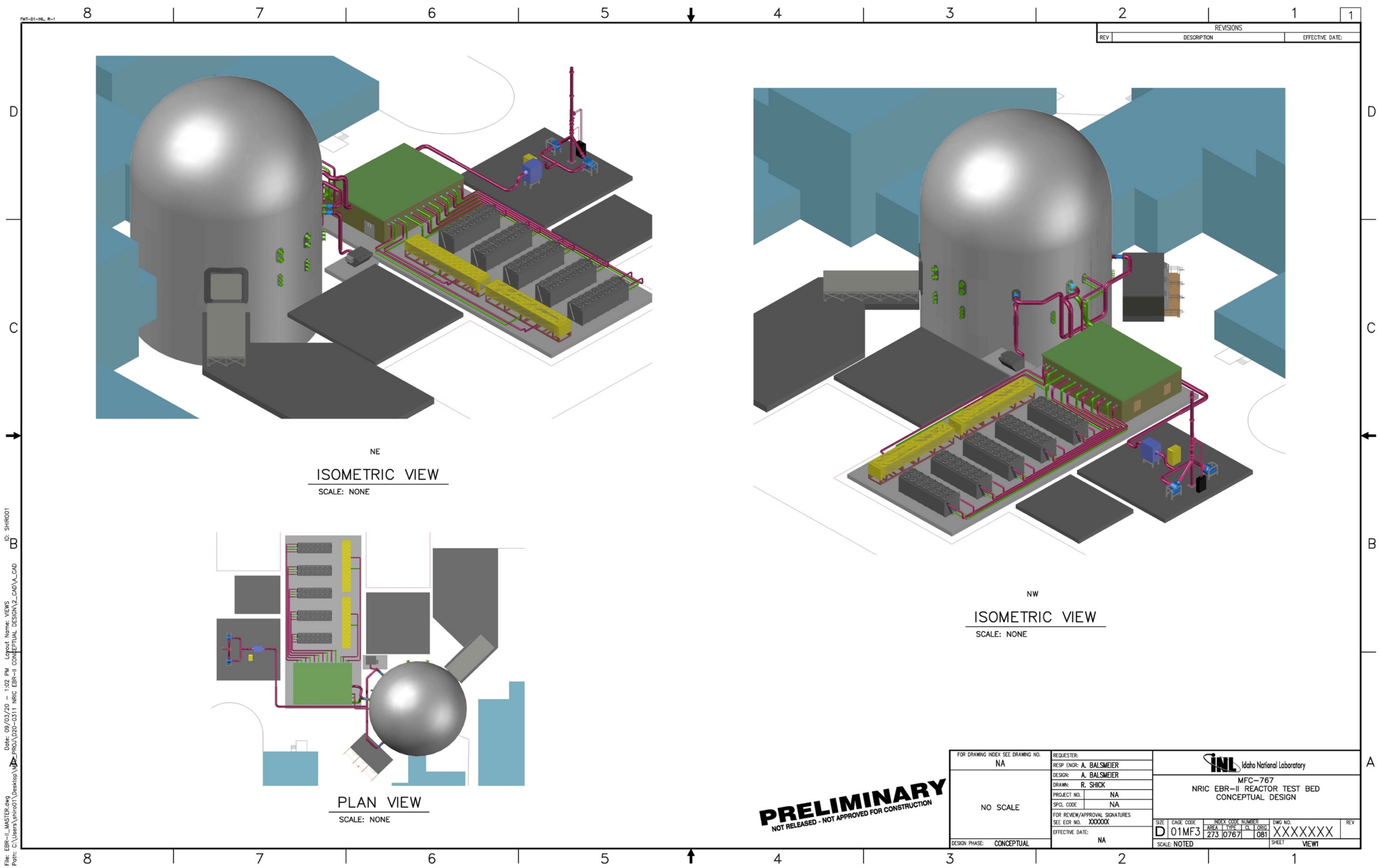
Number	Name	Description	Risk Type	Status	Strategy Method	Risk Owner	Identified Trigger Event	Probability	Consequence	Consequence Description
Risk-007	Fire suppression exemption request not approved	Fire suppression is necessary to meet code but may be difficult to realize. A DOE-HQ fire exemption might not be available by the start of reactor testing or may not be approved	Technical	Open	Accept	INL Technical Leadership	DOE does not grant an exemption or there are significant delays in the process.	30	60	Delay in test bed start up.
Risk-008	Safety class electrical sized incorrectly	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	Open	Transfer	INL Technical Leadership	A demonstrator expressed a need for additional Class 1E backup power.	5	30	
Risk-009	Reactor cooling system inadequate	The ETB reactor cooling system is not compatible with multiple reactor concepts	Technical	Open	Mitigate	INL Technical Leadership	The reactor produces too much heat	20	50	Significant modifications are required to the cooling system before a demonstration reactor can be tested.
Risk-010	Containment HVAC inadequate	The containment's HVAC system is not compatible with multiple reactor concepts.	Technical	Open	Mitigate	INL Technical Leadership	The reactor produces too much heat	10	60	The HVAC system is not able to remove enough heat from the containment and the containment area overheats causing damage to the structural integrity of the dome.
Risk-011	Excessive activation of ETB	Inadequate shielding may cause undue activation of the containment facility and support equipment	Technical	Open	Transfer	INL Technical Leadership	The reactor does not have sufficient shielding	20	80	Personnel are not able to enter the containment and perform maintenance on the reactor or facility equipment or prepare the reactor module for removal.
Risk-012	Not allowed to use original construction specifications	Original construction specifications are not allowed to be used and design and construction must meet all current design codes. The ETB may not meet current code requirements without significant modifications.	Business	Open	Accept	INL Technical Leadership	AHJ determines COR is invalid after design activities have begun.	20	50	The ETB may not meet current code requirements without significant modifications and cost
Risk-013	Delay in crucial component supply chain	Crucial components are unavailable for procurement without supply chain development	Technical	Open	Mitigate	INL Technical Leadership	Crucial component is identified with no alternatives, as unavailable without supply chain development	30	50	
Risk-014	Demonstrator changes design inputs	Postulated user requirements change which require functionality changes and require redesign	Programmatic	Open	Mitigate	INL Technical Leadership	Potential sysem user provides new testing requirements beyond designed capability at a late stage of design	70	50	

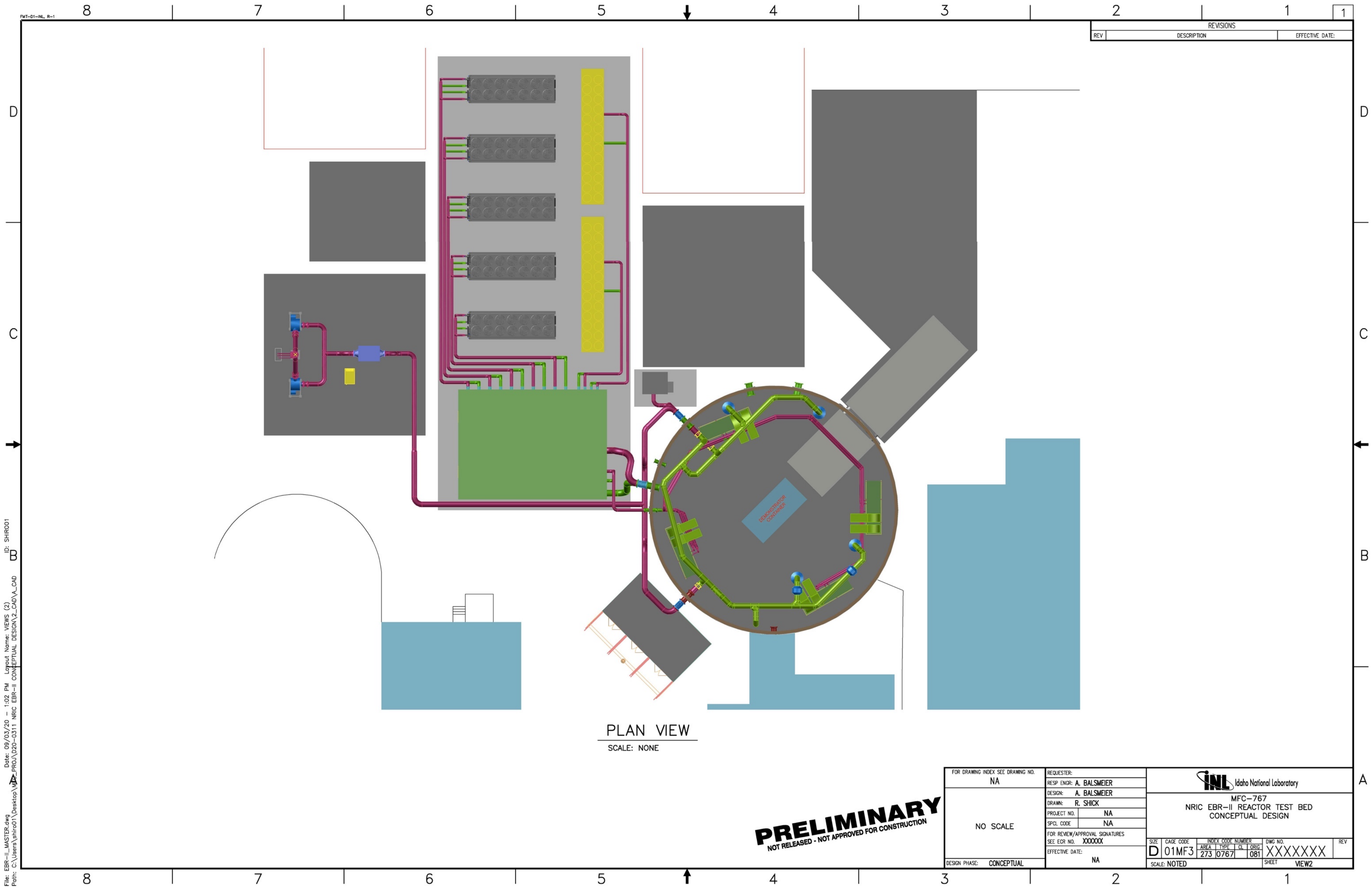
Number	Name	Description	Risk Type	Status	Strategy Method	Risk Owner	Identified Trigger Event	Probability	Consequence	Consequence Description
Risk-015	Inadequate INL support staff	Lack of available technical resources creates schedule delay	Programmatic	Open	Mitigate	INL Project Management	Resources unavailable to support project schedule	50	30	
Risk-016	Cost overrun on test bed system(s)	Rework is required or inaccurate cost estimates were provided for loop components	Programmatic	Open	Mitigate	INL Project Management	Vendor submits contract change request due to fabrication difficulties, etc.	50	50	
Risk-017	Emergent issues affect design documents	Rework is required on design documents (revisions, etc.) due to unexpected and required design changes	Technical	Open	Accept	INL Technical Leadership	New requirement to be incorporated into design identified	30	30	
Risk-018	Quality Components Unavailable	The project cannot procure, fabricate, or validate components to NQA-1 standards	Technical	Open	Mitigate	INL Project Management	Supplier of component cannot meet NQA-1 requirements	30	70	
Risk-019	Installed system components do not meet specifications	Schedule delays and possibly cost overruns occur due to difficulty in installing and testing components	Technical	Open	Mitigate	Installation Project Team	Supplied part fails acceptance/receipt inspection	40	50	
Risk-020	Readiness assessment is longer than planned	Scope, cost, or schedule of readiness assessments increases beyond baseline plan	Programmatic	Open	Mitigate	INL Project Management	Negative SPI/CPI trend on work package or scope add	30	50	
Risk-021	System Inspection/testing delays	Problems encountered during initial system inspections require additional schedule time to complete test bed startup	Technical	Open	Accept	Installation Project Team	System inspections yield unsatisfactory results	60	30	
Risk-022	Accident during system installation	Schedule delays incurred due to accident during system installation	Business	Open	Mitigate	INL Project Management	Accident occurs at facility	30	70	
Risk-023	Funding lapse or delay	DOE Programs supporting the implementation of ETB lose/reduce funding to the ETB program	Business	Open	Accept	INL Project Management	NRIC National Technical Director informs project of expected funding lapse	40	90	
Risk-024	Delay in DSA approval	Delay in obtaining vital information need to complete the DSA or other issues causes the submittal, review or approval to be delayed.	Technical	Open	Accept	INL Technical Leadership	DOE rejects ZTB documented safety analysis	10	70	Delay in approval of the DSA could result in substantial delays or cost increases
Risk-025	Inadequate subcontract staff	Lack of available technical resources creates schedule delay	Programmatic	Open	Mitigate	INL Project Management	Resources unavailable to support project schedule	30	30	
Risk-026	Contractor unable to meet requirements	Schedule delays and possibly cost overruns occur due to challenges with contractors meeting technical requirements included in contracts	Programmatic	Open	Transfer	INL Project Management	Supplier initiates contract change request	40	50	

Number	Name	Description	Risk Type	Status	Strategy Method	Risk Owner	Identified Trigger Event	Probability	Consequence	Consequence Description
Risk-027	Inclement weather delays construction	Inclement weather (wind/rain/cold, etc.) delays system installation schedule.	Programmatic	Open	Mitigate	INL Project Management	Anticipated weather conditions do not meet required installation/construction environmental conditions	50	50	
Risk-028	Requirements are not properly identified or are overlooked	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. Demonstrator or NRIC requirements are not clearly defined.	Technical	Open	Mitigate	INL Technical Leadership	Requirement identified that requires additional project scope to be completed	50	50	
Risk-029	RDP uses inappropriate interface assumptions	RDPs are being designed in parallel with ETB. Interfaces, physical or otherwise, between the ETB and an RDP may not be adequately captured during the design phase.	Technical	Open	Mitigate	INL Technical Leadership	Initial RDP encounters interface issues with ZTB	50	30	
Risk-030	Long lead items delayed	Long lead items cannot be ordered early enough in the project to meet expected project end date	Technical	Open	Mitigate	INL Project Management		70	70	
Risk-031	NEPA approval delayed	The NEPA process takes longer than expected or is not approved.	Business	Open	Accept	INL Project Management	NEPA process delay or rejection	30	90	
Risk-032	Subcontracting delays	Issuing subcontracts requires more schedule time than planned	Programmatic	Open		INL Project Management		70	50	
Risk-033	Inert gas leak to containment	Some reactors may use an inert cover gas in the reactor module. This gas could potentially leak out of the module and into the containment dome.		Open		Other		30	0	Inert gas could displace oxegyn in the containmet area creating an unsafe environment for personnel.

Appendix B

Drawings and Sketches

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MFC-767
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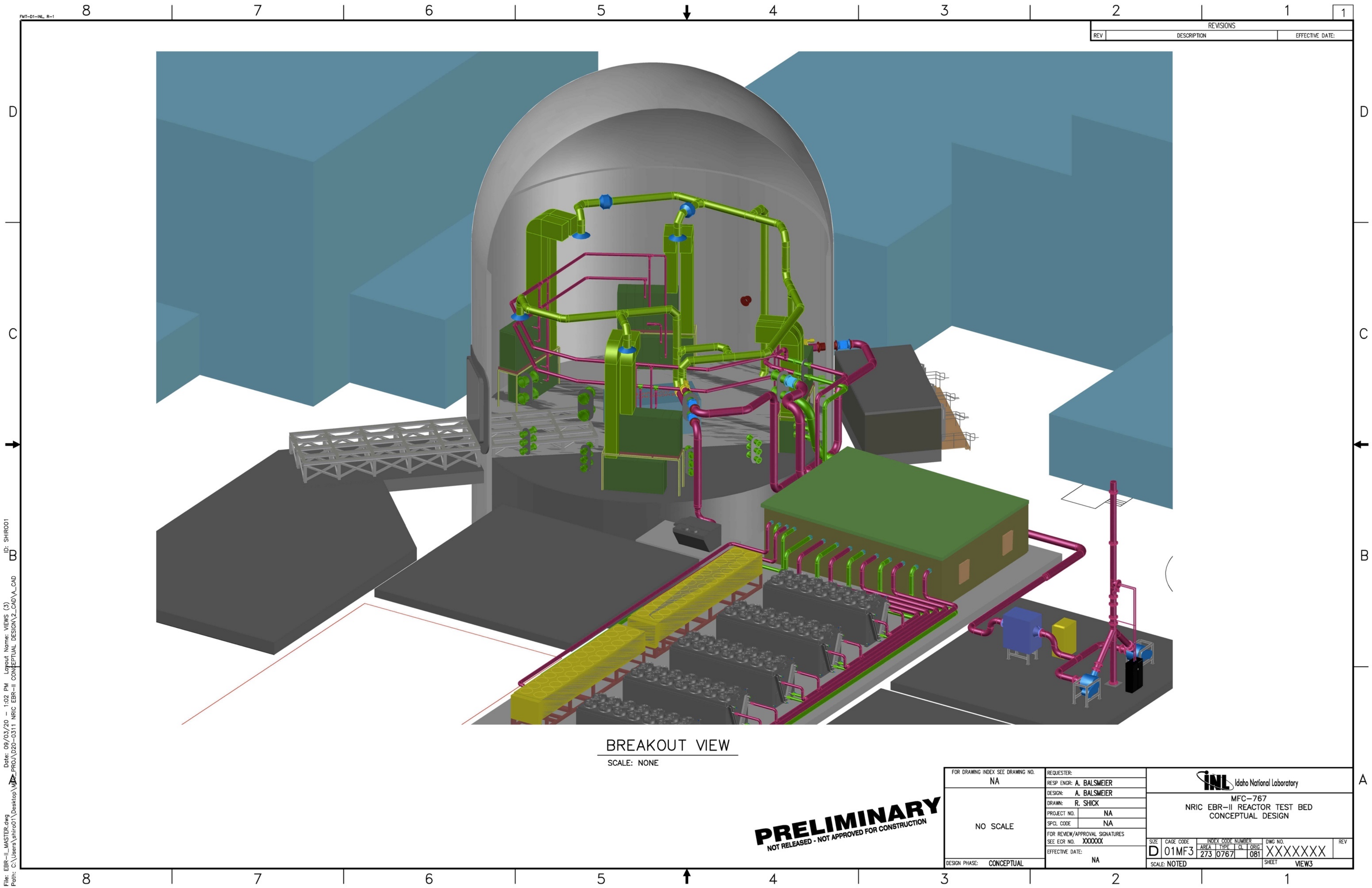
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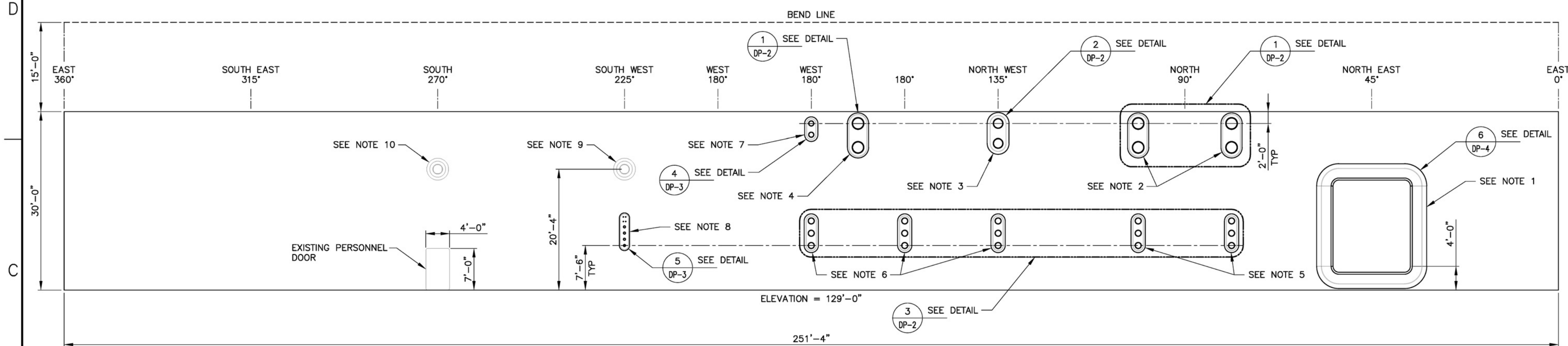

DOME INTERIOR ROLL OUT

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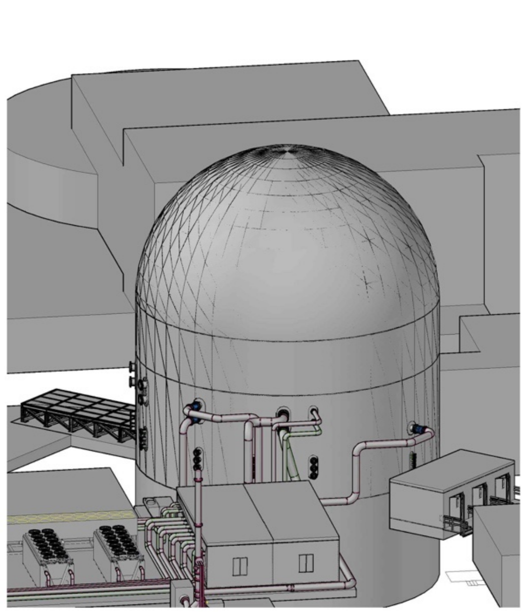

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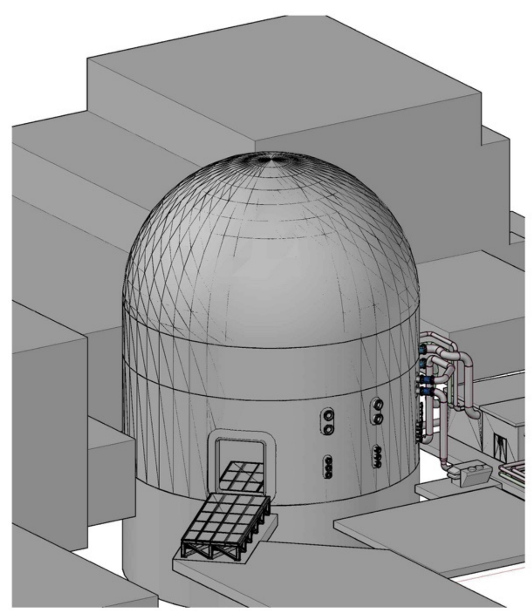

LOOKING SOUTH WEST

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NOTES

1. NEW HATCH, 13'-0" X 15'-6", ALIGN EASTERN EDGE OF BOTH HATCHES WITH REINFORCEMENT ≈ 2'-0" OUTSIDE OF OPENING.
2. NEW 24" DIAMETER PENETRATIONS: DEMONSTRATOR
3. NEW 20" DIAMETER PENETRATIONS: VENTILATION
4. NEW 24" DIAMETER PENETRATIONS: COOLING
5. NEW 12" ELECTRICAL PENETRATIONS: DEMONSTRATOR
6. NEW 12" ELECTRICAL PENETRATIONS: INL USE
7. NEW 10" DIAMETER PENETRATION: COOLING
8. NEW 1" TO 4" MECHANICAL PENETRATIONS: INL/DEMONSTRATOR
9. EXISTING 20" PENETRATION, OVER/UNDER PRESSURE: VENTILATION
10. EXISTING 20" PENETRATION

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DRAWN: R. SHICK
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Idaho National Laboratory
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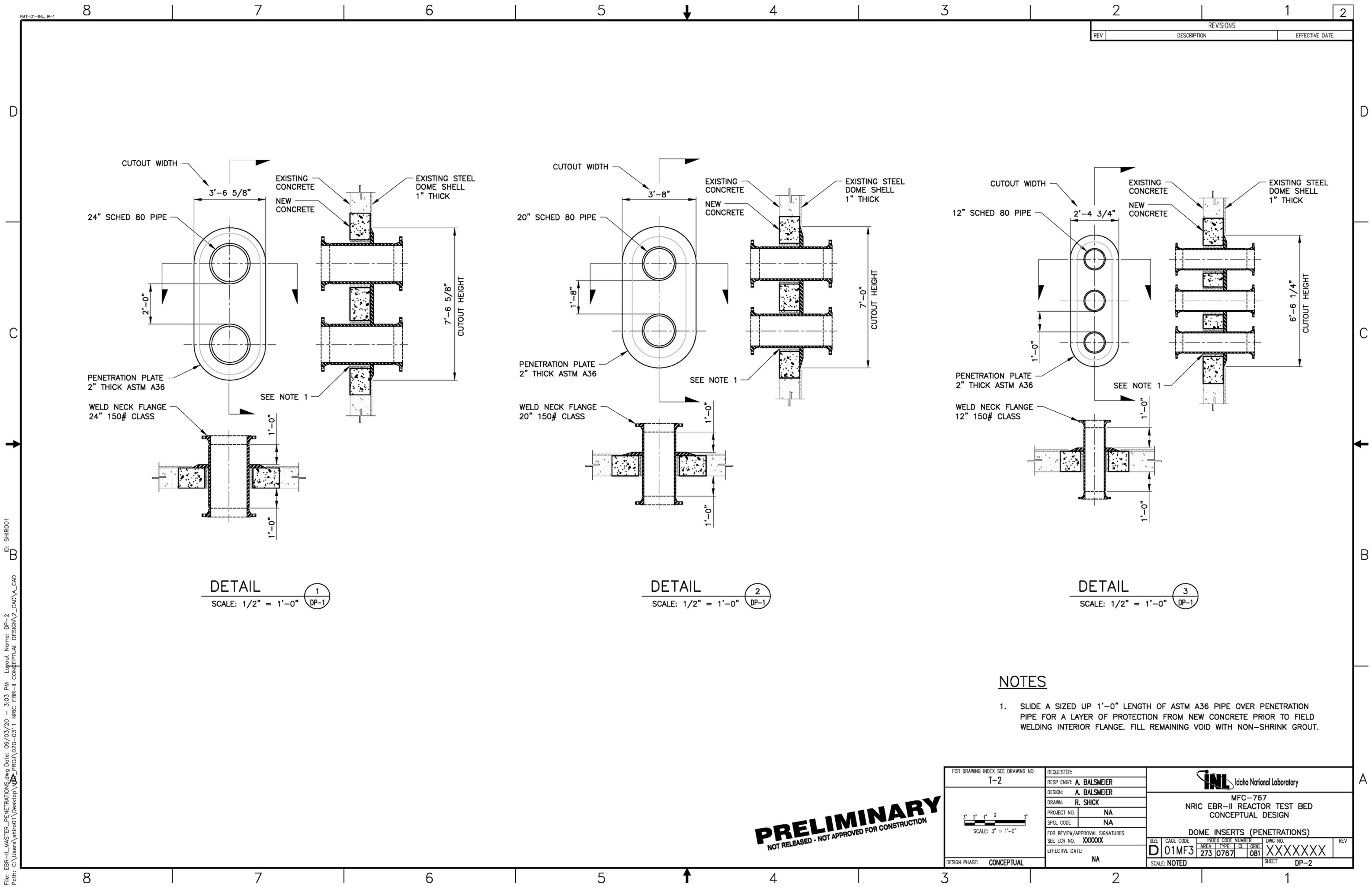
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7'-6 5/8" CUTOUT HEIGHT
PENETRATION PLATE 2" THICK ASTM A36
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WELD NECK FLANGE 24" 150# CLASS
1'-0"
1'-0"
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SCALE: 1/2" = 1'-0"
CUTOUT WIDTH
3'-8"
20" SCHED 80 PIPE
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NEW CONCRETE
EXISTING STEEL DOME SHELL 1" THICK
1'-8"
7'-0" CUTOUT HEIGHT
PENETRATION PLATE 2" THICK ASTM A36
SEE NOTE 1
WELD NECK FLANGE 20" 150# CLASS
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1'-0"
DETAIL 2 DP-1
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CUTOUT WIDTH
2'-4 3/4"
12" SCHED 80 PIPE
EXISTING CONCRETE
NEW CONCRETE
EXISTING STEEL DOME SHELL 1" THICK
1'-0"
6'-6 1/4" CUTOUT HEIGHT
PENETRATION PLATE 2" THICK ASTM A36
SEE NOTE 1
WELD NECK FLANGE 12" 150# CLASS
1'-0"
1'-0"
DETAIL 3 DP-1
SCALE: 1/2" = 1'-0"
NOTES
1. SLIDE A SIZED UP 1'-0" LENGTH OF ASTM A36 PIPE OVER PENETRATION PIPE FOR A LAYER OF PROTECTION FROM NEW CONCRETE PRIOR TO FIELD WELDING INTERIOR FLANGE. FILL REMAINING VOID WITH NON-SHRINK GROUT.
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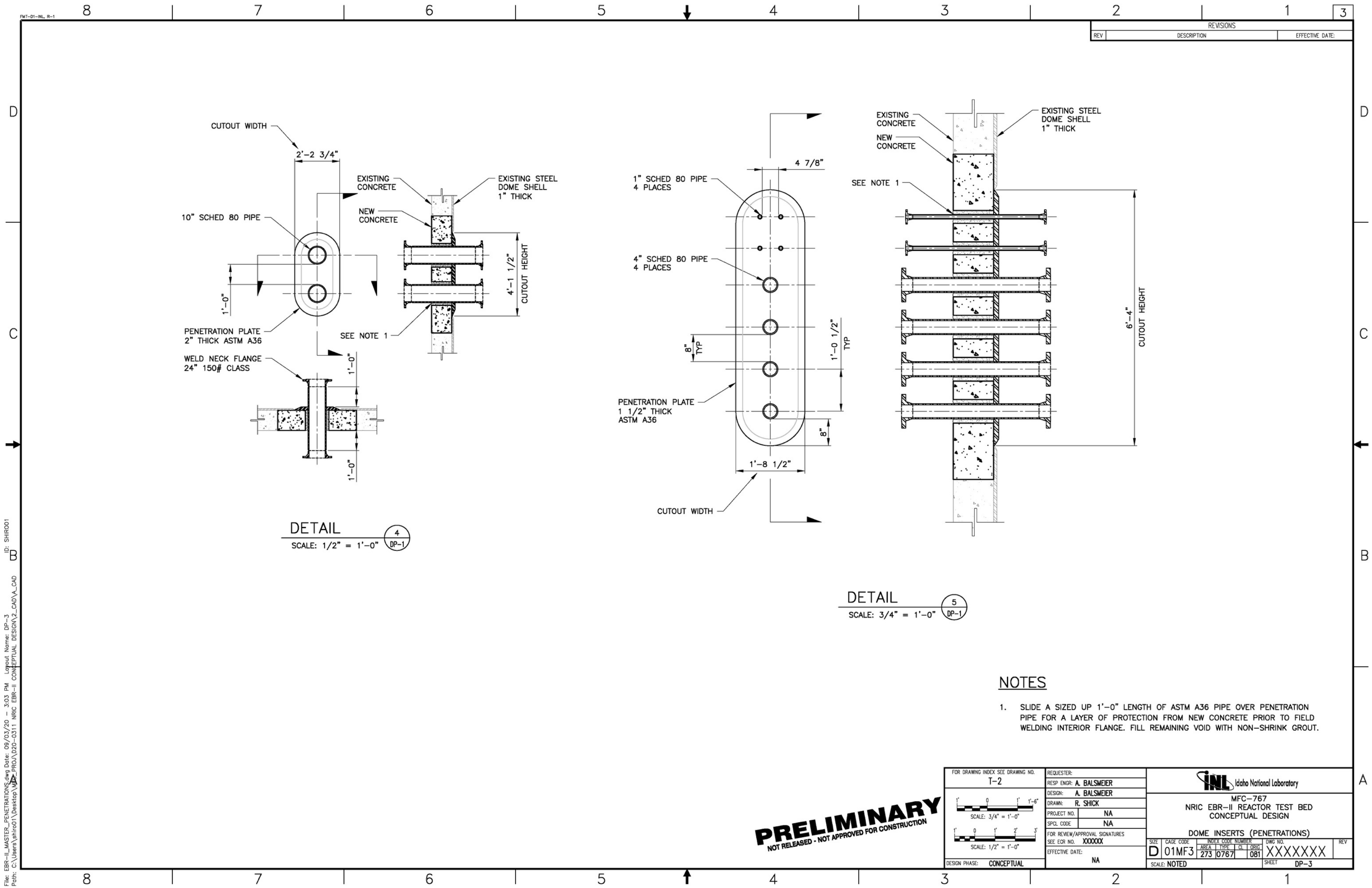
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1'-0"
PENETRATION PLATE 2" THICK ASTM A36
SEE NOTE 1
WELD NECK FLANGE 24" 150# CLASS
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4 7/8"
1" SCHED 80 PIPE 4 PLACES
4" SCHED 80 PIPE 4 PLACES
8" TYP
1'-0 1/2" TYP
PENETRATION PLATE 1 1/2" THICK ASTM A36
8"
1'-8 1/2"
CUTOUT WIDTH
6'-4" CUTOUT HEIGHT
DETAIL 5 DP-1
SCALE: 3/4" = 1'-0"
NOTES
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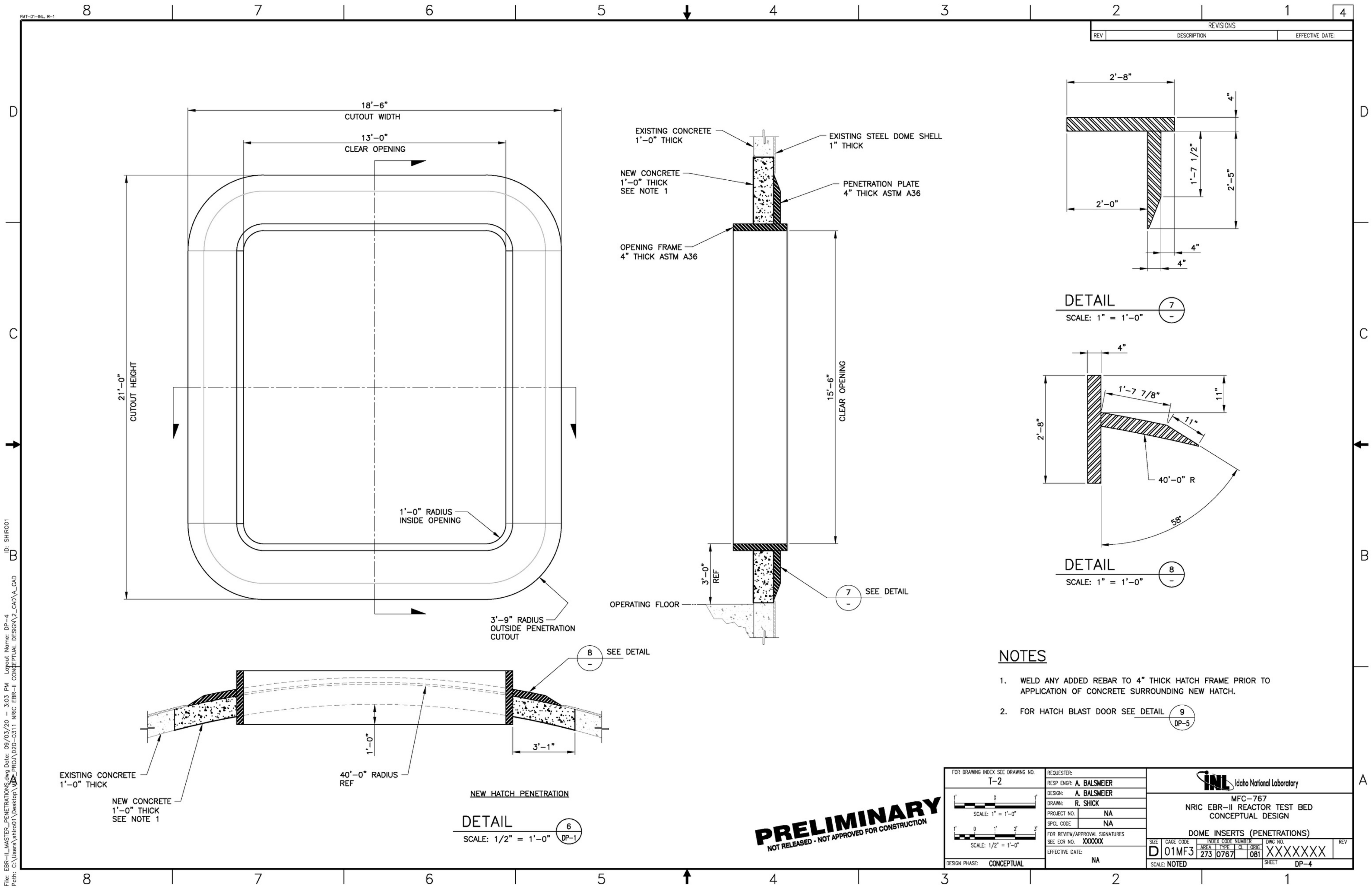
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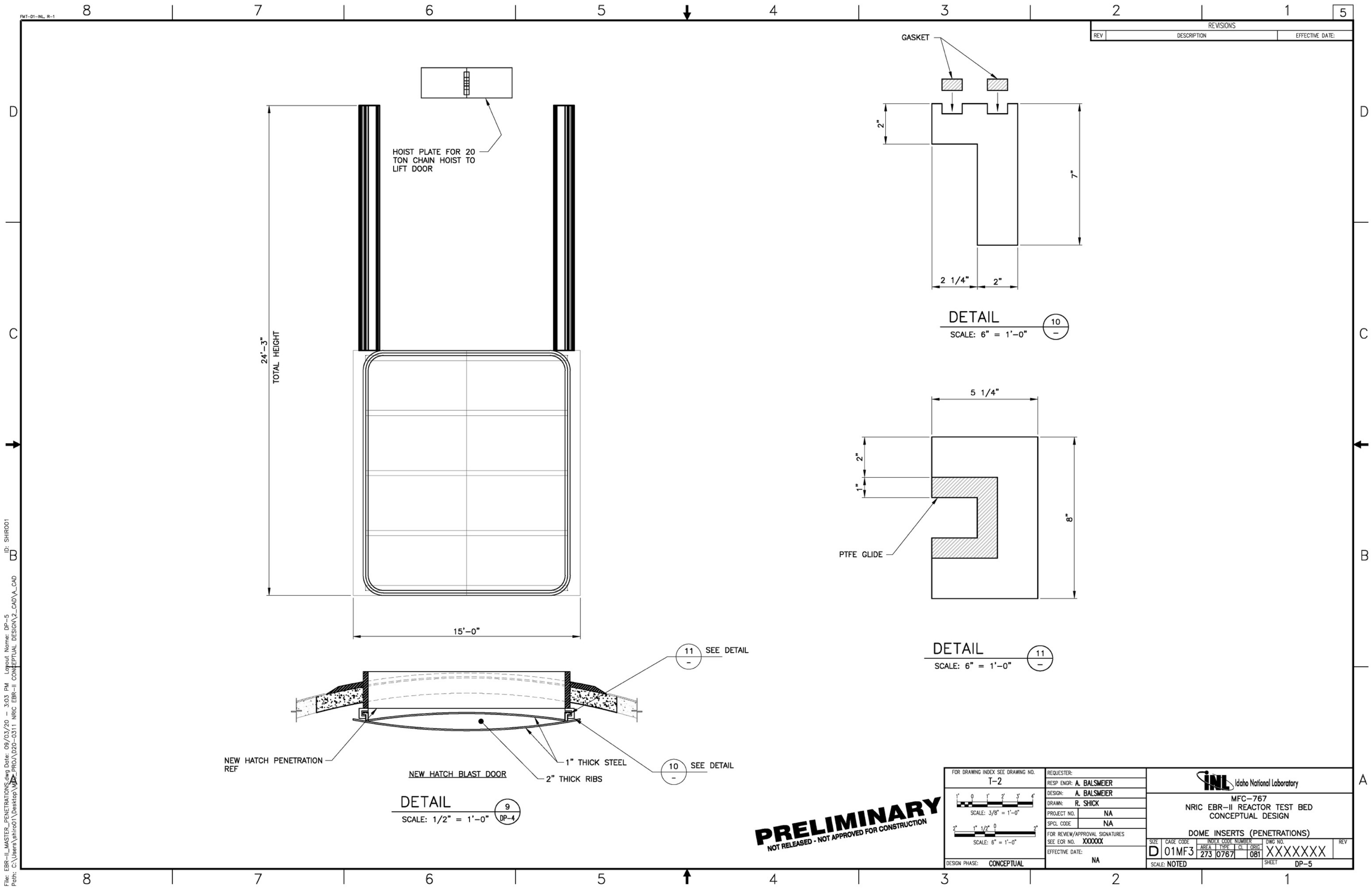
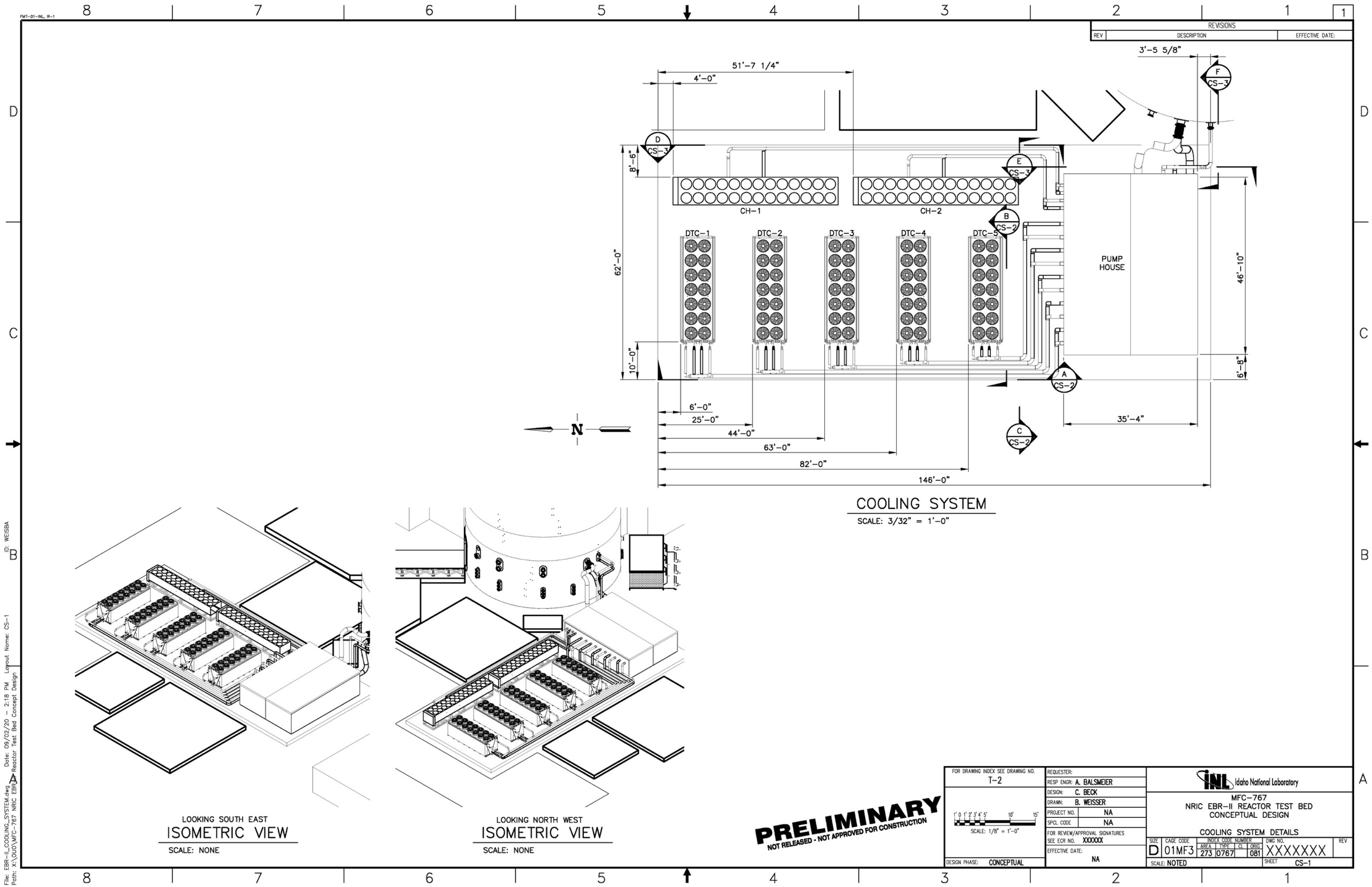
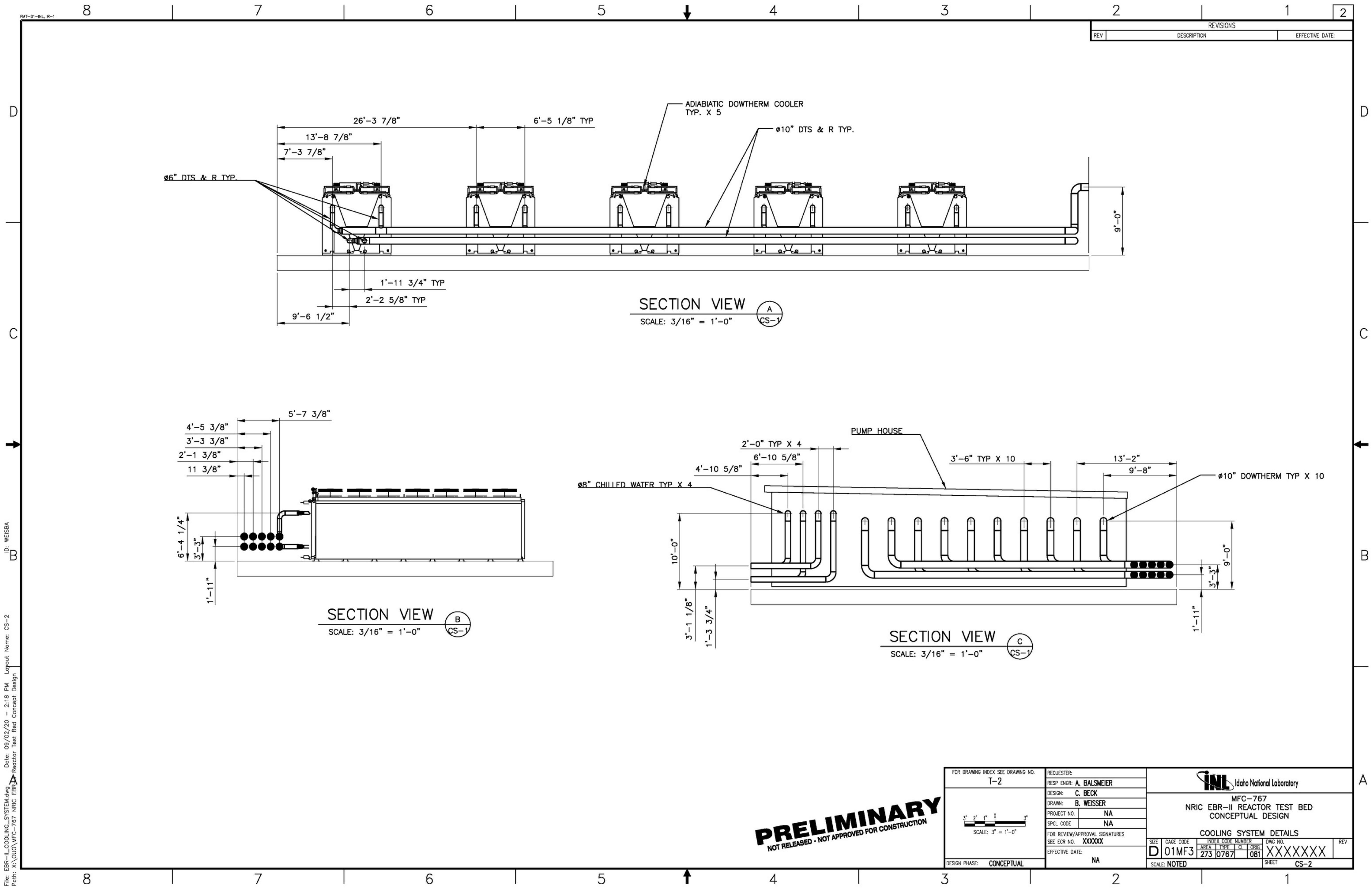
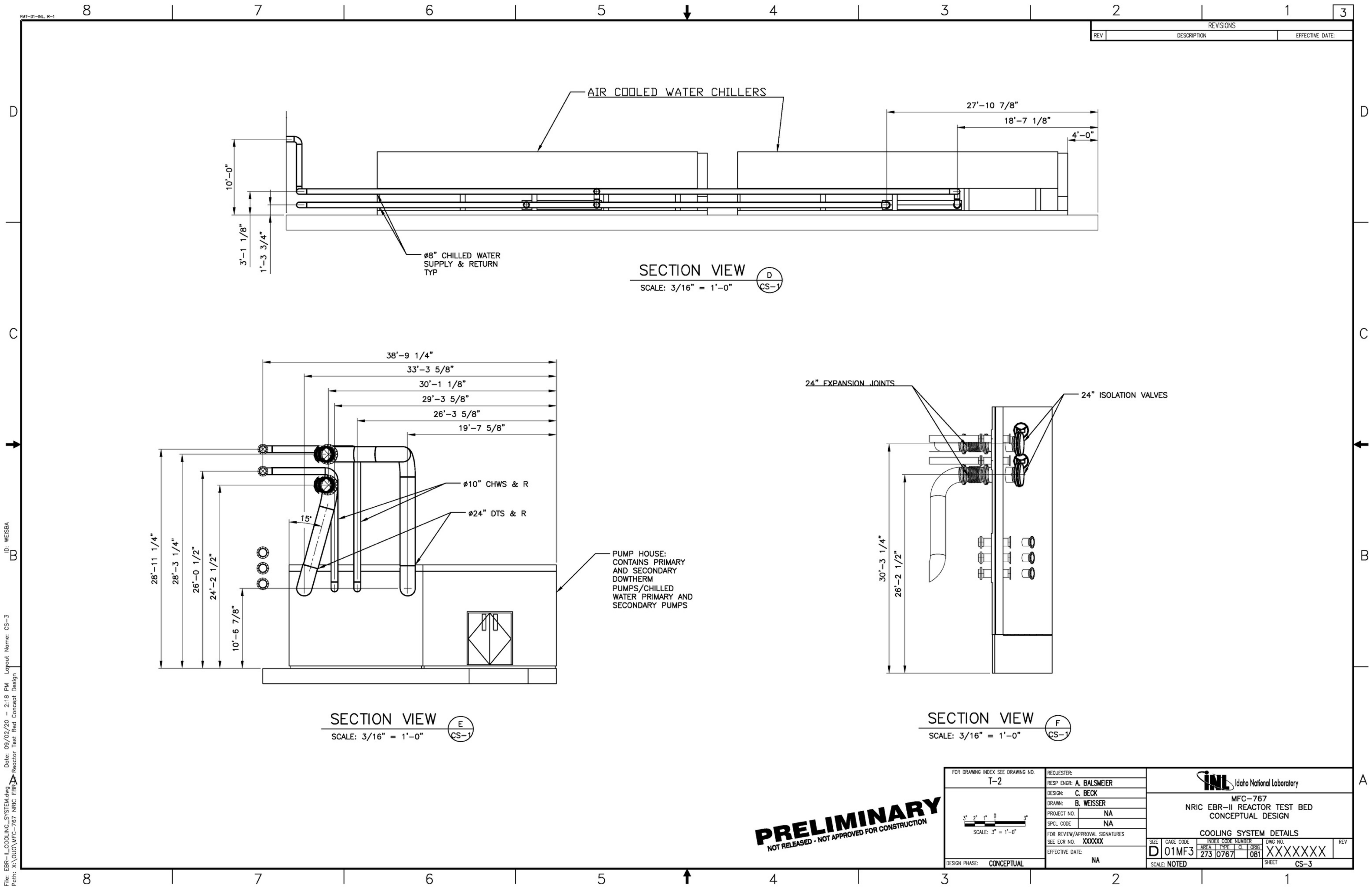
INSIDE OPENING
3'-9" RADIUS
OUTSIDE PENETRATION
CUTOUT
EXISTING CONCRETE
1'-0" THICK
NEW CONCRETE
1'-0" THICK
SEE NOTE 1
OPENING FRAME
4" THICK ASTM A36
EXISTING STEEL DOME SHELL
1" THICK
PENETRATION PLATE
4" THICK ASTM A36
15'-6"
CLEAR OPENING
3'-0"
REF
OPERATING FLOOR
7 SEE DETAIL
8 SEE DETAIL
1'-0"
3'-1"
40'-0" RADIUS
REF
NEW HATCH PENETRATION
DETAIL 6 DP-1
SCALE: 1/2" = 1'-0"
2'-8"
4"
1'-7 1/2"
2'-5"
2'-0"
4"
4"
DETAIL 7
SCALE: 1" = 1'-0"
4"
1'-7 7/8"
11"
11"
2'-8"
40'-0" R
58°
DETAIL 8
SCALE: 1" = 1'-0"
NOTES
1. WELD ANY ADDED REBAR TO 4" THICK HATCH FRAME PRIOR TO APPLICATION OF CONCRETE SURROUNDING NEW HATCH.
2. FOR HATCH BLAST DOOR SEE DETAIL 9 DP-5
PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION
FOR DRAWING INDEX SEE DRAWING NO. T-2
SCALE: 1" = 1'-0"
SCALE: 1/2" = 1'-0"
DESIGN PHASE: CONCEPTUAL
REQUESTER:
RESP ENGR: A. BALSMEIER
DESIGN: A. BALSMEIER
DRAWN: R. SHICK
PROJECT NO. NA
SPCL CODE NA
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO. XXXXXX
EFFECTIVE DATE: NA
Idaho National Laboratory
MFC-767
NRIC EBR-II REACTOR TEST BED
CONCEPTUAL DESIGN
DOME INSERTS (PENETRATIONS)
SIZE D
CAGE CODE 01MF3
INDEX CODE NUMBER 273 0767 081
DWG NO. XXXXXXX
SCALE: NOTED
SHEET DP-4

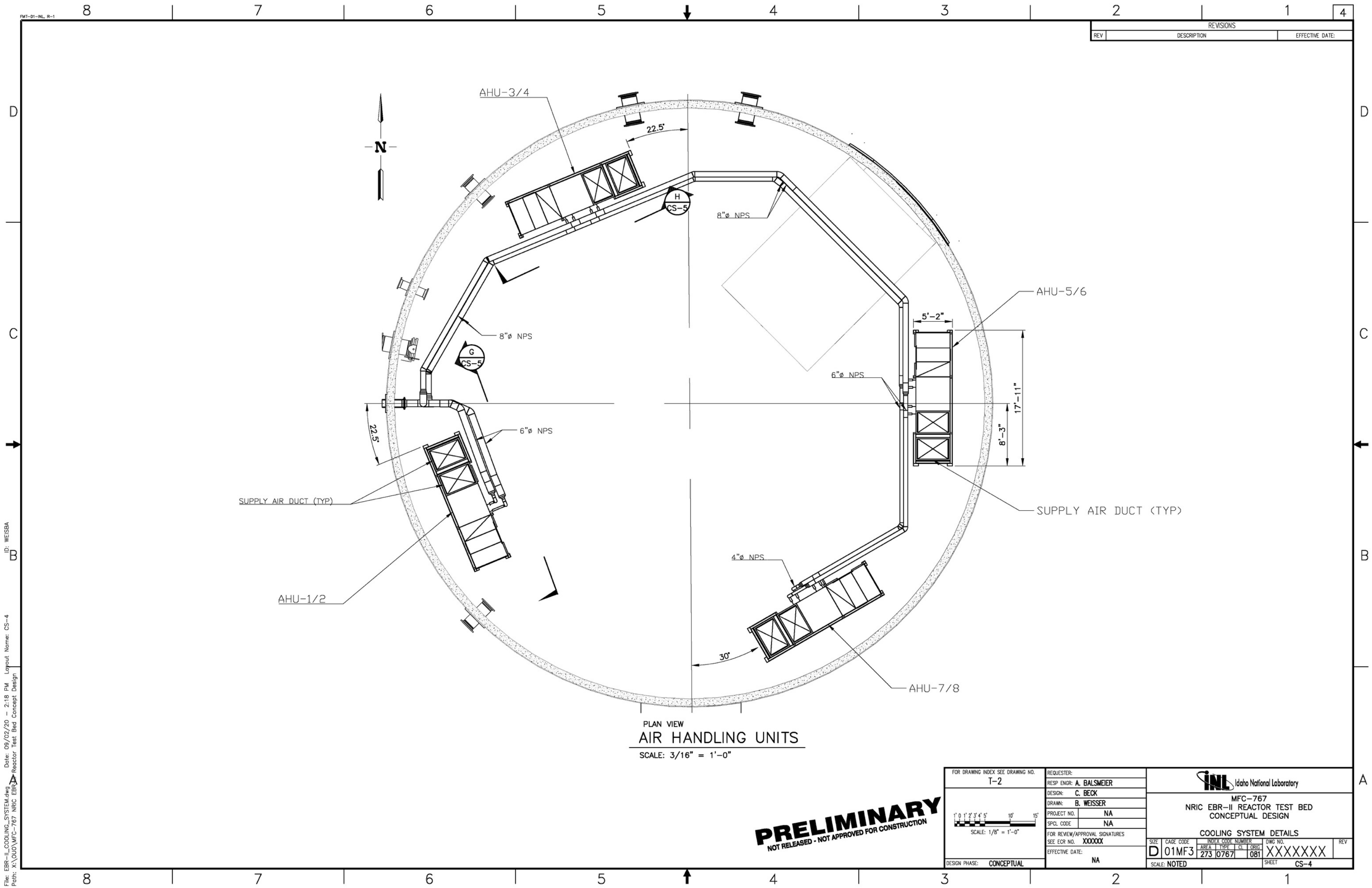

HOIST PLATE FOR 20 TON CHAIN HOIST TO LIFT DOOR
24'-3" TOTAL HEIGHT
15'-0"
NEW HATCH PENETRATION REF
NEW HATCH BLAST DOOR
1" THICK STEEL
2" THICK RIBS
SEE DETAIL
DETAIL 9 DP-4
SCALE: 1/2" = 1'-0"
GASKET
2"
7"
2 1/4"
DETAIL 10
SCALE: 6" = 1'-0"
5 1/4"
1"
8"
PTFE GLIDE
DETAIL 11
SCALE: 6" = 1'-0"
PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION
REVISIONS
REV
DESCRIPTION
EFFECTIVE DATE:
FOR DRAWING INDEX SEE DRAWING NO. T-2
SCALE: 3/8" = 1'-0"
SCALE: 6" = 1'-0"
DESIGN PHASE: CONCEPTUAL
REQUESTER:
RESP ENGR: A. BALSMEIER
DESIGN: A. BALSMEIER
DRAWN: R. SHICK
PROJECT NO. NA
SPCL CODE NA
FOR REVIEW/APPROVAL SIGNATURES
SEE ECR NO. XXXXXX
EFFECTIVE DATE: NA
Idaho National Laboratory
MFC-767
NRIC EBR-II REACTOR TEST BED
CONCEPTUAL DESIGN
DOME INSERTS (PENETRATIONS)
SIZE D
CAGE CODE 01MF3
273 0767 081
DWG NO. XXXXXXX
SCALE: NOTED
SHEET DP-5

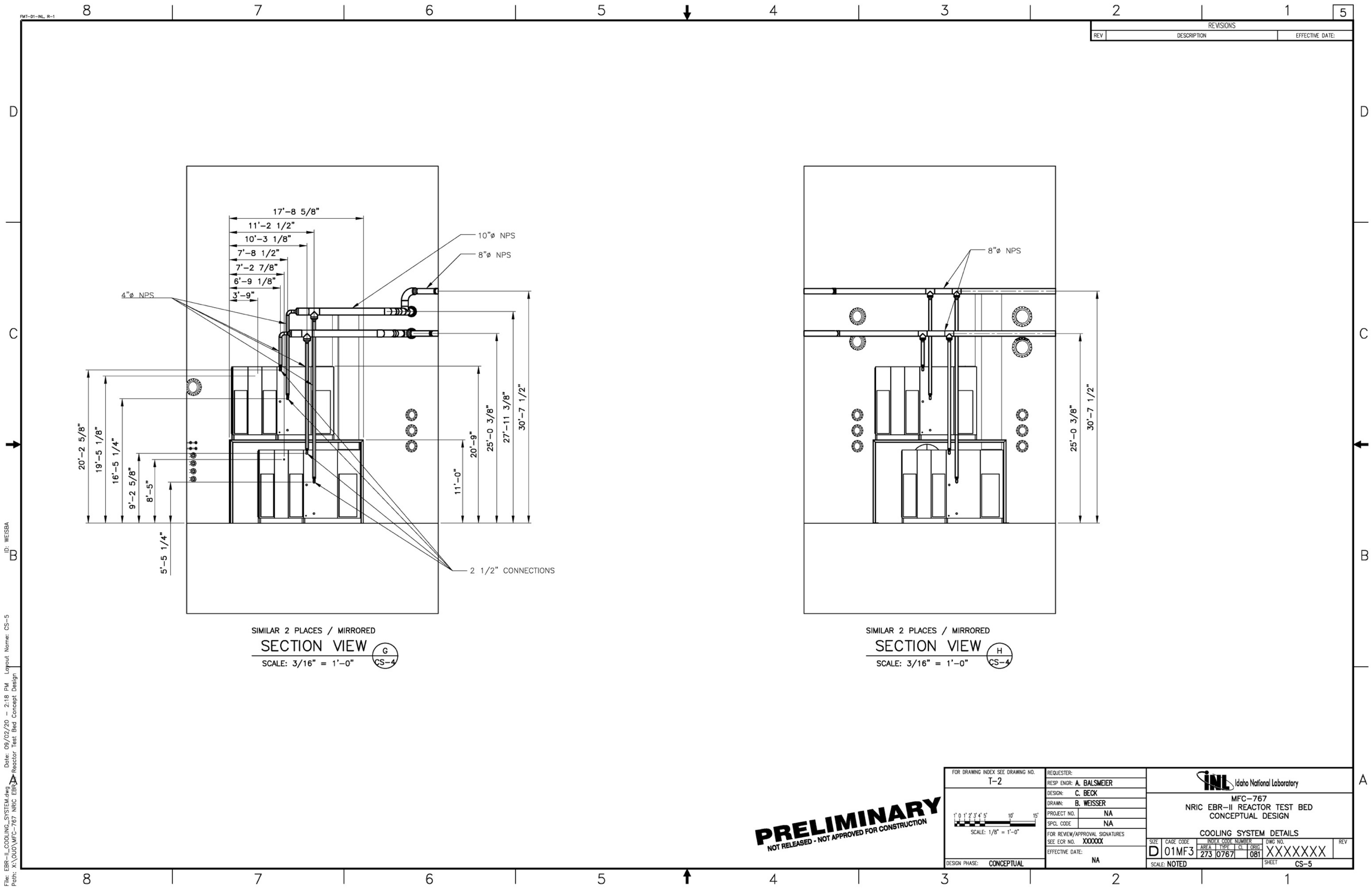

REVISIONS
REV
DESCRIPTION
EFFECTIVE DATE:
51'-7 1/4"
4'-0"
3'-5 5/8"
8'-6"
62'-0"
10'-0"
46'-10"
6'-8"
CH-1
CH-2
DTC-1
DTC-2
DTC-3
DTC-4
DTC-5
PUMP HOUSE
N
6'-0"
25'-0"
44'-0"
63'-0"
82'-0"
146'-0"
35'-4"
COOLING SYSTEM
SCALE: 3/32" = 1'-0"
LOOKING SOUTH EAST
ISOMETRIC VIEW
SCALE: NONE
LOOKING NORTH WEST
ISOMETRIC VIEW
SCALE: NONE
PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION
FOR DRAWING INDEX SEE DRAWING NO.
T-2
SCALE: 1/8" = 1'-0"
DESIGN PHASE: CONCEPTUAL
REQUESTER:
RESP ENGR: A. BALSMEIER
DESIGN: C. BECK
DRAWN: B. WEISSER
PROJECT NO. NA
SPCL CODE NA
FOR REVIEW/APPROVAL SIGNATURES
SEE ECR NO. XXXXXX
EFFECTIVE DATE: NA
Idaho National Laboratory
MFC-767
NRIC EBR-II REACTOR TEST BED
CONCEPTUAL DESIGN
COOLING SYSTEM DETAILS
SIZE D
CAGE CODE 01MF3
INDEX CODE NUMBER
AREA 273
TYPE 0767
CL
ORIG 081
DWG NO. XXXXXXX
REV
SCALE: NOTED
SHEET CS-1

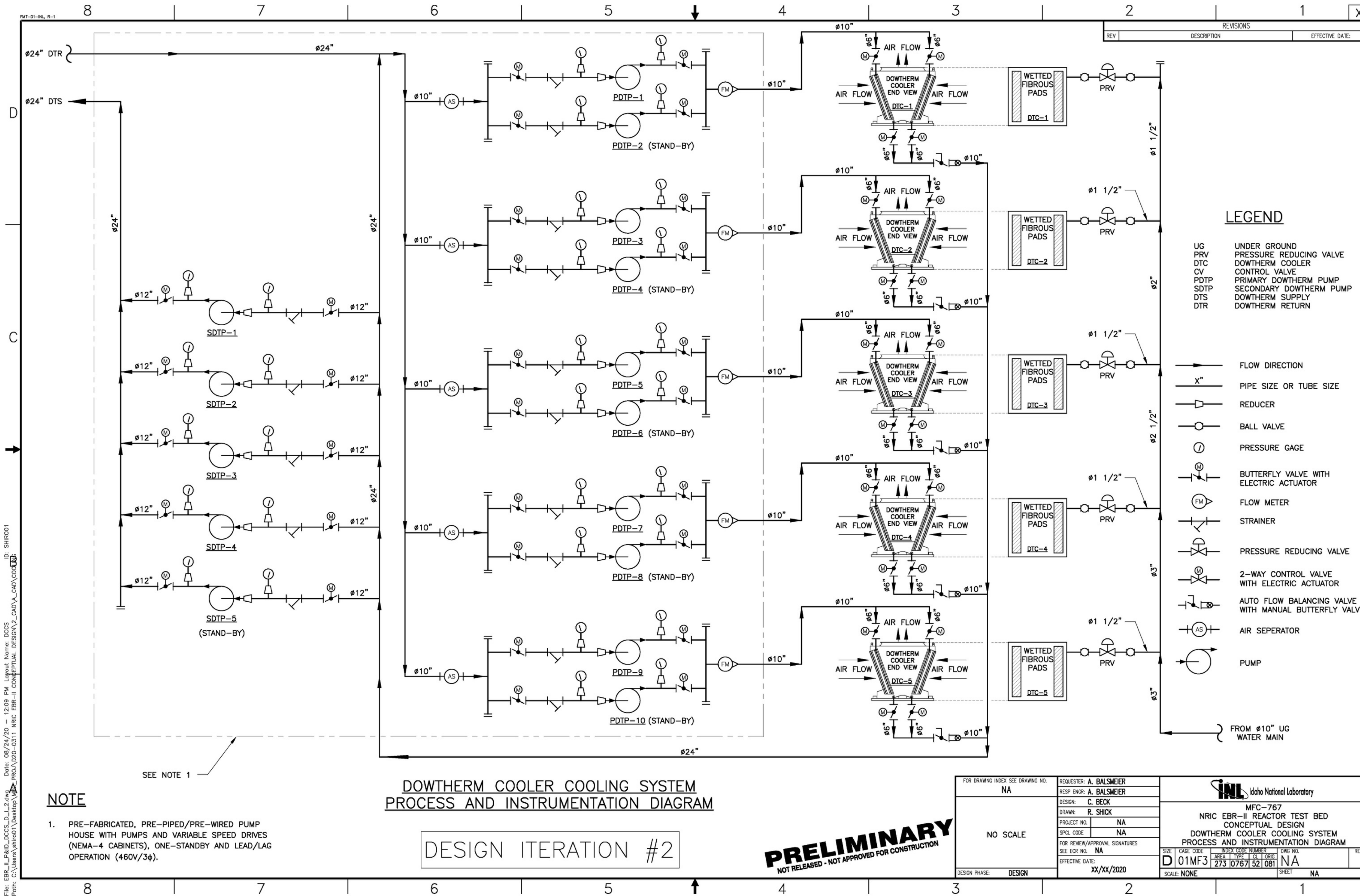

REVISIONS
REV
DESCRIPTION
EFFECTIVE DATE:
ADIABATIC DOWTHERM COOLER TYP. X 5
ø10" DTS & R TYP.
26'-3 7/8"
6'-5 1/8" TYP
13'-8 7/8"
7'-3 7/8"
ø6" DTS & R TYP.
9'-0"
1'-11 3/4" TYP
2'-2 5/8" TYP
9'-6 1/2"
SECTION VIEW
SCALE: 3/16" = 1'-0"
A
CS-1
5'-7 3/8"
4'-5 3/8"
3'-3 3/8"
2'-1 3/8"
11 3/8"
6'-4 1/4"
3'-3"
1'-11"
SECTION VIEW
SCALE: 3/16" = 1'-0"
B
CS-1
PUMP HOUSE
2'-0" TYP X 4
6'-10 5/8"
4'-10 5/8"
3'-6" TYP X 10
13'-2"
9'-8"
ø8" CHILLED WATER TYP X 4
ø10" DOWTHERM TYP X 10
10'-0"
9'-0"
3'-3"
3'-1 1/8"
1'-3 3/4"
1'-11"
SECTION VIEW
SCALE: 3/16" = 1'-0"
C
CS-1
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: C. BECK
DRAWN: B. WEISSER
PROJECT NO. NA
SPCL CODE NA
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO. XXXXXX
EFFECTIVE DATE: NA
INL Idaho National Laboratory
MFC-767
NRIC EBR-II REACTOR TEST BED
CONCEPTUAL DESIGN
COOLING SYSTEM DETAILS
SIZE D
CAGE CODE 01MF3
INDEX CODE NUMBER 273 0767 081
DWG NO. XXXXXXX
REV
SCALE: NOTED
SHEET CS-2

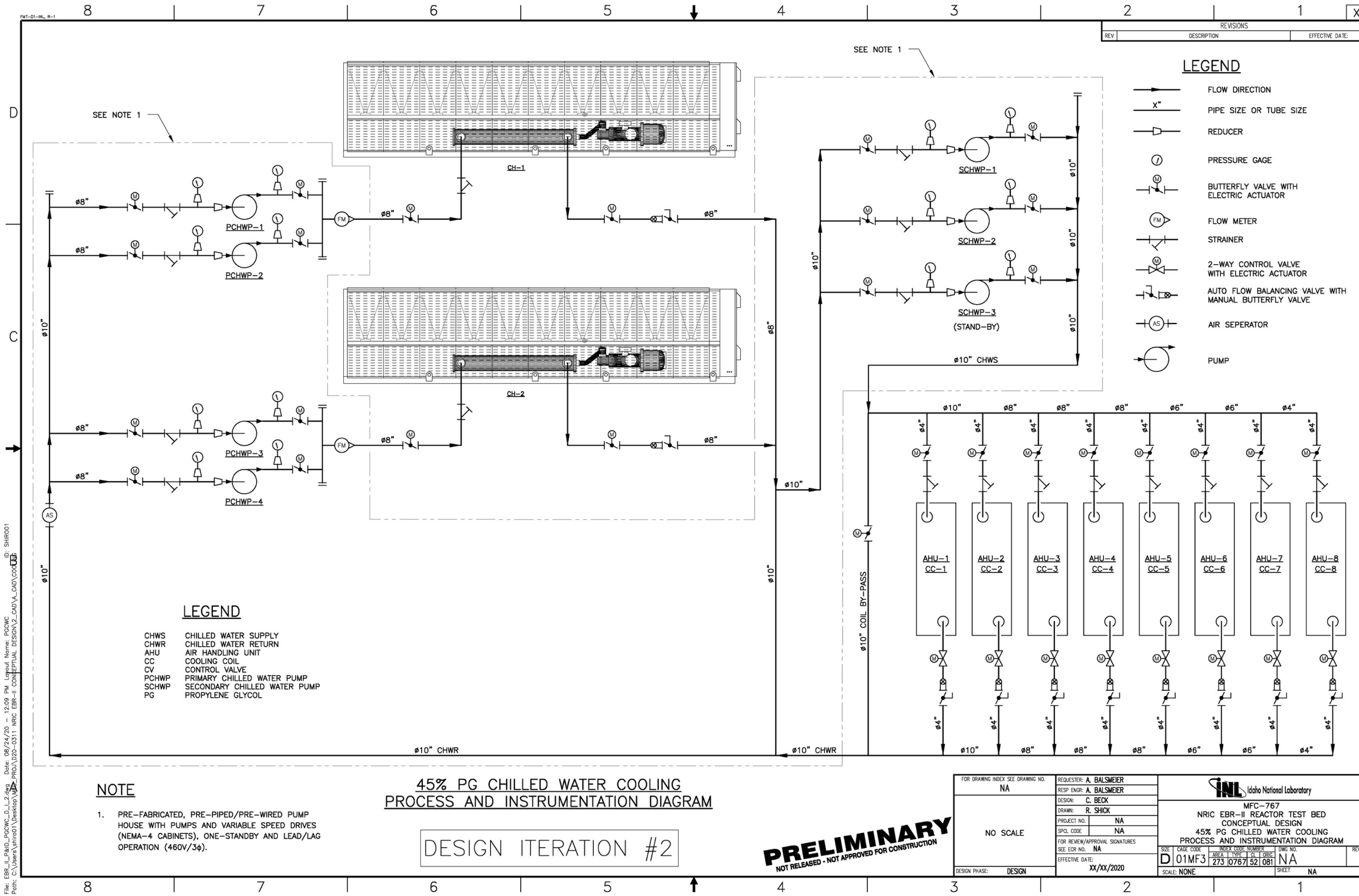


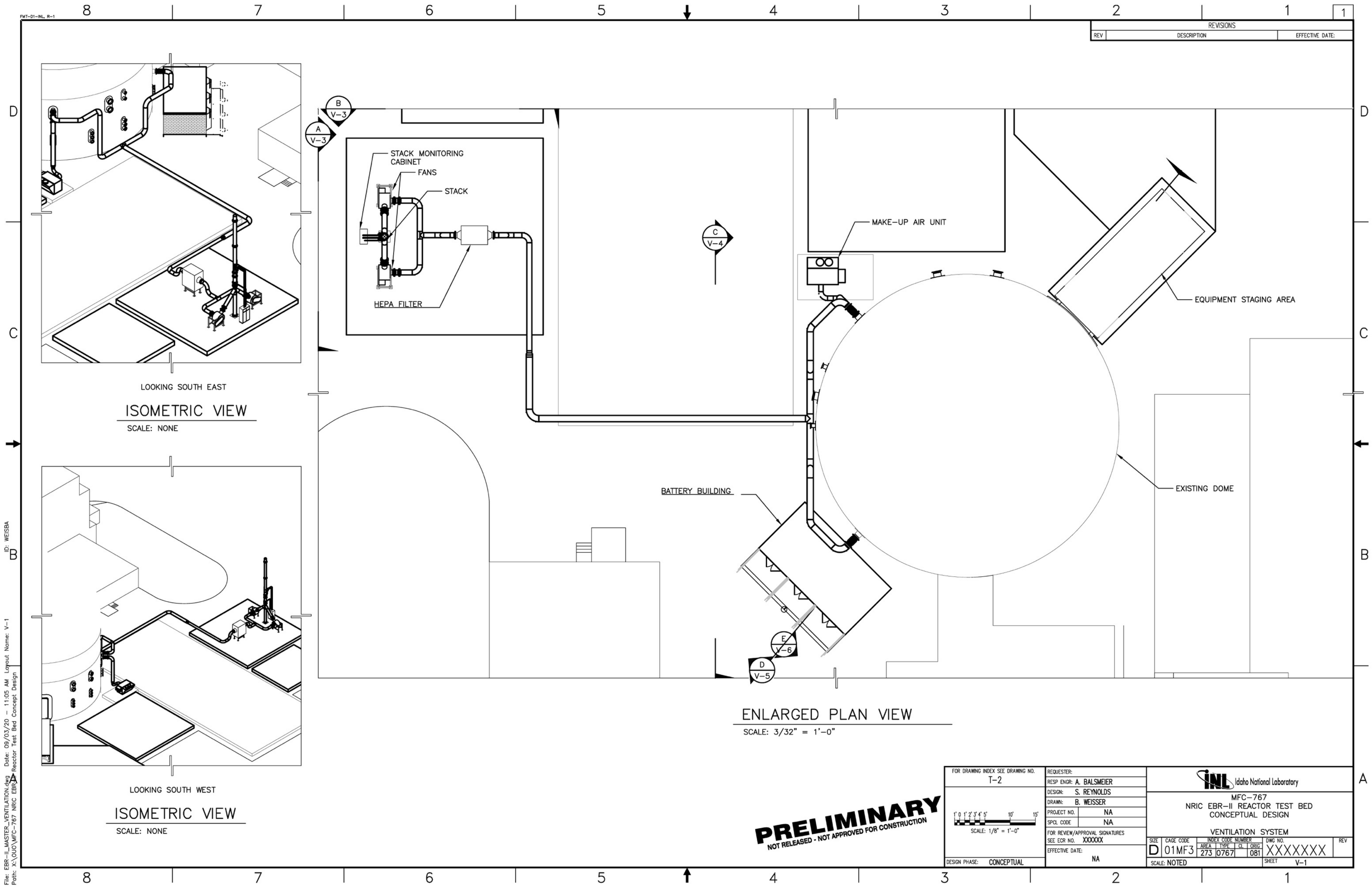
AIR COOLED WATER CHILLERS
27'-10 7/8"
18'-7 1/8"
4'-0"
10'-0"
3'-1 1/8"
1'-3 3/4"
ø8" CHILLED WATER SUPPLY & RETURN TYP
SECTION VIEW
SCALE: 3/16" = 1'-0"
D CS-1
38'-9 1/4"
33'-3 5/8"
30'-1 1/8"
29'-3 5/8"
26'-3 5/8"
19'-7 5/8"
ø10" CHWS & R
ø24" DTS & R
15°
28'-11 1/4"
28'-3 1/4"
26'-0 1/2"
24'-2 1/2"
10'-6 7/8"
PUMP HOUSE: CONTAINS PRIMARY AND SECONDARY DOWTHERM PUMPS/CHILLED WATER PRIMARY AND SECONDARY PUMPS
SECTION VIEW
SCALE: 3/16" = 1'-0"
E CS-1
24" EXPANSION JOINTS
24" ISOLATION VALVES
30'-3 1/4"
26'-2 1/2"
SECTION VIEW
SCALE: 3/16" = 1'-0"
F CS-1
REVISIONS
REV
DESCRIPTION
EFFECTIVE DATE:
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: C. BECK
DRAWN: B. WEISSER
PROJECT NO. NA
SPCL CODE NA
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO. XXXXXX
EFFECTIVE DATE: NA
Idaho National Laboratory
MFC-767
NRIC EBR-II REACTOR TEST BED CONCEPTUAL DESIGN
COOLING SYSTEM DETAILS
SIZE D
CAGE CODE 01MF3
INDEX CODE NUMBER AREA 273 TYPE 0767 CL ORIG 081
DWG NO. XXXXXXX
REV
SCALE: NOTED
SHEET CS-3

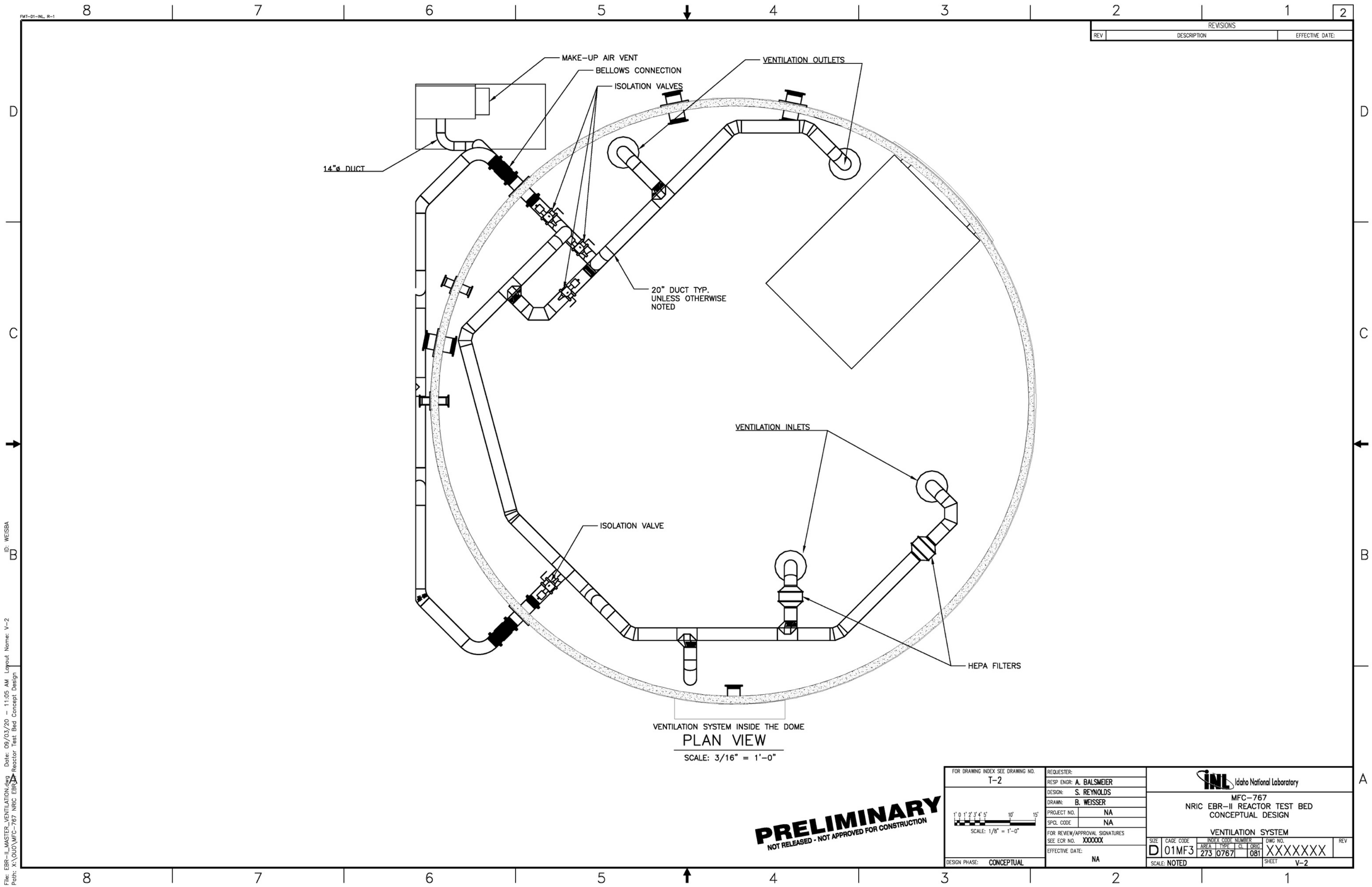

AHU-3/4
22.5°
N
8"ø NPS
H
CS-5
G
CS-5
AHU-5/6
5'-2"
17'-11"
8'-3"
6"ø NPS
22.5°
6"ø NPS
SUPPLY AIR DUCT (TYP)
SUPPLY AIR DUCT (TYP)
AHU-1/2
4"ø NPS
30°
AHU-7/8
PLAN VIEW
AIR HANDLING UNITS
SCALE: 3/16" = 1'-0"
REVISIONS
REV
DESCRIPTION
EFFECTIVE DATE:
PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION
FOR DRAWING INDEX SEE DRAWING NO. T-2
SCALE: 1/8" = 1'-0"
DESIGN PHASE: CONCEPTUAL
REQUESTER:
RESP ENGR: A. BALSMEIER
DESIGN: C. BECK
DRAWN: B. WEISSER
PROJECT NO. NA
SPCL CODE NA
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO. XXXXXX
EFFECTIVE DATE: NA
Idaho National Laboratory
MFC-767
NRIC EBR-II REACTOR TEST BED
CONCEPTUAL DESIGN
COOLING SYSTEM DETAILS
SIZE D
CAGE CODE 01MF3
INDEX CODE NUMBER AREA 273 TYPE 0767 CL ORIG 081
DWG NO. XXXXXXX
REV
SCALE: NOTED
SHEET CS-4

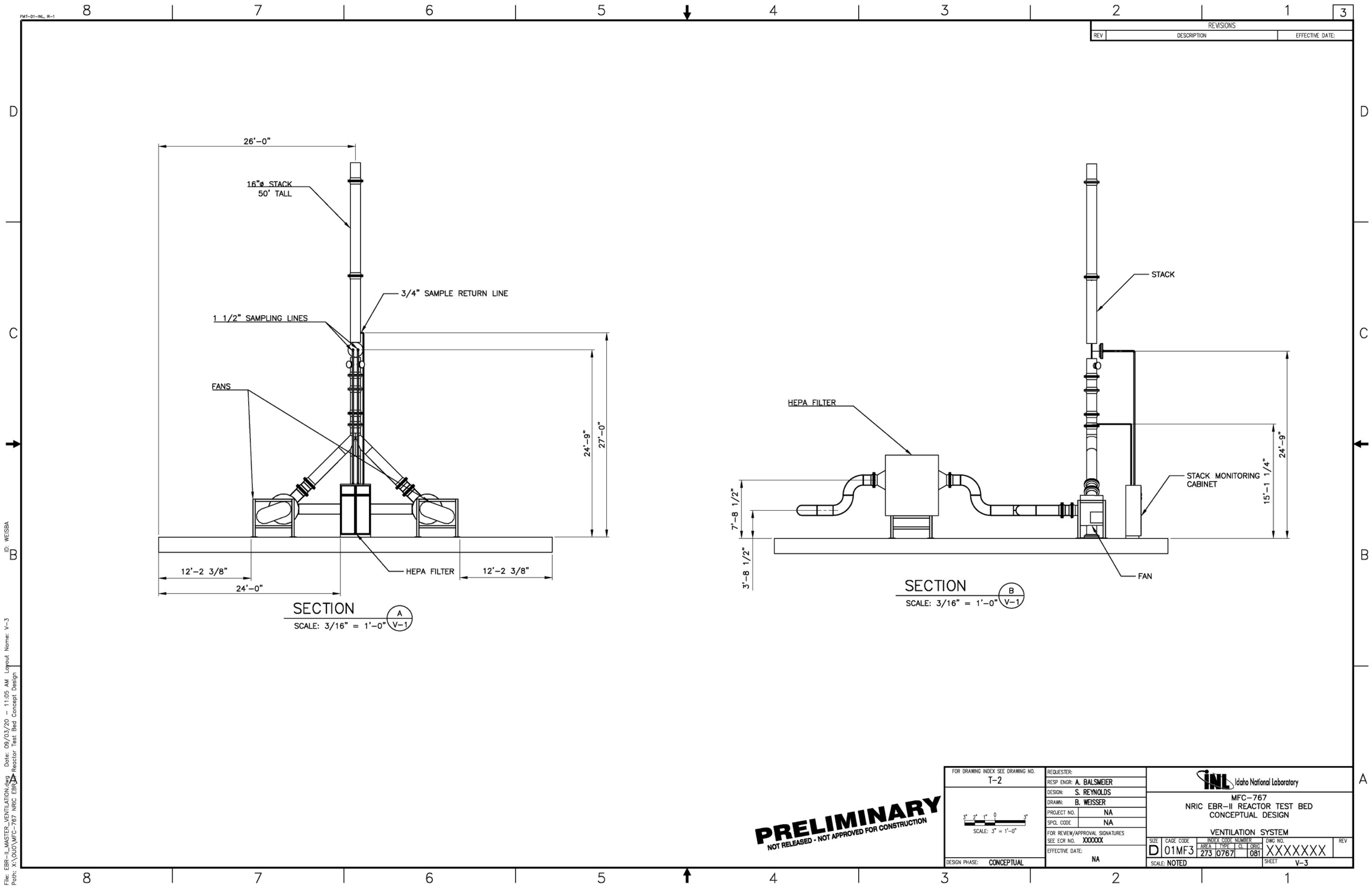

17'-8 5/8"
11'-2 1/2"
10'-3 1/8"
7'-8 1/2"
7'-2 7/8"
6'-9 1/8"
3'-9"
10"ø NPS
8"ø NPS
4"ø NPS
20'-2 5/8"
19'-5 1/8"
16'-5 1/4"
9'-2 5/8"
8'-5"
5'-5 1/4"
11'-0"
20'-9"
25'-0 3/8"
27'-11 3/8"
30'-7 1/2"
2 1/2" CONNECTIONS
SIMILAR 2 PLACES / MIRRORED
SECTION VIEW G CS-4
SCALE: 3/16" = 1'-0"
8"ø NPS
25'-0 3/8"
30'-7 1/2"
SIMILAR 2 PLACES / MIRRORED
SECTION VIEW H CS-4
SCALE: 3/16" = 1'-0"
REVISIONS
REV
DESCRIPTION
EFFECTIVE DATE:
PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION
FOR DRAWING INDEX SEE DRAWING NO. T-2
SCALE: 1/8" = 1'-0"
DESIGN PHASE: CONCEPTUAL
REQUESTER:
RESP ENGR: A. BALSMEIER
DESIGN: C. BECK
DRAWN: B. WEISSER
PROJECT NO. NA
SPCL CODE NA
FOR REVIEW/APPROVAL SIGNATURES
SEE ECR NO. XXXXXX
EFFECTIVE DATE: NA
Idaho National Laboratory
MFC-767
NRIC EBR-II REACTOR TEST BED
CONCEPTUAL DESIGN
COOLING SYSTEM DETAILS
SIZE D
CAGE CODE 01MF3
INDEX CODE NUMBER AREA 273 TYPE 0767 CL ORIG 081
DWG NO. XXXXXXX
REV
SCALE: NOTED
SHEET CS-5

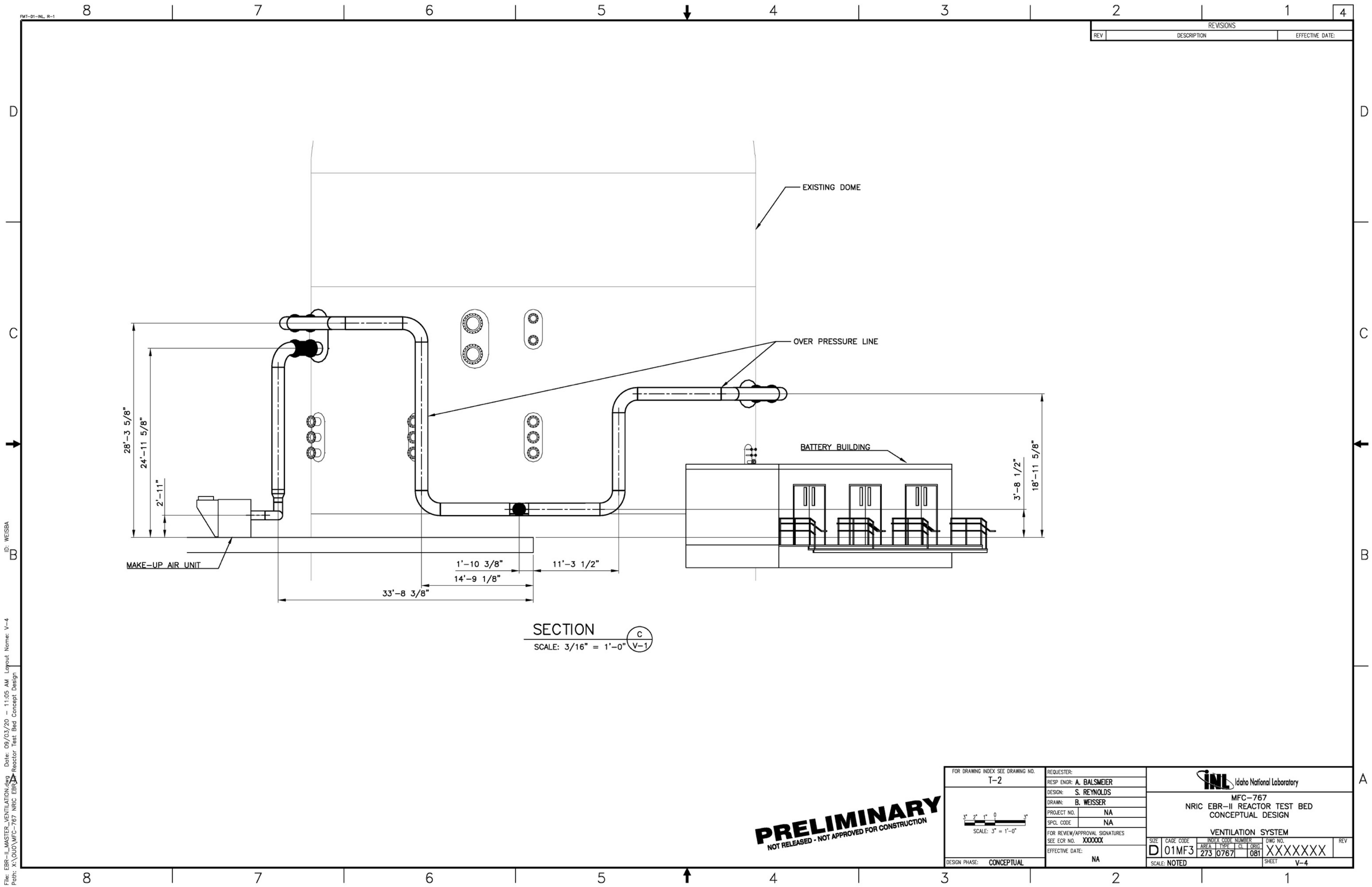

ø24" DTR
ø24" DTS
ø24"
ø10"
ø12"
ø6"
ø1 1/2"
ø2"
ø2 1/2"
ø3"
AIR FLOW
DOWTHERM COOLER END VIEW
DTC-1
DTC-2
DTC-3
DTC-4
DTC-5
WETTED FIBROUS PADS
PRV
PDTP-1
PDTP-2 (STAND-BY)
PDTP-3
PDTP-4 (STAND-BY)
PDTP-5
PDTP-6 (STAND-BY)
PDTP-7
PDTP-8 (STAND-BY)
PDTP-9
PDTP-10 (STAND-BY)
SDTP-1
SDTP-2
SDTP-3
SDTP-4
SDTP-5 (STAND-BY)
FROM ø10" UG WATER MAIN
SEE NOTE 1
LEGEND
UG UNDER GROUND
PRV PRESSURE REDUCING VALVE
DTC DOWTHERM COOLER
CV CONTROL VALVE
PDTP PRIMARY DOWTHERM PUMP
SDTP SECONDARY DOWTHERM PUMP
DTS DOWTHERM SUPPLY
DTR DOWTHERM RETURN
FLOW DIRECTION
PIPE SIZE OR TUBE SIZE
REDUCER
BALL VALVE
PRESSURE GAGE
BUTTERFLY VALVE WITH ELECTRIC ACTUATOR
FLOW METER
STRAINER
PRESSURE REDUCING VALVE
2-WAY CONTROL VALVE WITH ELECTRIC ACTUATOR
AUTO FLOW BALANCING VALVE WITH MANUAL BUTTERFLY VALVE
AIR SEPERATOR
PUMP
NOTE
1. PRE-FABRICATED, PRE-PIPED/PRE-WIRED PUMP HOUSE WITH PUMPS AND VARIABLE SPEED DRIVES (NEMA-4 CABINETS), ONE-STANDBY AND LEAD/LAG OPERATION (460V/3ϕ).
DOWTHERM COOLER COOLING SYSTEM
PROCESS AND INSTRUMENTATION DIAGRAM
DESIGN ITERATION #2
PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION
REVISIONS
REV DESCRIPTION EFFECTIVE DATE:
FOR DRAWING INDEX SEE DRAWING NO. NA
NO SCALE
DESIGN PHASE: DESIGN
REQUESTER: A. BALSMEIER
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-767
NRIC EBR-II REACTOR TEST BED
CONCEPTUAL DESIGN
DOWTHERM COOLER COOLING SYSTEM
PROCESS AND INSTRUMENTATION DIAGRAM
SIZE D
CAGE CODE 01MF3
INDEX CODE NUMBER 273 0767 52 081
DWG NO. NA
SCALE: NONE
SHEET NA

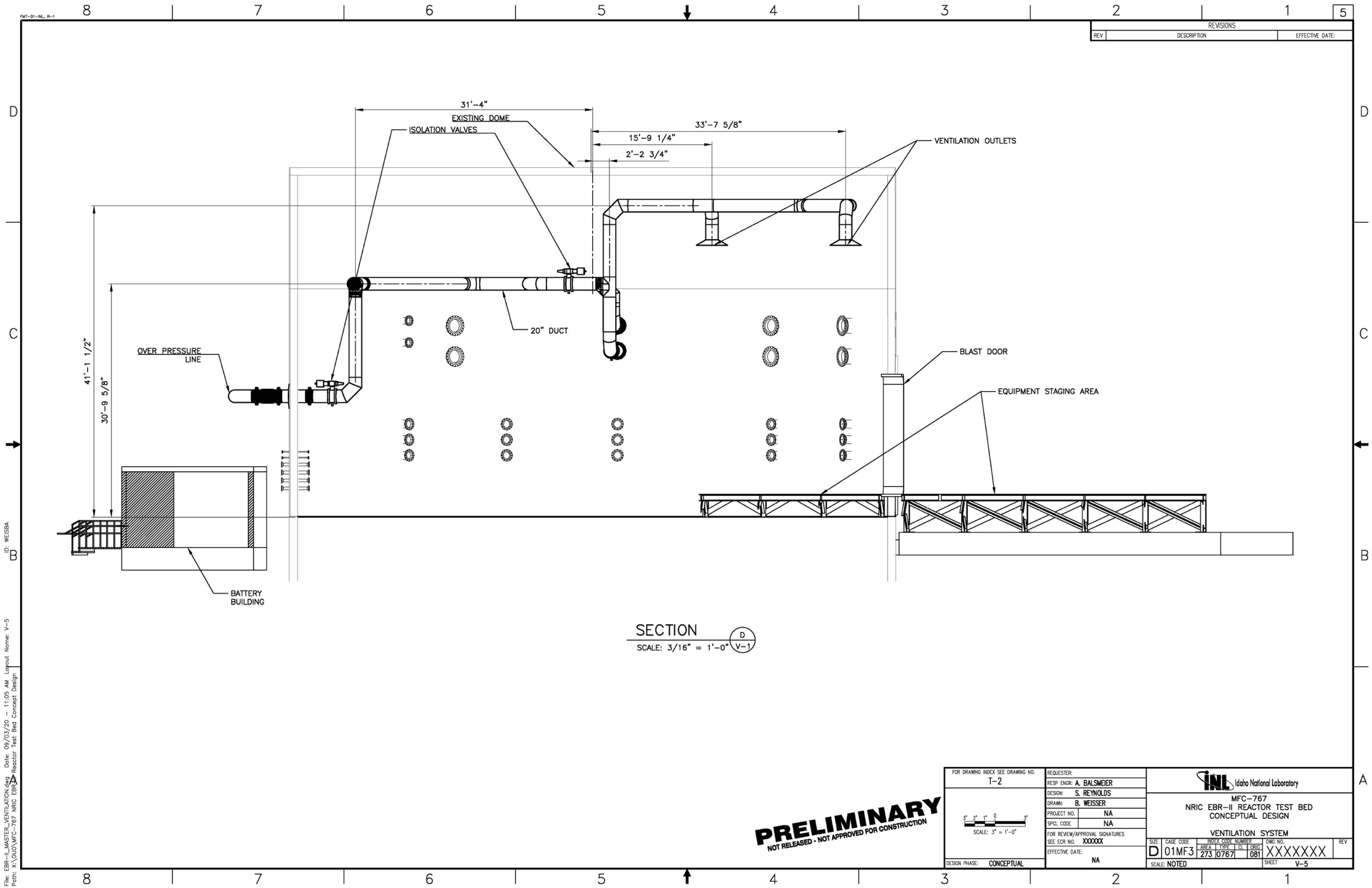

SEE NOTE 1
CH-1
CH-2
PCHWP-1
PCHWP-2
PCHWP-3
PCHWP-4
SCHWP-1
SCHWP-2
SCHWP-3
(STAND-BY)
ø10" CHWS
ø10" CHWR
ø10" COIL BY-PASS
AHU-1 CC-1
AHU-2 CC-2
AHU-3 CC-3
AHU-4 CC-4
AHU-5 CC-5
AHU-6 CC-6
AHU-7 CC-7
AHU-8 CC-8
LEGEND
FLOW DIRECTION
PIPE SIZE OR TUBE SIZE
REDUCER
PRESSURE GAGE
BUTTERFLY VALVE WITH ELECTRIC ACTUATOR
FLOW METER
STRAINER
2-WAY CONTROL VALVE WITH ELECTRIC ACTUATOR
AUTO FLOW BALANCING VALVE WITH MANUAL BUTTERFLY VALVE
AIR SEPERATOR
PUMP
LEGEND
CHWS CHILLED WATER SUPPLY
CHWR CHILLED WATER RETURN
AHU AIR HANDLING UNIT
CC COOLING COIL
CV CONTROL VALVE
PCHWP PRIMARY CHILLED WATER PUMP
SCHWP SECONDARY CHILLED WATER PUMP
PG PROPYLENE GLYCOL
NOTE
1. PRE-FABRICATED, PRE-PIPED/PRE-WIRED PUMP HOUSE WITH PUMPS AND VARIABLE SPEED DRIVES (NEMA-4 CABINETS), ONE-STANDBY AND LEAD/LAG OPERATION (460V/3ϕ).
45% PG CHILLED WATER COOLING
PROCESS AND INSTRUMENTATION DIAGRAM
DESIGN ITERATION #2
PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION
REVISIONS
NO SCALE
REQUESTER: A. BALSMEIER
RESP ENGR: A. BALSMEIER
DESIGN: C. BECK
DRAWN: R. SHICK
Idaho National Laboratory
MFC-767
NRIC EBR-II REACTOR TEST BED
CONCEPTUAL DESIGN
45% PG CHILLED WATER COOLING
PROCESS AND INSTRUMENTATION DIAGRAM
EFFECTIVE DATE: XX/XX/2020
DESIGN PHASE: DESIGN
SCALE: NONE

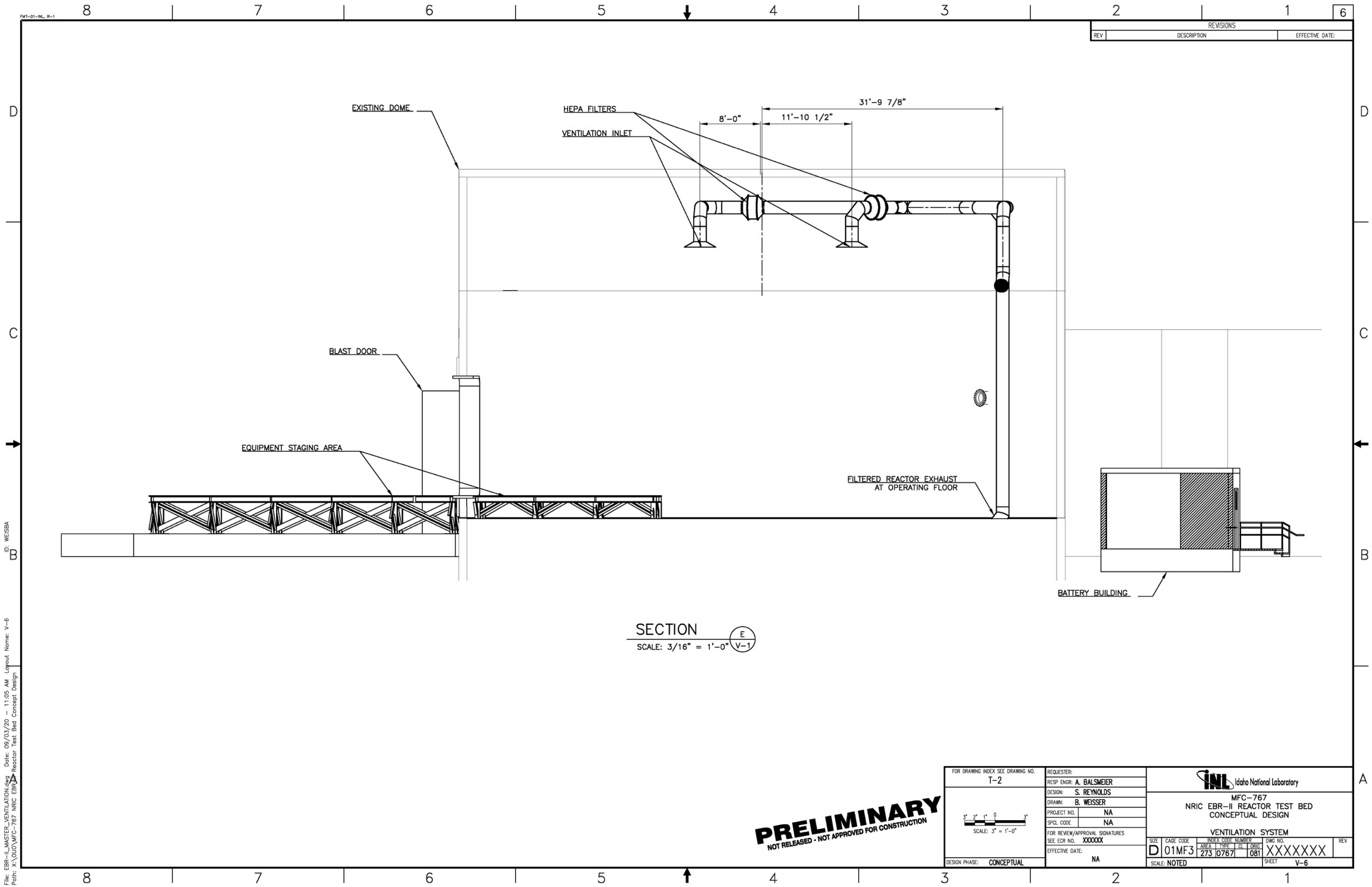

REVISIONS
REV
DESCRIPTION
EFFECTIVE DATE:
STACK MONITORING CABINET
FANS
STACK
HEPA FILTER
MAKE-UP AIR UNIT
EQUIPMENT STAGING AREA
EXISTING DOME
BATTERY BUILDING
LOOKING SOUTH EAST
ISOMETRIC VIEW
SCALE: NONE
LOOKING SOUTH WEST
ISOMETRIC VIEW
SCALE: NONE
ENLARGED PLAN VIEW
SCALE: 3/32" = 1'-0"
PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION
FOR DRAWING INDEX SEE DRAWING NO. T-2
SCALE: 1/8" = 1'-0"
DESIGN PHASE: CONCEPTUAL
REQUESTER:
RESP ENGR: A. BALSMEIER
DESIGN: S. REYNOLDS
DRAWN: B. WEISSER
PROJECT NO. NA
SPCL CODE NA
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO. XXXXXX
EFFECTIVE DATE: NA
Idaho National Laboratory
MFC-767
NRIC EBR-II REACTOR TEST BED
CONCEPTUAL DESIGN
VENTILATION SYSTEM
SIZE D
CAGE CODE 01MF3
INDEX CODE NUMBER AREA 273 TYPE 0767 CL ORIG 081
DWG NO. XXXXXXX
REV
SCALE: NOTED
SHEET V-1

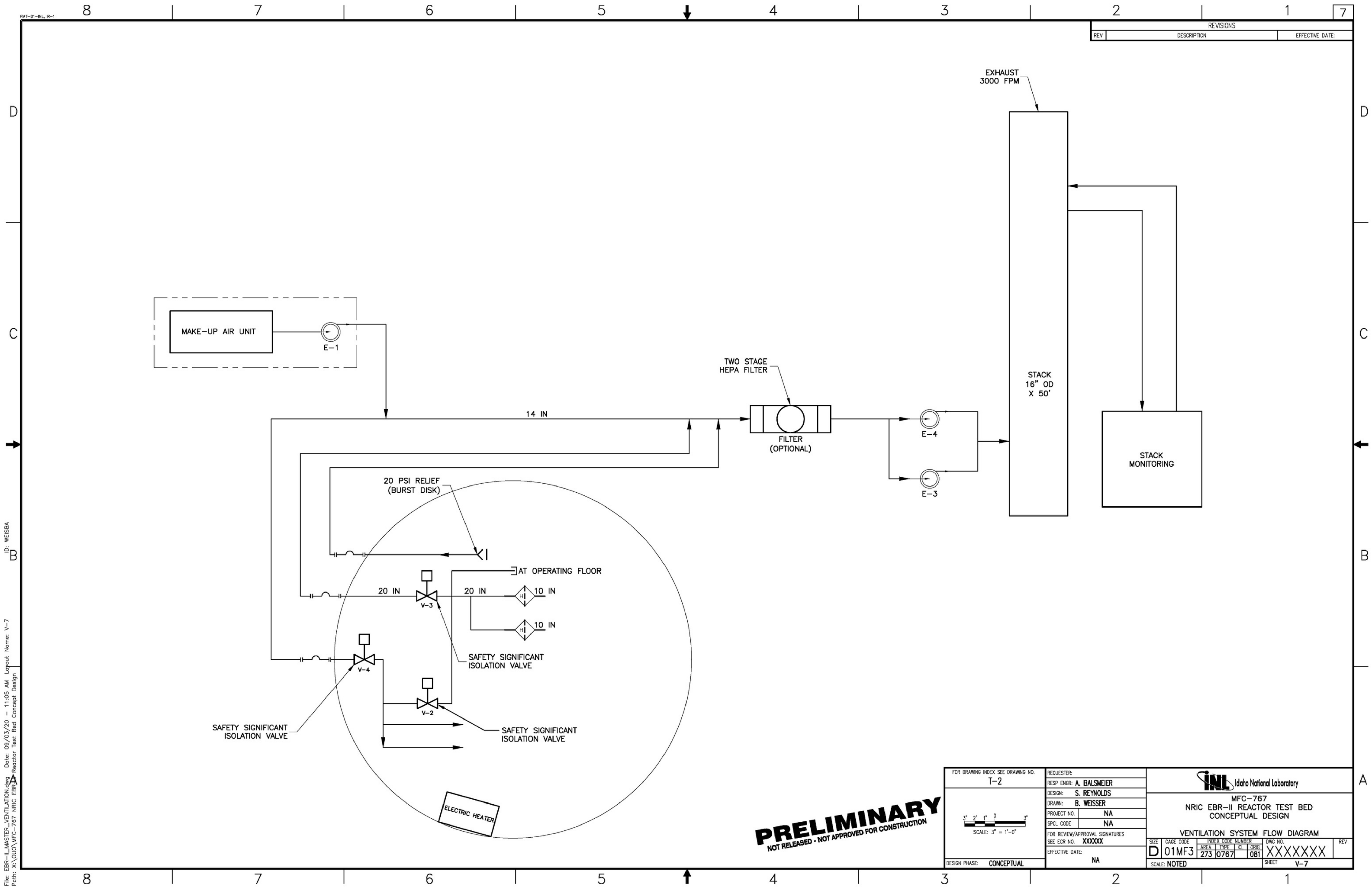

MAKE-UP AIR VENT
BELLOWS CONNECTION
ISOLATION VALVES
VENTILATION OUTLETS
14"ø DUCT
20" DUCT TYP. UNLESS OTHERWISE NOTED
VENTILATION INLETS
ISOLATION VALVE
HEPA FILTERS
VENTILATION SYSTEM INSIDE THE DOME
PLAN VIEW
SCALE: 3/16" = 1'-0"
REVISIONS
REV
DESCRIPTION
EFFECTIVE DATE:
PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION
FOR DRAWING INDEX SEE DRAWING NO. T-2
SCALE: 1/8" = 1'-0"
DESIGN PHASE: CONCEPTUAL
REQUESTER:
RESP ENGR: A. BALSMEIER
DESIGN: S. REYNOLDS
DRAWN: B. WEISSER
PROJECT NO. NA
SPCL CODE NA
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO. XXXXXX
EFFECTIVE DATE: NA
Idaho National Laboratory
MFC-767
NRIC EBR-II REACTOR TEST BED
CONCEPTUAL DESIGN
VENTILATION SYSTEM
SIZE D
CAGE CODE 01MF3
INDEX CODE NUMBER AREA 273 TYPE 0767 CL ORIG 081
DWG NO. XXXXXXX
REV
SCALE: NOTED
SHEET V-2

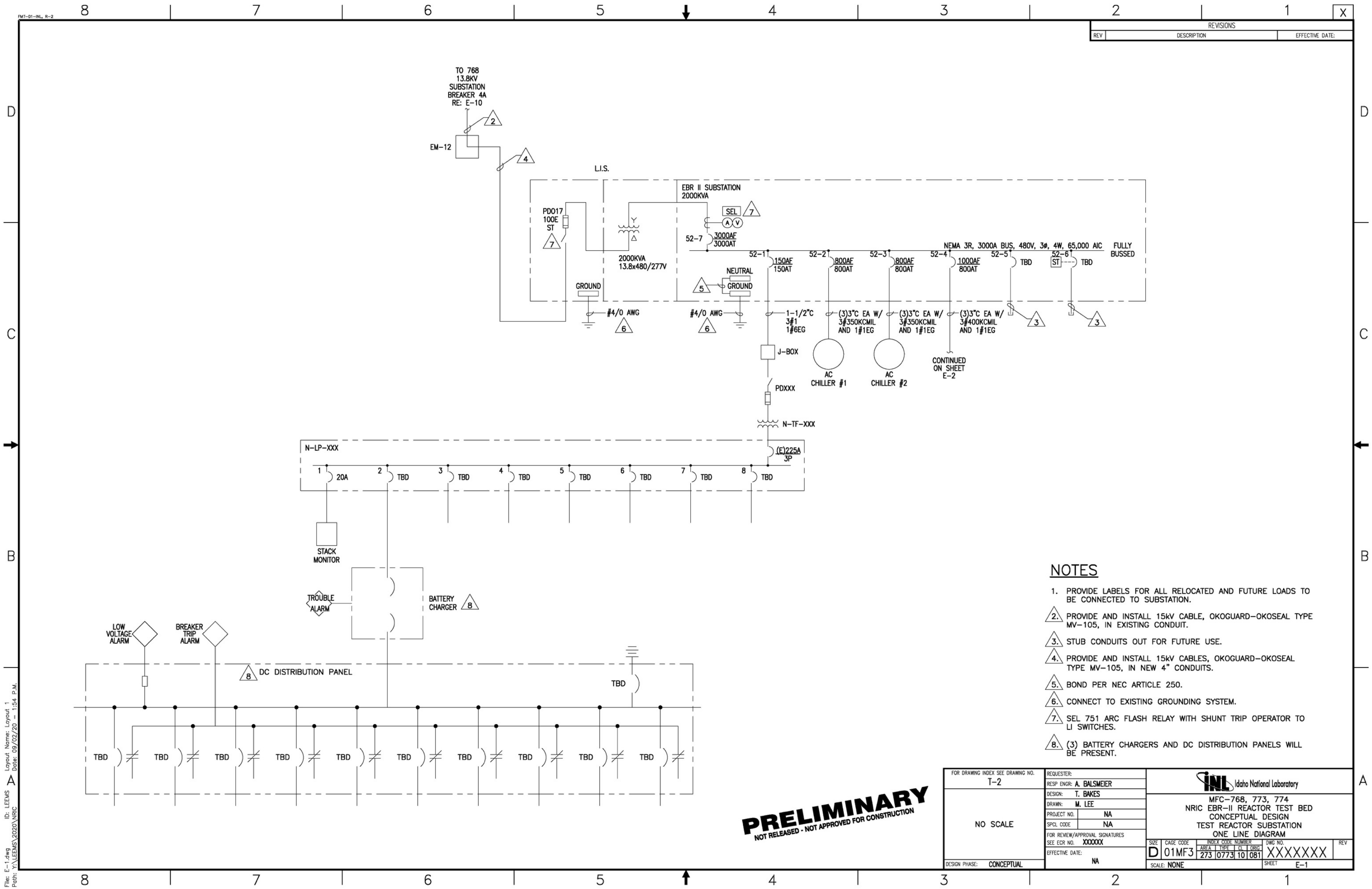

REVISIONS
REV
DESCRIPTION
EFFECTIVE DATE:
26'-0"
16"ø STACK
50' TALL
3/4" SAMPLE RETURN LINE
1 1/2" SAMPLING LINES
FANS
24'-9"
27'-0"
HEPA FILTER
12'-2 3/8"
12'-2 3/8"
24'-0"
SECTION A V-1
SCALE: 3/16" = 1'-0"
STACK
HEPA FILTER
STACK MONITORING CABINET
7'-8 1/2"
3'-8 1/2"
15'-1 1/4"
24'-9"
FAN
SECTION B V-1
SCALE: 3/16" = 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: S. REYNOLDS
DRAWN: B. WEISSER
PROJECT NO. NA
SPCL CODE NA
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO. XXXXXX
EFFECTIVE DATE: NA
Idaho National Laboratory
MFC-767
NRIC EBR-II REACTOR TEST BED
CONCEPTUAL DESIGN
VENTILATION SYSTEM
SIZE D
CAGE CODE 01MF3
INDEX CODE NUMBER AREA 273 TYPE 0767 CL ORIG 081
DWG NO. XXXXXXX
REV
SCALE: NOTED
SHEET V-3

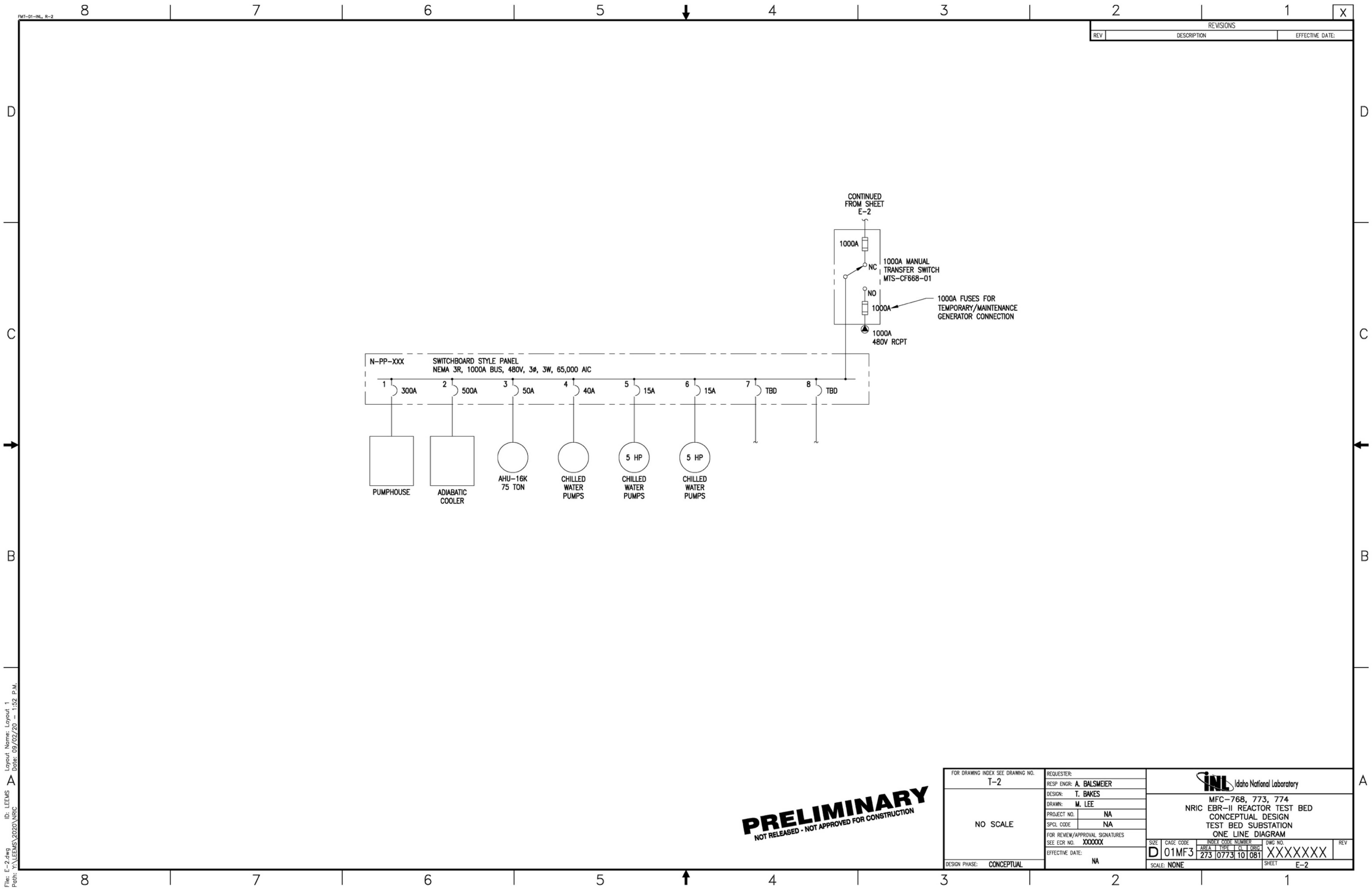

EXISTING DOME
OVER PRESSURE LINE
BATTERY BUILDING
MAKE-UP AIR UNIT
28'-3 5/8"
24'-11 5/8"
2'-11"
1'-10 3/8"
14'-9 1/8"
33'-8 3/8"
11'-3 1/2"
3'-8 1/2"
18'-11 5/8"
SECTION
SCALE: 3/16" = 1'-0"
C
V-1
PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION
REVISIONS
REV
DESCRIPTION
EFFECTIVE DATE:
FOR DRAWING INDEX SEE DRAWING NO. T-2
DESIGN PHASE: CONCEPTUAL
RESP ENGR: A. BALSMEIER
DESIGN: S. REYNOLDS
DRAWN: B. WEISSER
PROJECT NO. NA
SPCL CODE NA
SEE ECR NO. XXXXXX
EFFECTIVE DATE: NA
Idaho National Laboratory
MFC-767
NRIC EBR-II REACTOR TEST BED
CONCEPTUAL DESIGN
VENTILATION SYSTEM
SIZE D
CAGE CODE 01MF3
273 0767 081
DWG NO. XXXXXXX
SCALE: NOTED
SHEET V-4

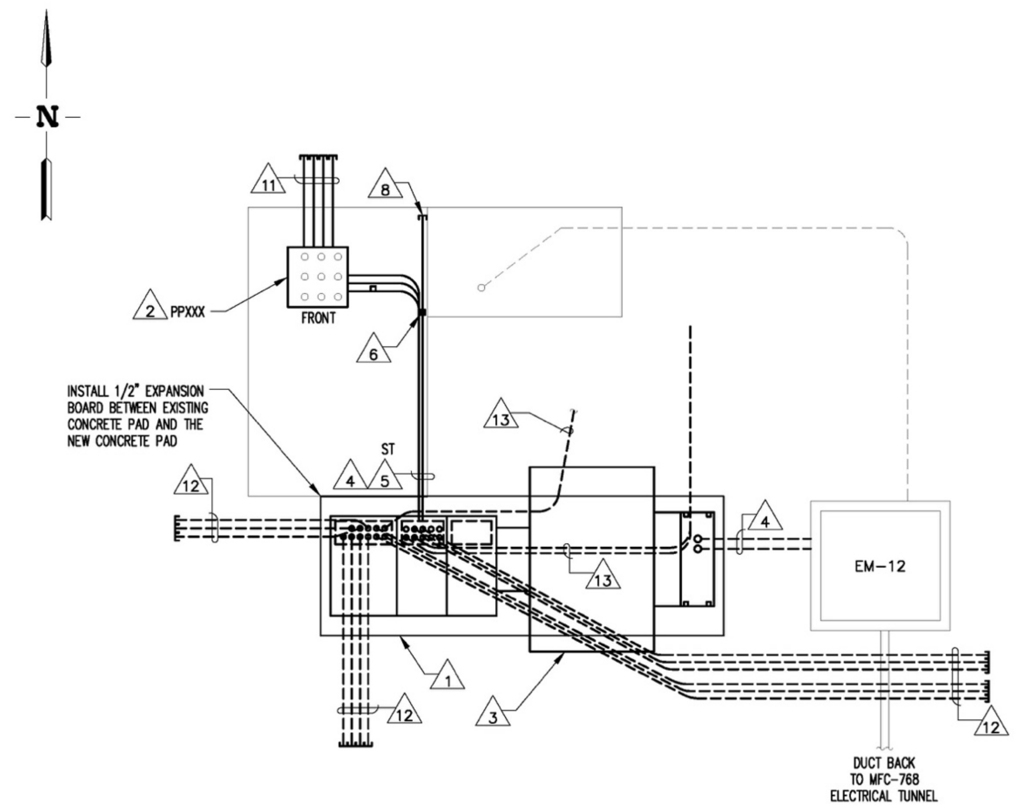

31'-4"
EXISTING DOME
ISOLATION VALVES
33'-7 5/8"
15'-9 1/4"
2'-2 3/4"
VENTILATION OUTLETS
20" DUCT
OVER PRESSURE LINE
41'-1 1/2"
30'-9 5/8"
BLAST DOOR
EQUIPMENT STAGING AREA
BATTERY BUILDING
SECTION D V-1
SCALE: 3/16" = 1'-0"
REVISIONS
REV
DESCRIPTION
EFFECTIVE DATE:
PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION
FOR DRAWING INDEX SEE DRAWING NO. T-2
SCALE: 3" = 1'-0"
DESIGN PHASE: CONCEPTUAL
REQUESTER:
RESP ENGR: A. BALSMEIER
DESIGN: S. REYNOLDS
DRAWN: B. WEISSER
PROJECT NO. NA
SPCL CODE NA
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO. XXXXXX
EFFECTIVE DATE: NA
Idaho National Laboratory
MFC-767
NRIC EBR-II REACTOR TEST BED
CONCEPTUAL DESIGN
VENTILATION SYSTEM
SIZE D
CAGE CODE 01MF3
INDEX CODE NUMBER AREA 273 TYPE 0767 CL ORIG 081
DWG NO. XXXXXXX
REV
SCALE: NOTED
SHEET V-5


EXISTING DOME
HEPA FILTERS
VENTILATION INLET
8'-0"
11'-10 1/2"
31'-9 7/8"
BLAST DOOR
EQUIPMENT STAGING AREA
FILTERED REACTOR EXHAUST AT OPERATING FLOOR
BATTERY BUILDING
SECTION
SCALE: 3/16" = 1'-0"
E
V-1
PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION
FOR DRAWING INDEX SEE DRAWING NO. T-2
REQUESTER:
RESP ENGR: A. BALSMEIER
DESIGN: S. REYNOLDS
DRAWN: B. WEISSER
PROJECT NO. NA
SPCL CODE NA
SEE ECR NO. XXXXXX
EFFECTIVE DATE: NA
DESIGN PHASE: CONCEPTUAL
Idaho National Laboratory
MFC-767
NRIC EBR-II REACTOR TEST BED
CONCEPTUAL DESIGN
VENTILATION SYSTEM
D 01MF3 273 0767 081 XXXXXXX
SCALE: NOTED
SHEET V-6

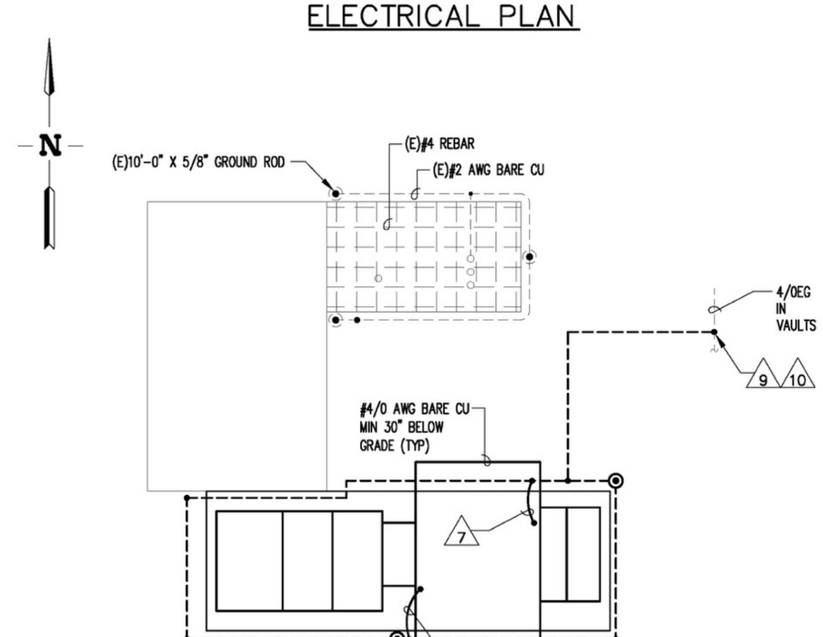

REVISIONS
REV
DESCRIPTION
EFFECTIVE DATE:
EXHAUST
3000 FPM
STACK
16" OD
X 50'
STACK
MONITORING
MAKE-UP AIR UNIT
E-1
14 IN
TWO STAGE
HEPA FILTER
FILTER
(OPTIONAL)
E-4
E-3
20 PSI RELIEF
(BURST DISK)
AT OPERATING FLOOR
20 IN
V-3
20 IN
10 IN
10 IN
SAFETY SIGNIFICANT
ISOLATION VALVE
V-4
V-2
SAFETY SIGNIFICANT
ISOLATION VALVE
SAFETY SIGNIFICANT
ISOLATION VALVE
ELECTRIC HEATER
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: S. REYNOLDS
DRAWN: B. WEISSER
PROJECT NO. NA
SPCL CODE NA
FOR REVIEW/APPROVAL SIGNATURES
SEE ECR NO. XXXXXX
EFFECTIVE DATE: NA
Idaho National Laboratory
MFC-767
NRIC EBR-II REACTOR TEST BED
CONCEPTUAL DESIGN
VENTILATION SYSTEM FLOW DIAGRAM
SIZE D
CAGE CODE 01MF3
INDEX CODE NUMBER AREA 273 TYPE 0767 CL ORIG 081
DWG NO. XXXXXXX
REV
SCALE: NOTED
SHEET V-7


TO 768
13.8KV
SUBSTATION
BREAKER 4A
RE: E-10
EM-12
L.I.S.
EBR II SUBSTATION
2000KVA
PD017
100E
ST
SEL
52-7
3000AF
3000AT
2000KVA
13.8x480/277V
GROUND
NEUTRAL
GROUND
#4/0 AWG
#4/0 AWG
NEMA 3R, 3000A BUS, 480V, 3Ø, 4W, 65,000 AIC
FULLY BUSSED
52-1 150AF 150AT
52-2 800AF 800AT
52-3 800AF 800AT
52-4 1000AF 800AT
52-5 TBD
52-6 ST TBD
1-1/2"C 3#1 1#6EG
(3)3"C EA W/ 3#350KCMIL AND 1#1EG
(3)3"C EA W/ 3#350KCMIL AND 1#1EG
(3)3"C EA W/ 3#400KCMIL AND 1#1EG
J-BOX
AC CHILLER #1
AC CHILLER #2
CONTINUED ON SHEET E-2
PDXXX
N-TF-XXX
N-LP-XXX
(E)225A 3P
20A
TBD
STACK MONITOR
TROUBLE ALARM
BATTERY CHARGER
LOW VOLTAGE ALARM
BREAKER TRIP ALARM
DC DISTRIBUTION PANEL
TBD
NOTES
1. PROVIDE LABELS FOR ALL RELOCATED AND FUTURE LOADS TO BE CONNECTED TO SUBSTATION.
2. PROVIDE AND INSTALL 15kV CABLE, OKOGUARD-OKOSEAL TYPE MV-105, IN EXISTING CONDUIT.
3. STUB CONDUITS OUT FOR FUTURE USE.
4. PROVIDE AND INSTALL 15kV CABLES, OKOGUARD-OKOSEAL TYPE MV-105, IN NEW 4" CONDUITS.
5. BOND PER NEC ARTICLE 250.
6. CONNECT TO EXISTING GROUNDING SYSTEM.
7. SEL 751 ARC FLASH RELAY WITH SHUNT TRIP OPERATOR TO LI SWITCHES.
8. (3) BATTERY CHARGERS AND DC DISTRIBUTION PANELS WILL BE PRESENT.
PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION
REVISIONS
REV DESCRIPTION EFFECTIVE DATE:
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-768, 773, 774
NRIC EBR-II REACTOR TEST BED
CONCEPTUAL DESIGN
TEST REACTOR SUBSTATION
ONE LINE DIAGRAM
SIZE D CAGE CODE 01MF3 INDEX CODE NUMBER 273 0773 10 081 DWG NO. XXXXXXX REV
SCALE: NONE SHEET E-1


REVISIONS
REV
DESCRIPTION
EFFECTIVE DATE:
CONTINUED FROM SHEET E-2
1000A
1000A MANUAL TRANSFER SWITCH MTS-CF668-01
NC
NO
1000A
1000A FUSES FOR TEMPORARY/MAINTENANCE GENERATOR CONNECTION
1000A 480V RCPT
N-PP-XXX
SWITCHBOARD STYLE PANEL
NEMA 3R, 1000A BUS, 480V, 3Ø, 3W, 65,000 AIC
1 300A
2 500A
3 50A
4 40A
5 15A
6 15A
7 TBD
8 TBD
PUMPHOUSE
ADIABATIC COOLER
AHU-16K 75 TON
CHILLED WATER PUMPS
5 HP
CHILLED WATER PUMPS
5 HP
CHILLED WATER PUMPS
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-768, 773, 774
NRIC EBR-II REACTOR TEST BED
CONCEPTUAL DESIGN
TEST BED SUBSTATION
ONE LINE DIAGRAM
SIZE D
CAGE CODE 01MF3
INDEX CODE NUMBER AREA 273 TYPE 0773 CL 10 ORIG 081
DWG NO. XXXXXXX
REV
SCALE: NONE
SHEET E-2



ELECTRICAL PLAN



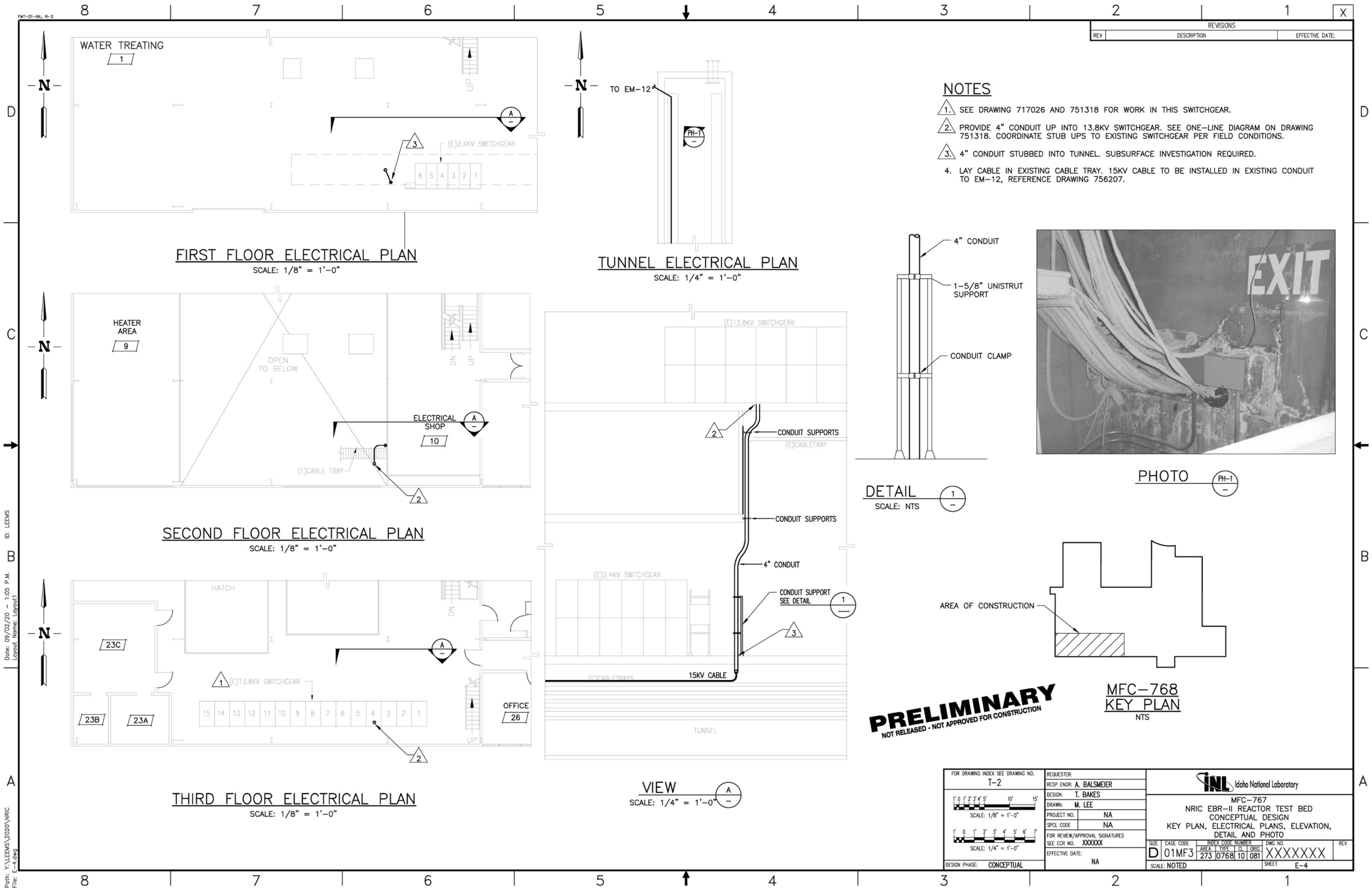
GROUNDING PLAN

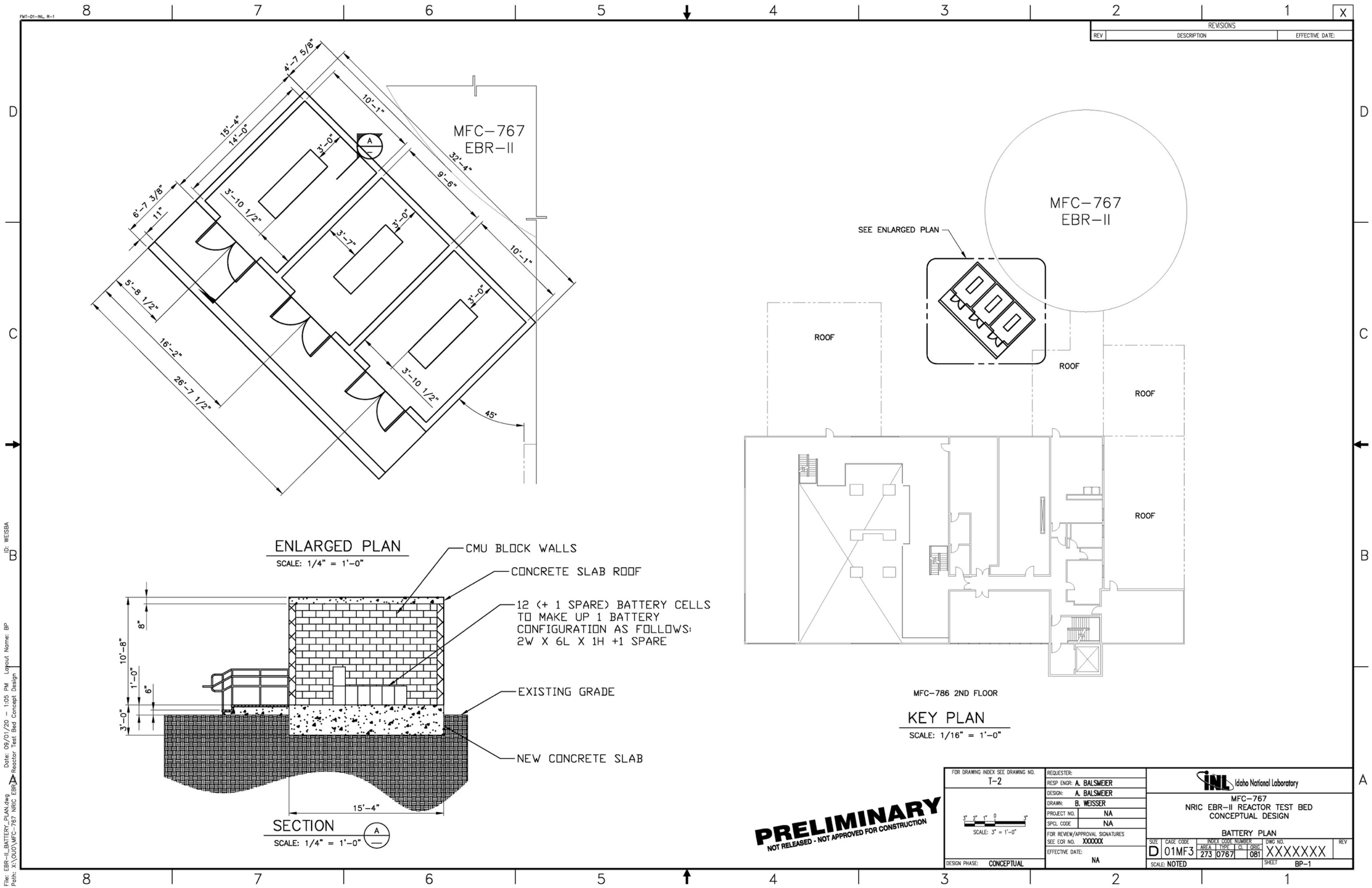
NOTES

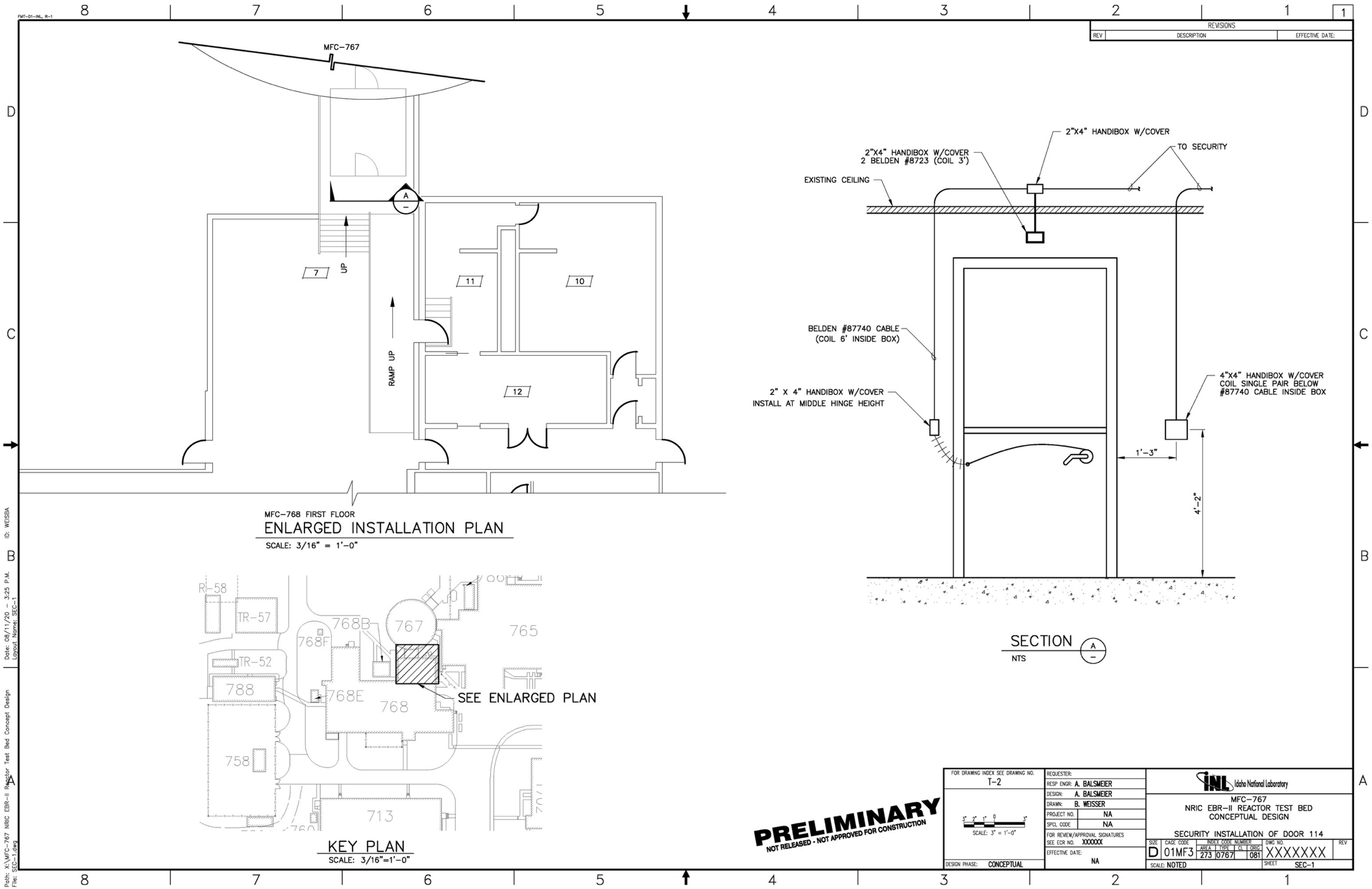
1. PROVIDE CONCRETE PAD FOR NEW EBR II SUBSTATION.
2. PROVIDE AND INSTALL NEW DISTRIBUTION PANEL PP-XXX. SEE ONE-LINE DIAGRAM ON SHEET E-1.
3. PROVIDE AND INSTALL NEW EBR II SUBSTATION. SEE ONE-LINE DIAGRAM ON SHEET E-1.
4. SEE ONE-LINE DIAGRAM ON SHEET E-1 FOR CONDUIT AND CONDUCTORS. COORDINATE ROUTING IN THE FIELD.
5. AFTER NEW EBR II SUBSTATION HAS BEEN INSTALLED, RE-FEED NEW PANEL PP-XXX FROM NEW SUBSTATION.
6. PROVIDE UNISTRUT SUPPORT RACK FOR ABOVE-GRADE CONDUITS. SEE UNISTRUT MOUNTING DETAIL-1 ON SHEET E-3.
7. SEE ONE-LINE DIAGRAM ON SHEET E-1 FOR GROUNDING.
8. STUB 3" CONDUIT FOR FUTURE USE.
9. CONNECT TO EXISTING GROUNDING ELECTRODE SYSTEM. #4/0 COPPER LOCATED IN EACH VAULT.
10. VERIFY THAT THE NEW GROUNDING ELECTRODE SYSTEM IS LESS THAN 5 OHMS PRIOR TO CONNECTING TO EXISTING GROUNDING ELECTRODE SYSTEM. IF NOT LESS THAN 5 OHMS, INSTALL ADDITIONAL GROUNDING RODS AT SIMILAR SPACING AS EXISTING TO LOWER RESISTANCE AS REQUIRED.
11. STUB (4) 2" CONDUITS FOR FUTURE USE.
12. PROVIDE AND INSTALL (13) 3" CONDUITS, (6) TO THE EAST, (3) TO THE WEST, AND (4) TO THE SOUTH. EXTEND APPROXIMATELY 2' FROM EDGE OF PAD. CAP AND MARK FOR FUTURE LOCATING.
13. EXTEND EXISTING 3" CONDUIT, CAP EXISTING CONDUIT ABOVE GROUND AND IDENTIFY AS SPARE.
14. DISTANCES SHOWN ARE APPROXIMATE. MUST MEET CODE MINIMUMS.

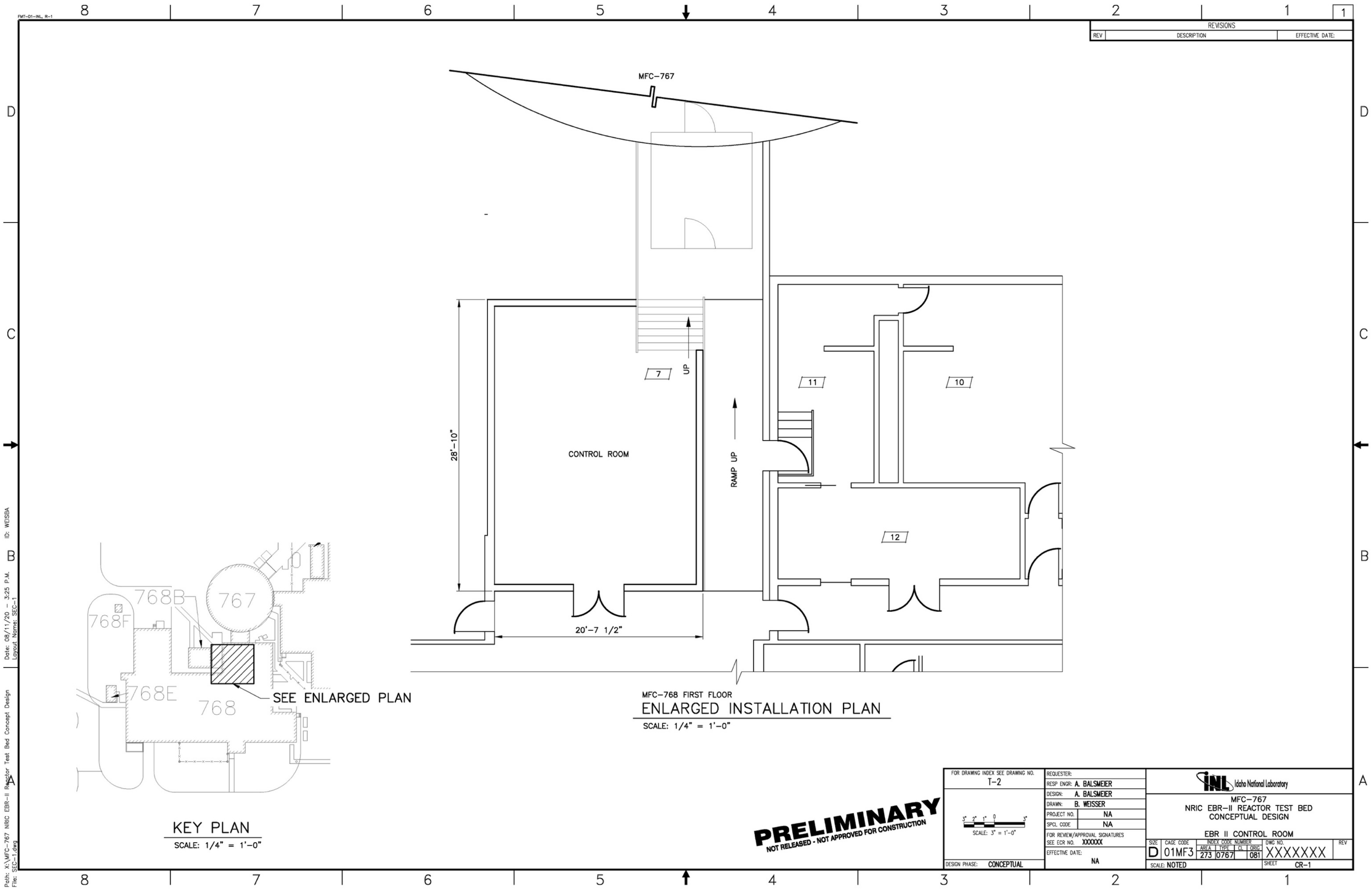
PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION

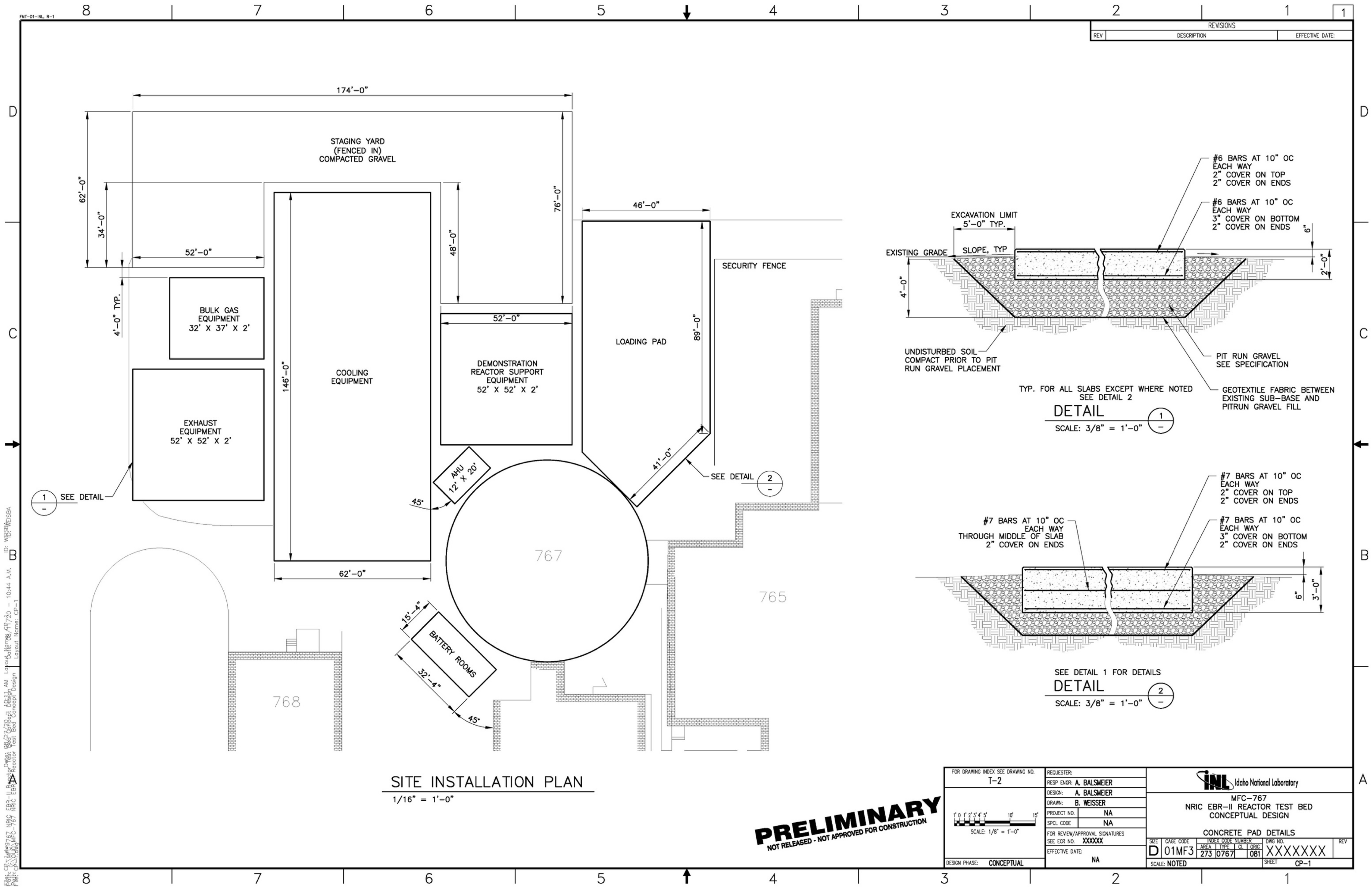
FOR DRAWING INDEX SEE DRAWING NO. T-2	REQUESTER:	Idaho National Laboratory
NO SCALE	RESP ENGR: A. BALSMEIER	MFC-767 NRIC EBR-II REACTOR TEST BED CONCEPTUAL DESIGN TEST BED SUBSTATION ELECTRICAL AND GROUNDING PLANS
	DESIGN: T. BAKES	SIZE: D; CAGE CODE: 01MF3; INDEX CODE NUMBER: AREA 273, TYPE 0773, CL 10, ORIG 081; DWG NO. XXXXXXX; REV
	DRAWN: M. LEE	SCALE: NONE
	PROJECT NO. NA	SHEET E-3
	SPCL CODE NA	
	FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO. XXXXXX	
DESIGN PHASE: CONCEPTUAL	EFFECTIVE DATE: NA	


WATER TREATING
1
(E)2.4KV SWITCHGEAR
FIRST FLOOR ELECTRICAL PLAN
SCALE: 1/8" = 1'-0"
TO EM-12
PH-1
TUNNEL ELECTRICAL PLAN
SCALE: 1/4" = 1'-0"
NOTES
1. SEE DRAWING 717026 AND 751318 FOR WORK IN THIS SWITCHGEAR.
2. PROVIDE 4" CONDUIT UP INTO 13.8KV SWITCHGEAR. SEE ONE-LINE DIAGRAM ON DRAWING 751318. COORDINATE STUB UPS TO EXISTING SWITCHGEAR PER FIELD CONDITIONS.
3. 4" CONDUIT STUBBED INTO TUNNEL. SUBSURFACE INVESTIGATION REQUIRED.
4. LAY CABLE IN EXISTING CABLE TRAY. 15KV CABLE TO BE INSTALLED IN EXISTING CONDUIT TO EM-12, REFERENCE DRAWING 756207.
HEATER AREA
9
OPEN TO BELOW
ELECTRICAL SHOP
10
(E)CABLE TRAY
SECOND FLOOR ELECTRICAL PLAN
SCALE: 1/8" = 1'-0"
(E)13.8KV SWITCHGEAR
CONDUIT SUPPORTS
(E)CABLETRAY
4" CONDUIT
CONDUIT SUPPORT SEE DETAIL
(E)2.4KV SWITCHGEAR
15KV CABLE
TUNNEL
4" CONDUIT
1-5/8" UNISTRUT SUPPORT
CONDUIT CLAMP
DETAIL
SCALE: NTS
EXIT
PHOTO
HATCH
23C
23B
23A
(E)13.8KV SWITCHGEAR
OFFICE
26
THIRD FLOOR ELECTRICAL PLAN
SCALE: 1/8" = 1'-0"
VIEW
SCALE: 1/4" = 1'-0"
AREA OF CONSTRUCTION
MFC-768
KEY PLAN
NTS
PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION
REVISIONS
REV DESCRIPTION EFFECTIVE DATE:
FOR DRAWING INDEX SEE DRAWING NO. T-2
REQUESTER:
RESP ENGR: A. BALSMEIER
DESIGN: T. BAKES
DRAWN: M. LEE
PROJECT NO. NA
SPCL CODE NA
SEE ECR NO. XXXXXX
EFFECTIVE DATE: NA
DESIGN PHASE: CONCEPTUAL
Idaho National Laboratory
MFC-767
NRIC EBR-II REACTOR TEST BED
CONCEPTUAL DESIGN
KEY PLAN, ELECTRICAL PLANS, ELEVATION, DETAIL AND PHOTO
SIZE D CAGE CODE 01MF3
AREA 273 TYPE 0768 CL 10 ORIG 081
DWG NO. XXXXXXX
SCALE: NOTED
SHEET E-4

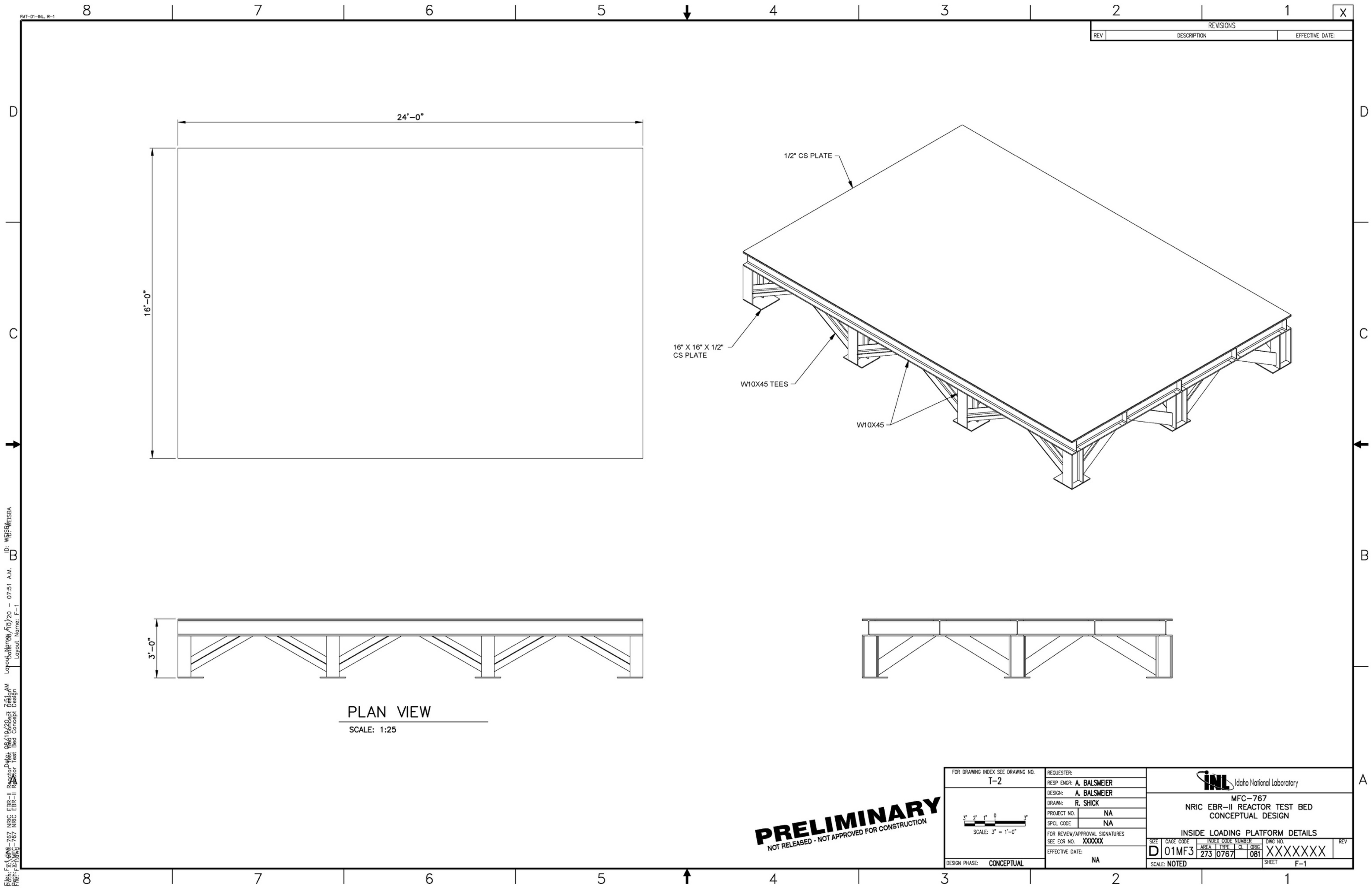

MFC-767
EBR-II
4'-7 5/8"
10'-1"
15'-4"
14'-0"
3'-0"
32'-4"
9'-6"
6'-7 3/8"
11"
3'-10 1/2"
3'-0"
3'-7"
10'-1"
5'-8 1/2"
3'-0"
16'-2"
26'-7 1/2"
3'-10 1/2"
45°
ENLARGED PLAN
SCALE: 1/4" = 1'-0"
CMU BLOCK WALLS
CONCRETE SLAB ROOF
12 (+ 1 SPARE) BATTERY CELLS TO MAKE UP 1 BATTERY CONFIGURATION AS FOLLOWS: 2W X 6L X 1H +1 SPARE
EXISTING GRADE
NEW CONCRETE SLAB
10'-8"
8"
1'-0"
6"
3'-0"
15'-4"
SECTION
SCALE: 1/4" = 1'-0"
MFC-767
EBR-II
SEE ENLARGED PLAN
ROOF
ROOF
ROOF
ROOF
MFC-786 2ND FLOOR
KEY PLAN
SCALE: 1/16" = 1'-0"
PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION
REVISIONS
REV
DESCRIPTION
EFFECTIVE DATE:
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-767
NRIC EBR-II REACTOR TEST BED
CONCEPTUAL DESIGN
BATTERY PLAN
SIZE D
CAGE CODE 01MF3
INDEX CODE NUMBER AREA 273 TYPE 0767 CL ORIG 081
DWG NO. XXXXXXX
REV
SCALE: NOTED
SHEET BP-1

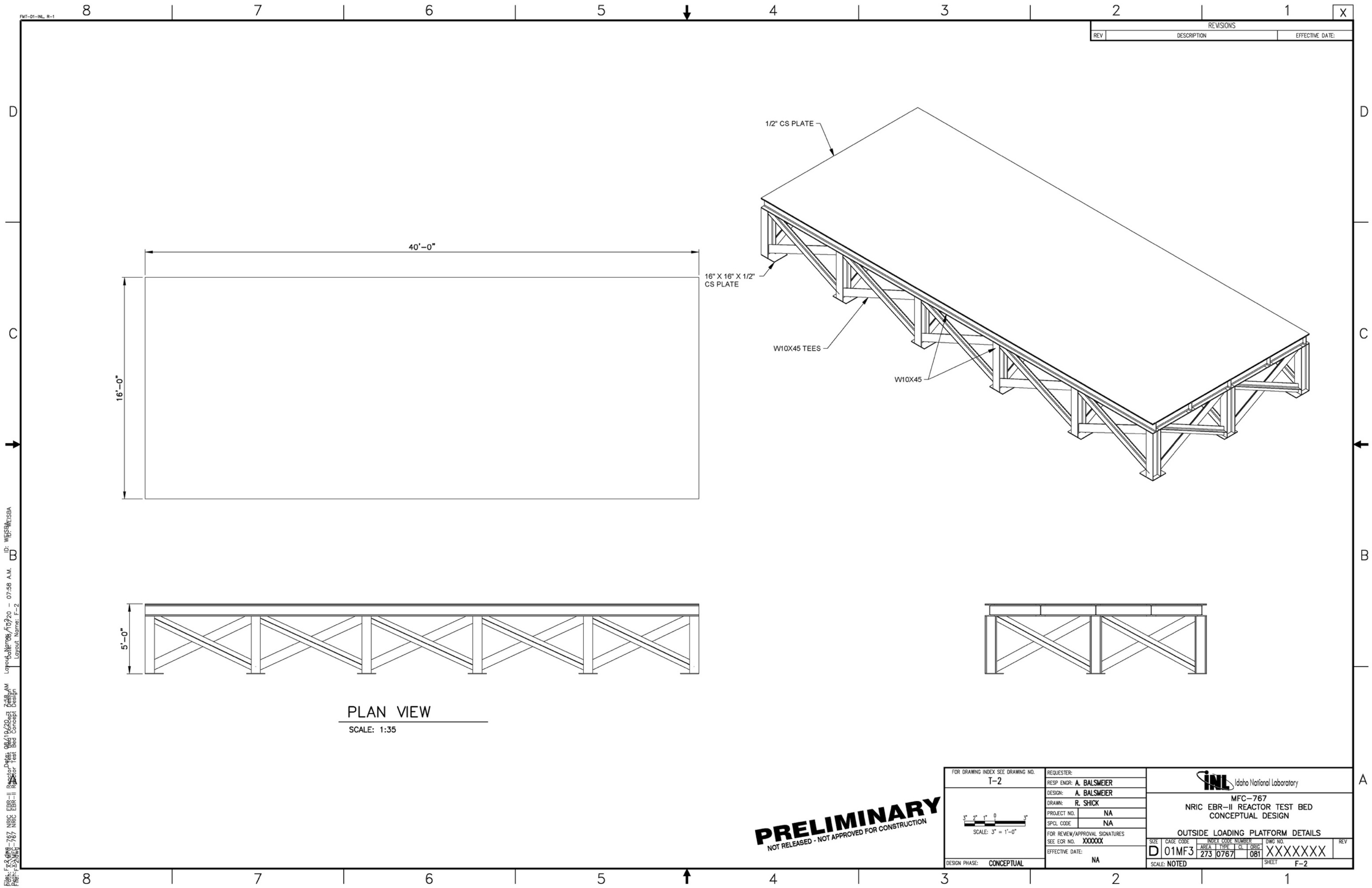

MFC-767
MFC-768 FIRST FLOOR
ENLARGED INSTALLATION PLAN
SCALE: 3/16" = 1'-0"
KEY PLAN
SCALE: 3/16"=1'-0"
SEE ENLARGED PLAN
2"X4" HANDIBOX W/COVER
TO SECURITY
2"X4" HANDIBOX W/COVER
2 BELDEN #8723 (COIL 3')
EXISTING CEILING
BELDEN #87740 CABLE
(COIL 6' INSIDE BOX)
2" X 4" HANDIBOX W/COVER
INSTALL AT MIDDLE HINGE HEIGHT
4"X4" HANDIBOX W/COVER
COIL SINGLE PAIR BELOW
#87740 CABLE INSIDE BOX
1'-3"
4'-2"
SECTION A
NTS
PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION
REVISIONS
REV DESCRIPTION EFFECTIVE DATE:
FOR DRAWING INDEX SEE DRAWING NO. T-2
DESIGN PHASE: CONCEPTUAL
REQUESTER:
RESP ENGR: A. BALSMEIER
DESIGN: A. BALSMEIER
DRAWN: B. WEISSER
PROJECT NO. NA
SPCL CODE NA
SEE ECR NO. XXXXXX
EFFECTIVE DATE: NA
Idaho National Laboratory
MFC-767
NRIC EBR-II REACTOR TEST BED
CONCEPTUAL DESIGN
SECURITY INSTALLATION OF DOOR 114
SIZE D CAGE CODE 01MF3 AREA 273 TYPE 0767 ORIG 081 DWG NO. XXXXXXX
SCALE: NOTED SHEET SEC-1


MFC-767
CONTROL ROOM
7
11
10
12
UP
RAMP UP
28'-10"
20'-7 1/2"
MFC-768 FIRST FLOOR
ENLARGED INSTALLATION PLAN
SCALE: 1/4" = 1'-0"
768B
767
768F
768E
768
SEE ENLARGED PLAN
KEY PLAN
SCALE: 1/4" = 1'-0"
PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION
REVISIONS
REV
DESCRIPTION
EFFECTIVE DATE:
FOR DRAWING INDEX SEE DRAWING NO.
T-2
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
DESIGN PHASE: CONCEPTUAL
Idaho National Laboratory
MFC-767
NRIC EBR-II REACTOR TEST BED
CONCEPTUAL DESIGN
EBR II CONTROL ROOM
SIZE D
CAGE CODE 01MF3
273 0767 081
XXXXXXX
SCALE: NOTED
SHEET CR-1

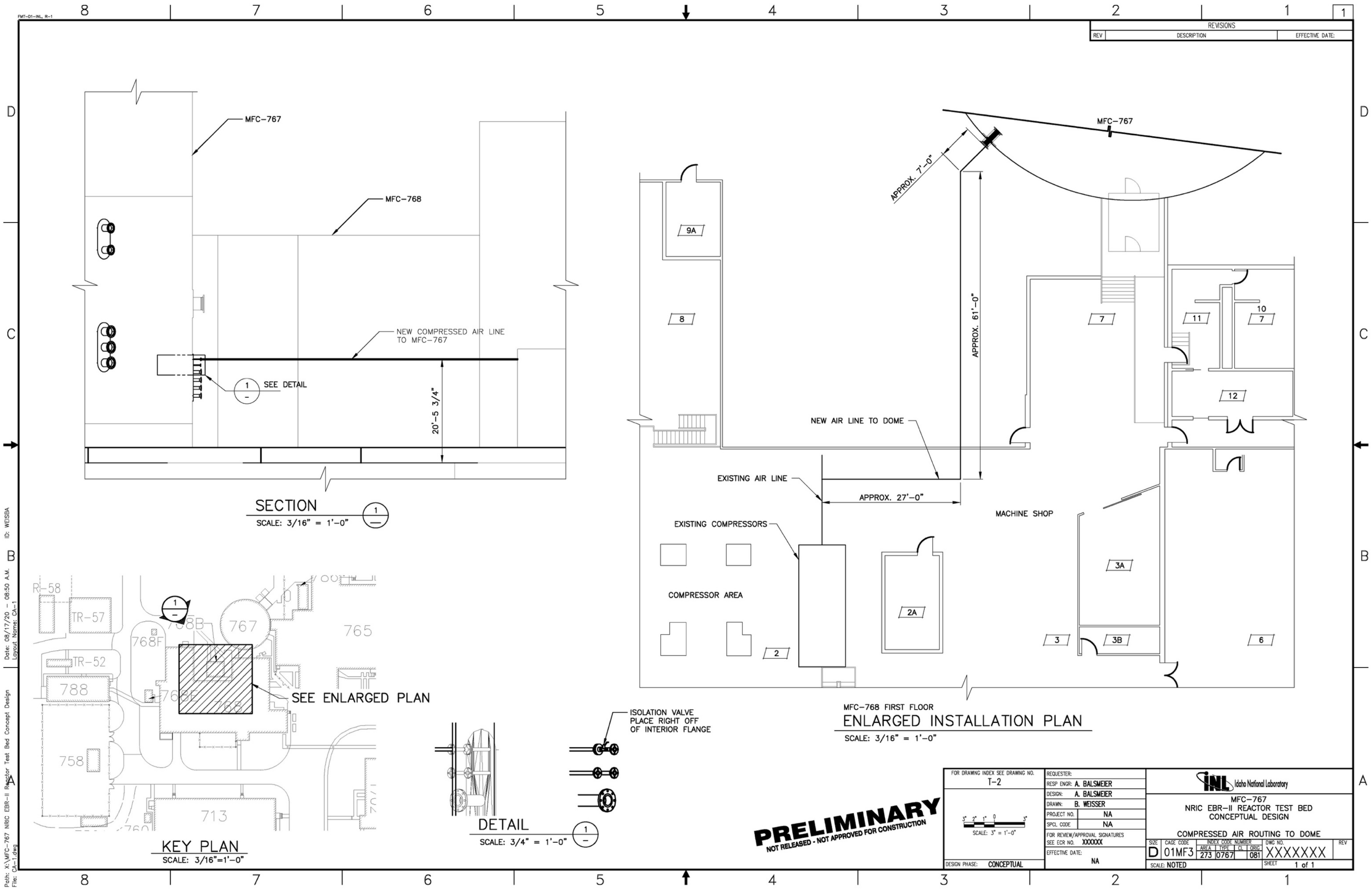


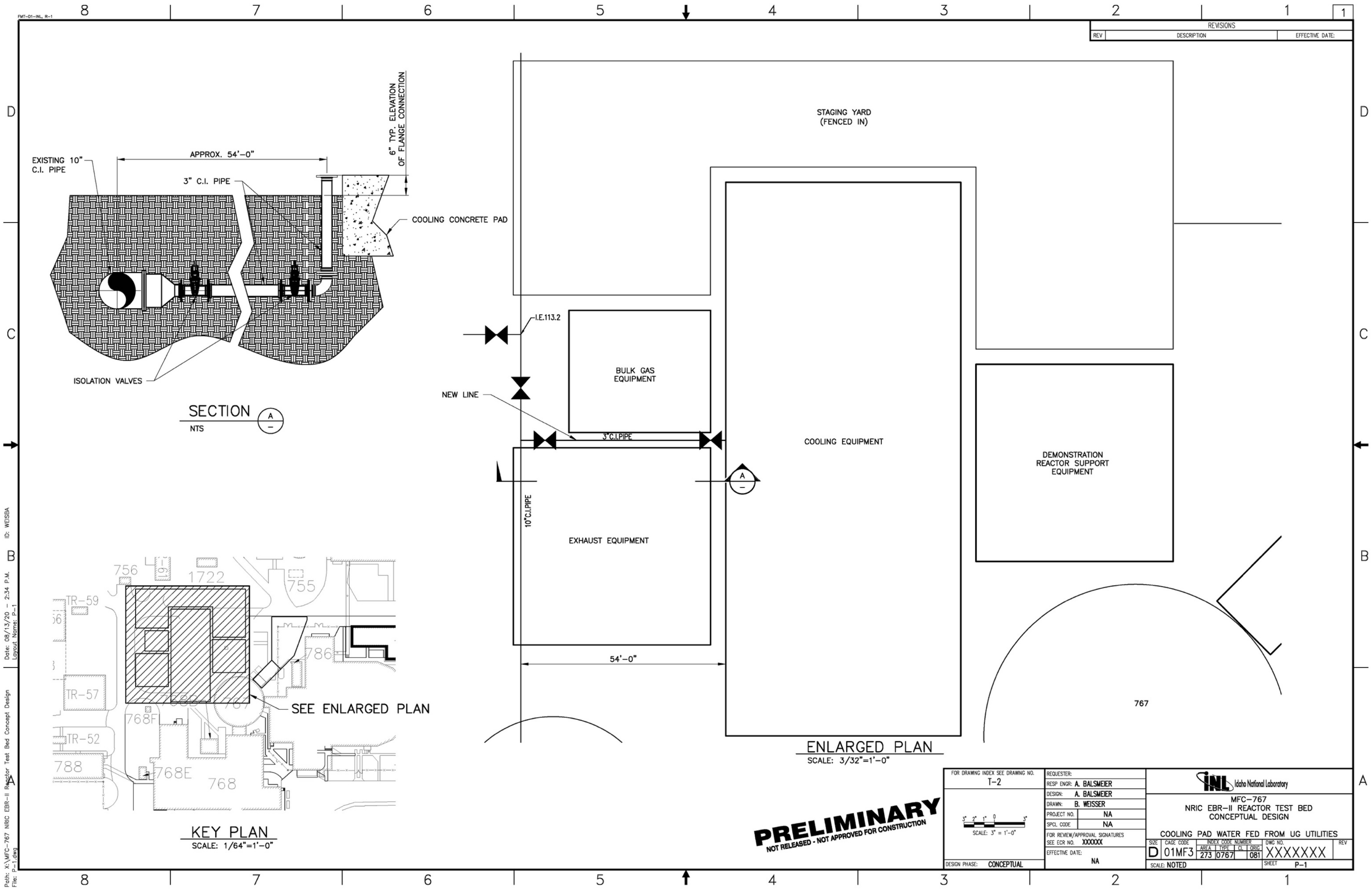
STAGING YARD
(FENCED IN)
COMPACTED GRAVEL
174'-0"
62'-0"
34'-0"
76'-0"
52'-0"
48'-0"
46'-0"
4'-0" TYP.
BULK GAS EQUIPMENT 32' X 37' X 2'
EXHAUST EQUIPMENT 52' X 52' X 2'
COOLING EQUIPMENT
146'-0"
62'-0"
DEMONSTRATION REACTOR SUPPORT EQUIPMENT 52' X 52' X 2'
LOADING PAD
89'-0"
41'-0"
SECURITY FENCE
AHU 12' X 20'
45°
767
765
768
15'-4"
BATTERY ROOMS
32'-4"
SEE DETAIL 1
SEE DETAIL 2
SITE INSTALLATION PLAN
1/16" = 1'-0"
EXCAVATION LIMIT 5'-0" TYP.
EXISTING GRADE
SLOPE, TYP
#6 BARS AT 10" OC EACH WAY 2" COVER ON TOP 2" COVER ON ENDS
#6 BARS AT 10" OC EACH WAY 3" COVER ON BOTTOM 2" COVER ON ENDS
4'-0"
6"
2'-0"
UNDISTURBED SOIL COMPACT PRIOR TO PIT RUN GRAVEL PLACEMENT
PIT RUN GRAVEL SEE SPECIFICATION
GEOTEXTILE FABRIC BETWEEN EXISTING SUB-BASE AND PITRUN GRAVEL FILL
TYP. FOR ALL SLABS EXCEPT WHERE NOTED SEE DETAIL 2
DETAIL 1
SCALE: 3/8" = 1'-0"
#7 BARS AT 10" OC EACH WAY 2" COVER ON TOP 2" COVER ON ENDS
#7 BARS AT 10" OC EACH WAY THROUGH MIDDLE OF SLAB 2" COVER ON ENDS
#7 BARS AT 10" OC EACH WAY 3" COVER ON BOTTOM 2" COVER ON ENDS
6"
3'-0"
SEE DETAIL 1 FOR DETAILS
DETAIL 2
SCALE: 3/8" = 1'-0"
PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION
REVISIONS
REV DESCRIPTION EFFECTIVE DATE:
FOR DRAWING INDEX SEE DRAWING NO. T-2
SCALE: 1/8" = 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-767
NRIC EBR-II REACTOR TEST BED CONCEPTUAL DESIGN
CONCRETE PAD DETAILS
SIZE D CAGE CODE 01MF3
273 0767 081 XXXXXXX
SCALE: NOTED
SHEET CP-1

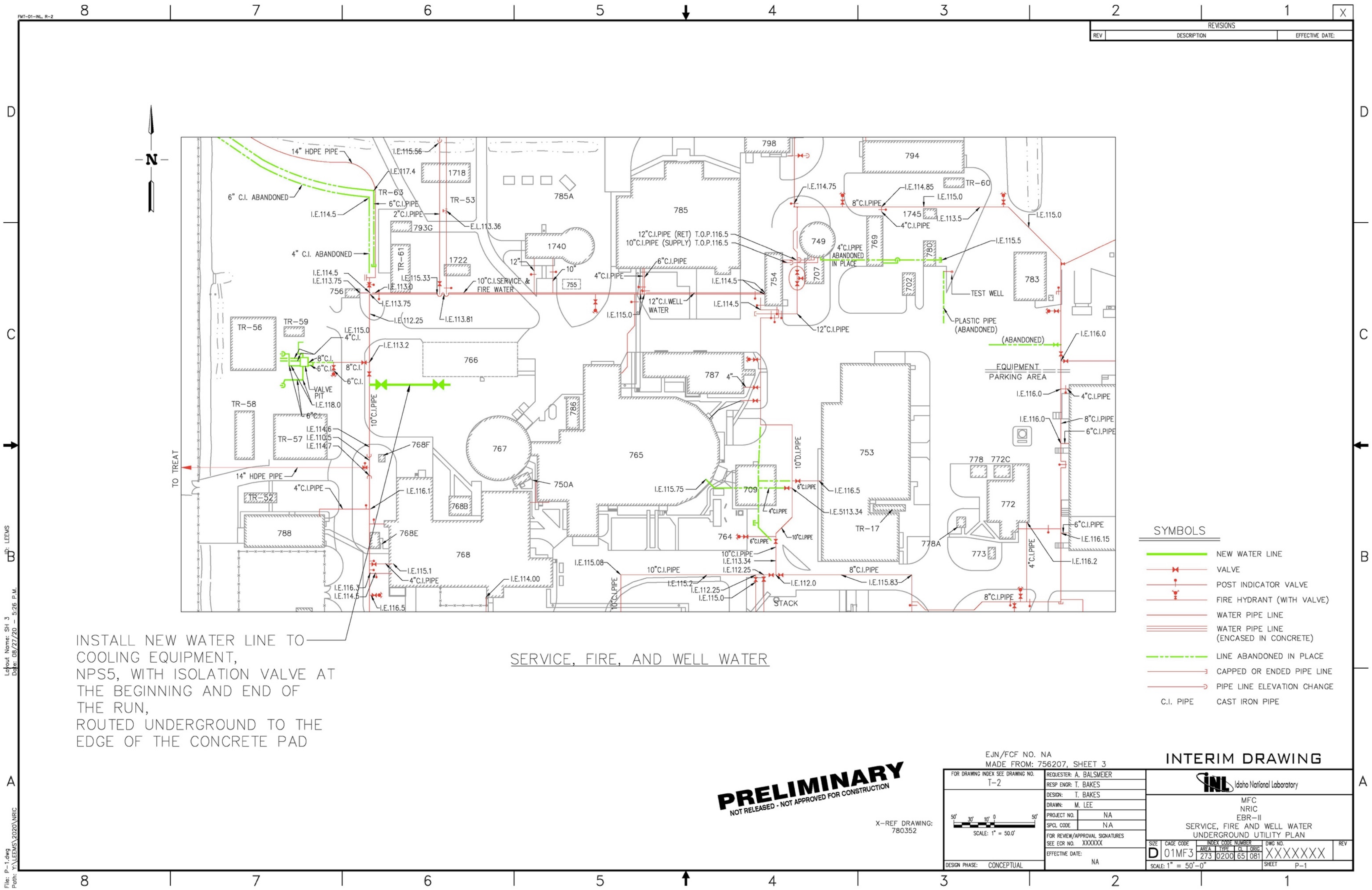

24'–0"
16'–0"
3'–0"
1/2" CS PLATE
16" X 16" X 1/2"
CS PLATE
W10X45 TEES
W10X45
PLAN VIEW
SCALE: 1:25
PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION
REVISIONS
REV
DESCRIPTION
EFFECTIVE DATE:
FOR DRAWING INDEX SEE DRAWING NO.
T–2
SCALE: 3" = 1'–0"
DESIGN PHASE: CONCEPTUAL
REQUESTER:
RESP ENGR: A. BALSMEIER
DESIGN: A. BALSMEIER
DRAWN: R. SHICK
PROJECT NO. NA
SPCL CODE NA
FOR REVIEW/APPROVAL SIGNATURES
SEE ECR NO. XXXXXX
EFFECTIVE DATE: NA
Idaho National Laboratory
MFC–767
NRIC EBR–II REACTOR TEST BED
CONCEPTUAL DESIGN
INSIDE LOADING PLATFORM DETAILS
SIZE D
CAGE CODE 01MF3
INDEX CODE NUMBER
AREA 273
TYPE 0767
CL
ORIG 081
DWG NO. XXXXXXX
REV
SCALE: NOTED
SHEET F–1

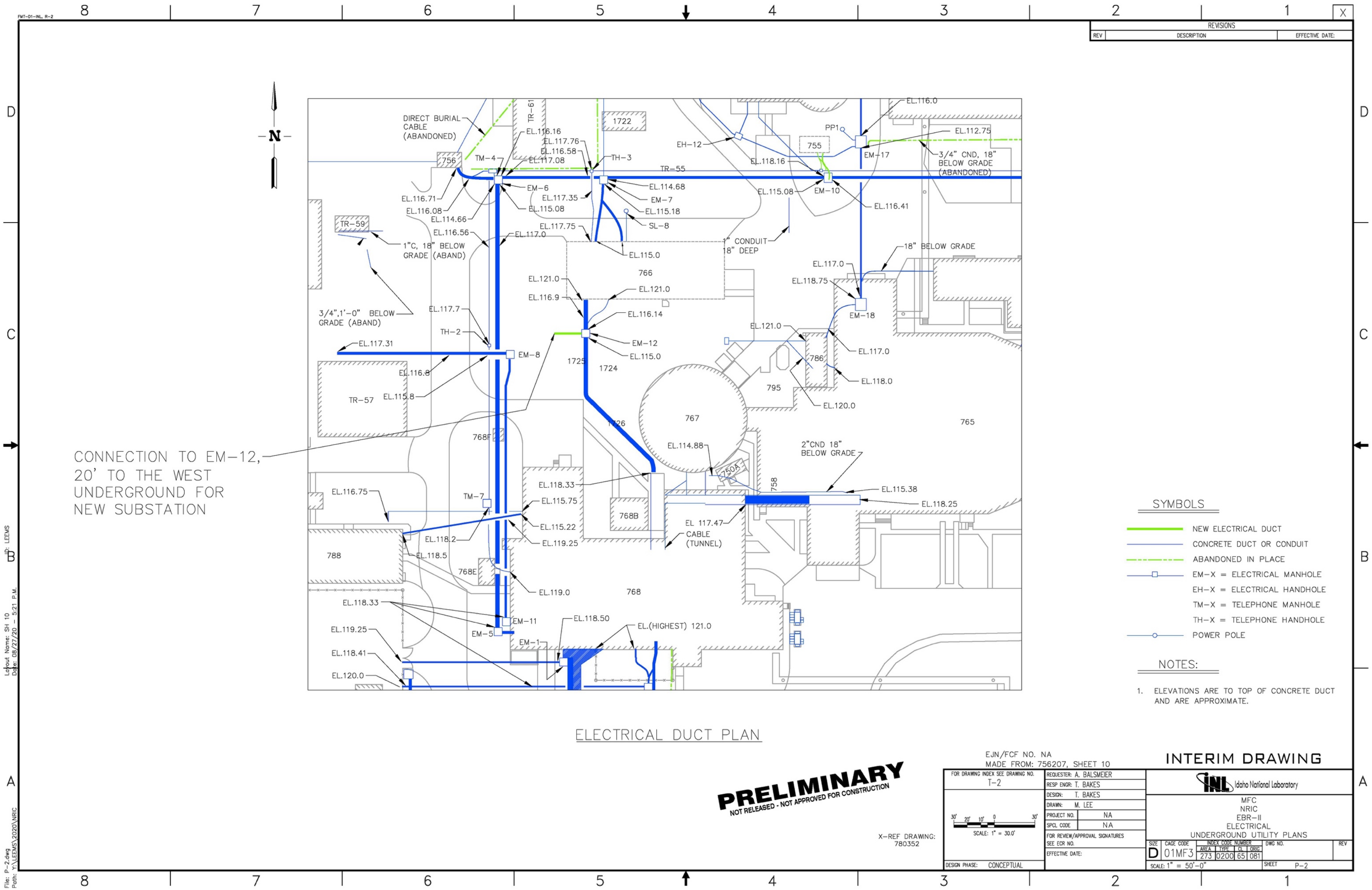


REVISIONS
REV
DESCRIPTION
EFFECTIVE DATE:
1/2" CS PLATE
40'–0"
16'–0"
16" X 16" X 1/2" CS PLATE
W10X45 TEES
W10X45
5'–0"
PLAN VIEW
SCALE: 1:35
PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION
FOR DRAWING INDEX SEE DRAWING NO. T–2
SCALE: 3" = 1'–0"
DESIGN PHASE: CONCEPTUAL
REQUESTER:
RESP ENGR: A. BALSMEIER
DESIGN: A. BALSMEIER
DRAWN: R. SHICK
PROJECT NO. NA
SPCL CODE NA
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO. XXXXXX
EFFECTIVE DATE: NA
Idaho National Laboratory
MFC–767
NRIC EBR–II REACTOR TEST BED
CONCEPTUAL DESIGN
OUTSIDE LOADING PLATFORM DETAILS
SIZE D
CAGE CODE 01MF3
INDEX CODE NUMBER AREA 273 TYPE 0767 CL ORIG 081
DWG NO. XXXXXXX
REV
SCALE: NOTED
SHEET F–2


MFC-767
MFC-768
NEW COMPRESSED AIR LINE TO MFC-767
SEE DETAIL
20'-5 3/4"
SECTION
SCALE: 3/16" = 1'-0"
SEE ENLARGED PLAN
KEY PLAN
SCALE: 3/16"=1'-0"
ISOLATION VALVE PLACE RIGHT OFF OF INTERIOR FLANGE
DETAIL
SCALE: 3/4" = 1'-0"
APPROX. 7'-0"
APPROX. 61'-0"
NEW AIR LINE TO DOME
EXISTING AIR LINE
APPROX. 27'-0"
EXISTING COMPRESSORS
COMPRESSOR AREA
MACHINE SHOP
MFC-768 FIRST FLOOR
ENLARGED INSTALLATION PLAN
SCALE: 3/16" = 1'-0"
PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION
REVISIONS
REQUESTER:
RESP ENGR: A. BALSMEIER
DESIGN: A. BALSMEIER
DRAWN: B. WEISSER
PROJECT NO. NA
SPCL CODE NA
SEE ECR NO. XXXXXX
EFFECTIVE DATE: NA
DESIGN PHASE: CONCEPTUAL
Idaho National Laboratory
MFC-767
NRIC EBR-II REACTOR TEST BED
CONCEPTUAL DESIGN
COMPRESSED AIR ROUTING TO DOME
D 01MF3 273 0767 081 XXXXXXX
SCALE: NOTED
SHEET 1 of 1


STAGING YARD
(FENCED IN)
EXISTING 10" C.I. PIPE
APPROX. 54'-0"
3" C.I. PIPE
6" TYP. ELEVATION OF FLANGE CONNECTION
COOLING CONCRETE PAD
ISOLATION VALVES
SECTION A
NTS
I.E.113.2
BULK GAS EQUIPMENT
NEW LINE
3"C.I.PIPE
COOLING EQUIPMENT
DEMONSTRATION REACTOR SUPPORT EQUIPMENT
10"C.I.PIPE
EXHAUST EQUIPMENT
54'-0"
767
SEE ENLARGED PLAN
KEY PLAN
SCALE: 1/64"=1'-0"
ENLARGED PLAN
SCALE: 3/32"=1'-0"
PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION
REVISIONS
REV DESCRIPTION EFFECTIVE DATE:
FOR DRAWING INDEX SEE DRAWING NO. T-2
REQUESTER:
RESP ENGR: A. BALSMEIER
DESIGN: A. BALSMEIER
DRAWN: B. WEISSER
PROJECT NO. NA
SPCL CODE NA
SEE ECR NO. XXXXXX
EFFECTIVE DATE: NA
DESIGN PHASE: CONCEPTUAL
Idaho National Laboratory
MFC-767
NRIC EBR-II REACTOR TEST BED CONCEPTUAL DESIGN
COOLING PAD WATER FED FROM UG UTILITIES
D 01MF3 273 0767 081 XXXXXXX
SCALE: NOTED
SHEET P-1


SERVICE, FIRE, AND WELL WATER
INSTALL NEW WATER LINE TO COOLING EQUIPMENT, NPS5, WITH ISOLATION VALVE AT THE BEGINNING AND END OF THE RUN, ROUTED UNDERGROUND TO THE EDGE OF THE CONCRETE PAD
SYMBOLS
NEW WATER LINE
VALVE
POST INDICATOR VALVE
FIRE HYDRANT (WITH VALVE)
WATER PIPE LINE
WATER PIPE LINE (ENCASED IN CONCRETE)
LINE ABANDONED IN PLACE
CAPPED OR ENDED PIPE LINE
PIPE LINE ELEVATION CHANGE
C.I. PIPE CAST IRON PIPE
INTERIM DRAWING
PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION
EJN/FCF NO. NA
MADE FROM: 756207, SHEET 3
X-REF DRAWING: 780352
REQUESTER: A. BALSMEIER
RESP ENGR: T. BAKES
DESIGN: T. BAKES
DRAWN: M. LEE
DESIGN PHASE: CONCEPTUAL
Idaho National Laboratory
MFC
NRIC
EBR-II
SERVICE, FIRE AND WELL WATER
UNDERGROUND UTILITY PLAN
SCALE: 1" = 50'-0"
SHEET P-1
REVISIONS
TO TREAT
STACK
EQUIPMENT PARKING AREA
14" HDPE PIPE
765
767
768
753
785
787


CONNECTION TO EM-12, 20' TO THE WEST UNDERGROUND FOR NEW SUBSTATION
ELECTRICAL DUCT PLAN
SYMBOLS
NEW ELECTRICAL DUCT
CONCRETE DUCT OR CONDUIT
ABANDONED IN PLACE
EM-X = ELECTRICAL MANHOLE
EH-X = ELECTRICAL HANDHOLE
TM-X = TELEPHONE MANHOLE
TH-X = TELEPHONE HANDHOLE
POWER POLE
NOTES:
1. ELEVATIONS ARE TO TOP OF CONCRETE DUCT AND ARE APPROXIMATE.
PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION
INTERIM DRAWING
EJN/FCF NO. NA
MADE FROM: 756207, SHEET 10
X-REF DRAWING: 780352
Idaho National Laboratory
MFC
NRIC
EBR-II
ELECTRICAL
UNDERGROUND UTILITY PLANS
DESIGN PHASE: CONCEPTUAL
SCALE: 1" = 50'-0"
P-2

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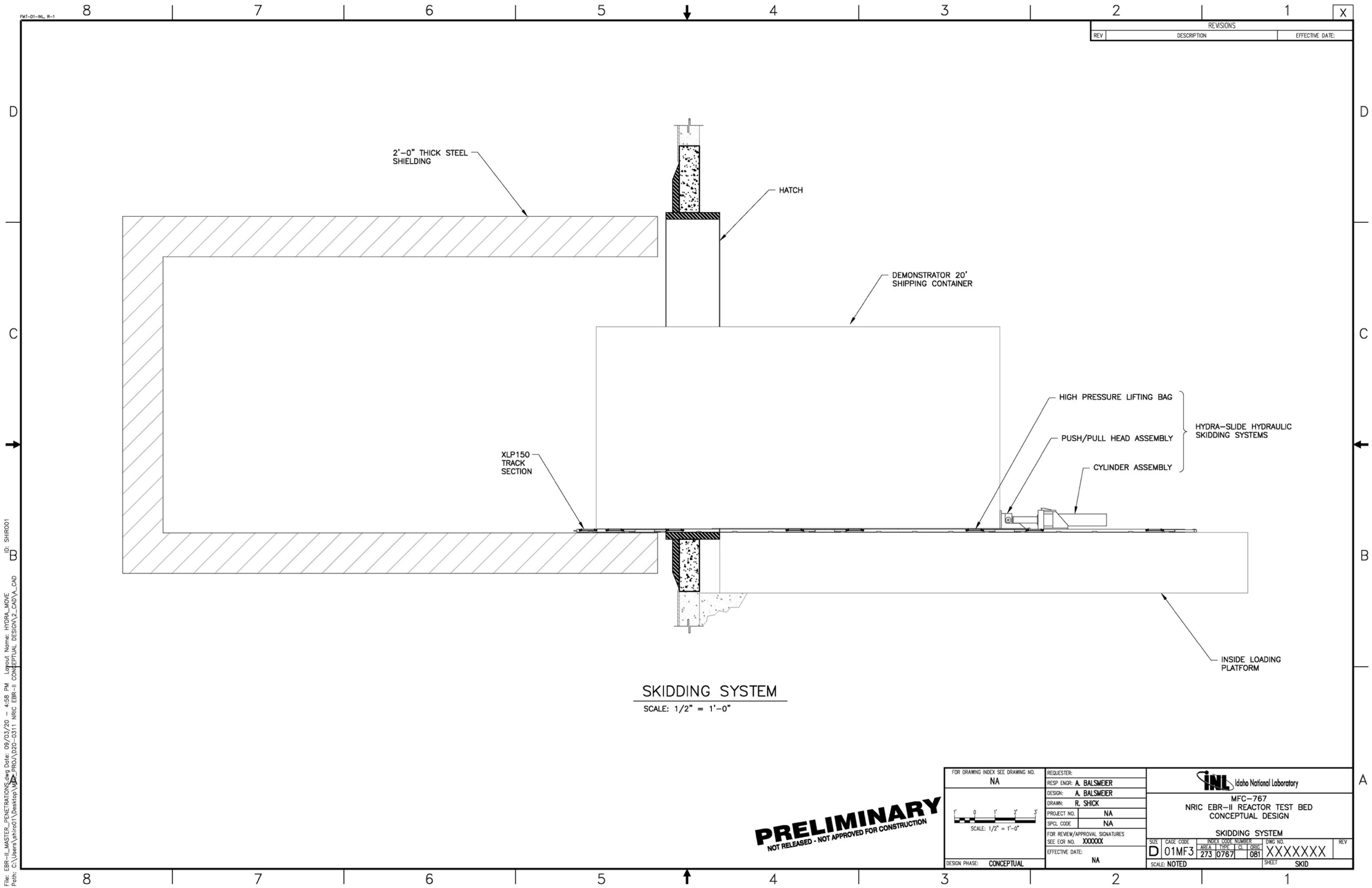
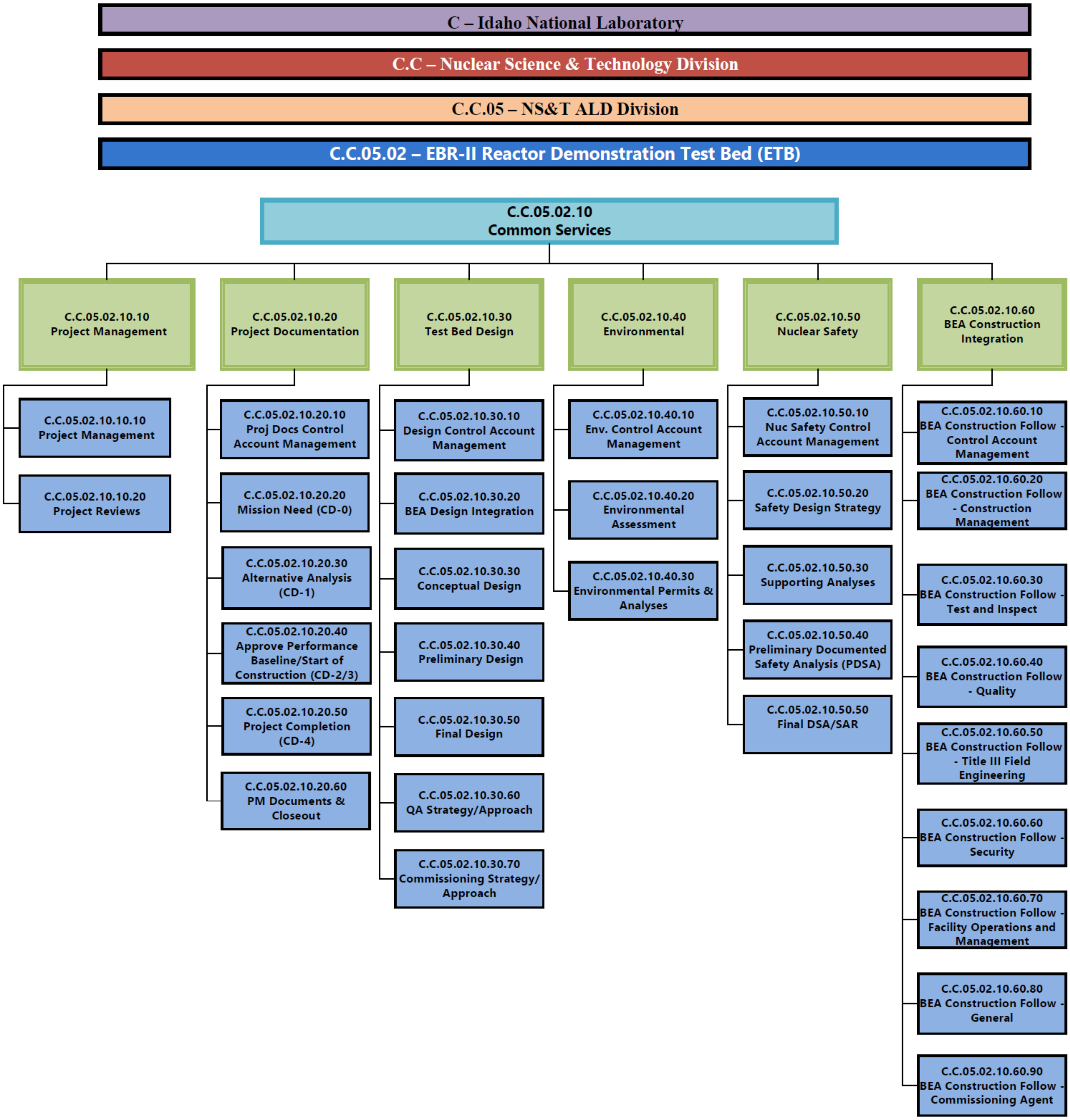
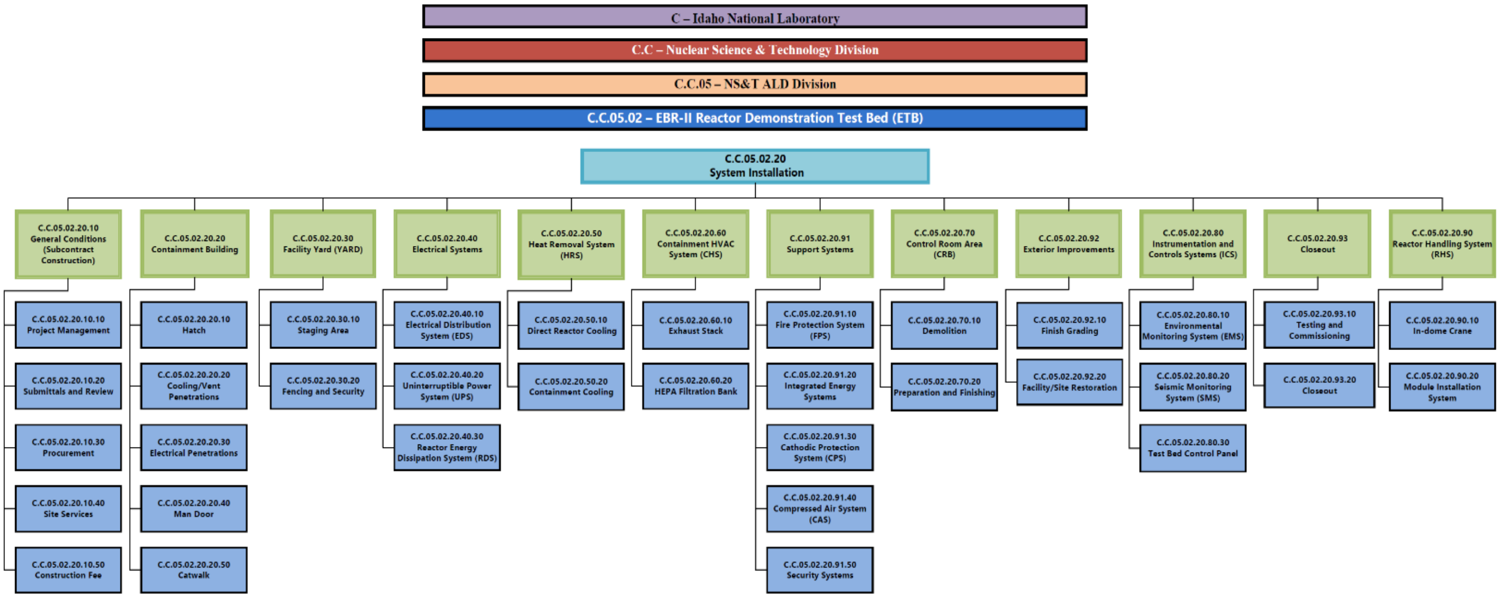


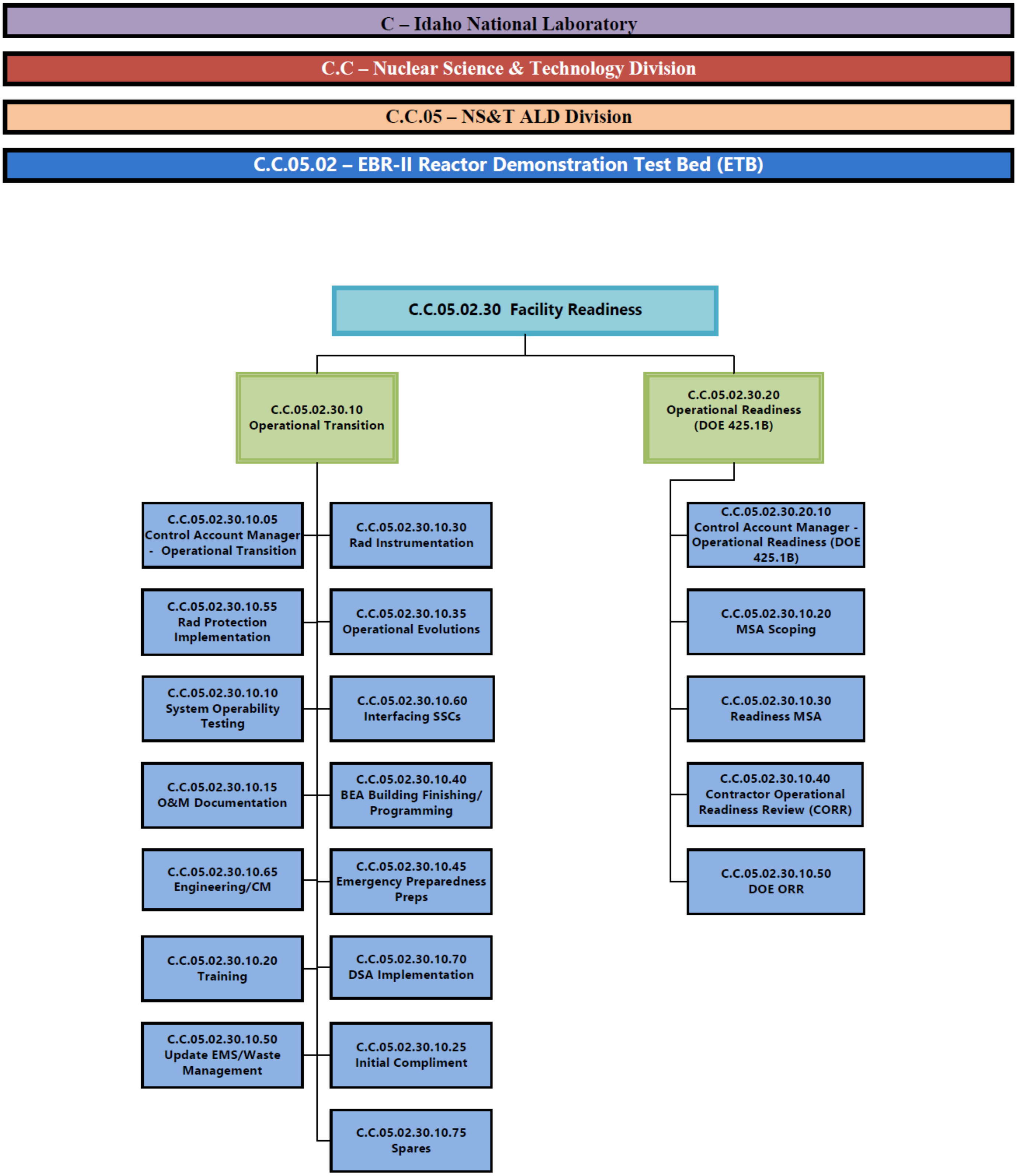
2'-0" THICK STEEL SHIELDING
HATCH
DEMONSTRATOR 20' SHIPPING CONTAINER
HIGH PRESSURE LIFTING BAG
PUSH/PULL HEAD ASSEMBLY
CYLINDER ASSEMBLY
HYDRA-SLIDE HYDRAULIC SKIDDING SYSTEMS
XLP150 TRACK SECTION
INSIDE LOADING PLATFORM
SKIDDING SYSTEM
SCALE: 1/2" = 1'-0"
REVISIONS
REV
DESCRIPTION
EFFECTIVE DATE:
PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION
FOR DRAWING INDEX SEE DRAWING NO. NA
SCALE: 1/2" = 1'-0"
DESIGN PHASE: CONCEPTUAL
REQUESTER:
RESP ENGR: A. BALSMEIER
DESIGN: A. BALSMEIER
DRAWN: R. SHICK
PROJECT NO. NA
SPCL CODE NA
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO. XXXXXX
EFFECTIVE DATE: NA
Idaho National Laboratory
MFC-767
NRIC EBR-II REACTOR TEST BED
CONCEPTUAL DESIGN
SKIDDING SYSTEM
SIZE D
CAGE CODE 01MF3
INDEX CODE NUMBER AREA 273 TYPE 0767 CL ORIG 081
DWG NO. XXXXXXX
REV
SCALE: NOTED
SHEET SKID

Appendix C

Work Breakdown Structure




C – Idaho National Laboratory
C.C – Nuclear Science & Technology Division
C.C.05 – NS&T ALD Division
C.C.05.02 – EBR-II Reactor Demonstration Test Bed (ETB)
C.C.05.02.20 System Installation
C.C.05.02.20.10 General Conditions (Subcontract Construction)
C.C.05.02.20.10.10 Project Management
C.C.05.02.20.10.20 Submittals and Review
C.C.05.02.20.10.30 Procurement
C.C.05.02.20.10.40 Site Services
C.C.05.02.20.10.50 Construction Fee
C.C.05.02.20.20 Containment Building
C.C.05.02.20.20.10 Hatch
C.C.05.02.20.20.20 Cooling/Vent Penetrations
C.C.05.02.20.20.30 Electrical Penetrations
C.C.05.02.20.20.40 Man Door
C.C.05.02.20.20.50 Catwalk
C.C.05.02.20.30 Facility Yard (YARD)
C.C.05.02.20.30.10 Staging Area
C.C.05.02.20.30.20 Fencing and Security
C.C.05.02.20.40 Electrical Systems
C.C.05.02.20.40.10 Electrical Distribution System (EDS)
C.C.05.02.20.40.20 Uninterruptible Power System (UPS)
C.C.05.02.20.40.30 Reactor Energy Dissipation System (RDS)
C.C.05.02.20.50 Heat Removal System (HRS)
C.C.05.02.20.50.10 Direct Reactor Cooling
C.C.05.02.20.50.20 Containment Cooling
C.C.05.02.20.60 Containment HVAC System (CHS)
C.C.05.02.20.60.10 Exhaust Stack
C.C.05.02.20.60.20 HEPA Filtration Bank
C.C.05.02.20.91 Support Systems
C.C.05.02.20.91.10 Fire Protection System (FPS)
C.C.05.02.20.91.20 Integrated Energy Systems
C.C.05.02.20.91.30 Cathodic Protection System (CPS)
C.C.05.02.20.91.40 Compressed Air System (CAS)
C.C.05.02.20.91.50 Security Systems
C.C.05.02.20.70 Control Room Area (CRB)
C.C.05.02.20.70.10 Demolition
C.C.05.02.20.70.20 Preparation and Finishing
C.C.05.02.20.92 Exterior Improvements
C.C.05.02.20.92.10 Finish Grading
C.C.05.02.20.92.20 Facility/Site Restoration
C.C.05.02.20.80 Instrumentation and Controls Systems (ICS)
C.C.05.02.20.80.10 Environmental Monitoring System (EMS)
C.C.05.02.20.80.20 Seismic Monitoring System (SMS)
C.C.05.02.20.80.30 Test Bed Control Panel
C.C.05.02.20.93 Closeout
C.C.05.02.20.93.10 Testing and Commissioning
C.C.05.02.20.93.20 Closeout
C.C.05.02.20.90 Reactor Handling System (RHS)
C.C.05.02.20.90.10 In-dome Crane
C.C.05.02.20.90.20 Module Installation System


C – Idaho National Laboratory
C.C – Nuclear Science & Technology Division
C.C.05 – NS&T ALD Division
C.C.05.02 – EBR-II Reactor Demonstration Test Bed (ETB)
C.C.05.02.30 Facility Readiness
C.C.05.02.30.10 Operational Transition
C.C.05.02.30.20 Operational Readiness (DOE 425.1B)
C.C.05.02.30.10.05 Control Account Manager - Operational Transition
C.C.05.02.30.10.30 Rad Instrumentation
C.C.05.02.30.10.55 Rad Protection Implementation
C.C.05.02.30.10.35 Operational Evolutions
C.C.05.02.30.10.10 System Operability Testing
C.C.05.02.30.10.60 Interfacing SSCs
C.C.05.02.30.10.15 O&M Documentation
C.C.05.02.30.10.40 BEA Building Finishing/ Programming
C.C.05.02.30.10.65 Engineering/CM
C.C.05.02.30.10.45 Emergency Preparedness Preps
C.C.05.02.30.10.20 Training
C.C.05.02.30.10.70 DSA Implementation
C.C.05.02.30.10.50 Update EMS/Waste Management
C.C.05.02.30.10.25 Initial Compliment
C.C.05.02.30.10.75 Spares
C.C.05.02.30.20.10 Control Account Manager - Operational Readiness (DOE 425.1B)
C.C.05.02.30.10.20 MSA Scoping
C.C.05.02.30.10.30 Readiness MSA
C.C.05.02.30.10.40 Contractor Operational Readiness Review (CORR)
C.C.05.02.30.10.50 DOE ORR

Appendix D

Project Issues

Project Issues							Caused by		
Number	**Name**	**Description**	**Type**	**Status**	**Priority**	**Resolution**	**Name**	**Number**	**Description**
Issue-001	Determine Compressed Air Requirements	Determine the capacity and quality of the existing MFC distribution system to inform demonstration reactor designs. Do we need to solicit feedback from demonstration partners for how much air they need?	Informal Evaluation	Open	Moderate		Compressed Air System	CAS	The compressed air system provides compressed air to users requiring it in the ETB.
							Compressed Air	3.2.2	The demonstration reactor shall require less than [TBD] scfm of ANSI/ISA-7.0.01-1996 quality instrument air at [TBD] psi during operations.
							Provide Compressed Air	ETB.2.3	
Issue-002	Determine IES Testing Capability	What capabilities are needed in the facility for integrated energy systems testing?	Technical Decision	Open	Moderate		IES Testing	6.3	ETB shall provide the capability for integrated energy systems type testing.
Issue-003	Determine Path Forward on Cathodic Protection	Need to discuss with MFC engineering - has potential to delay operations	Technical Decision	Open	Moderate		Provide Cathodic Protection	ETB.1.5	
Issue-004	NOG-1 Crane	DOE O 420.1C requires NOG-1 cranes for safety applications - Determine whether moving a fueled reactor module is considered safety or non-safety.	Technical Decision	Closed	Moderate	The program is not going to build a crane to meet NOG-1 requirements. The reactor and reactor modules will be designed to meet code requirements to ensure the crane does not need to meet NOG-1 requirements. This may need to be added to the demonstrator requirements.	Polar Crane Availability	3.1.2.10	A polar crane capable of lifting 75 tons shall be available inside the EBR-II containment.
							Handle Demonstration Reactors Throughout Operations	ETB.2.7	The facility needs to be able to move and maintain demonstration reactors while they are in operation within the containment.
Issue-005	Determine Fire Protection Strategy	Need to determine method of suppression and start DOE headquarters exemption process as soon as possible.	Technical Decision	Open	Serious		Suppress Fire	ETB.6.1.3	
							Provide Fire Protection	ETB.6.1	
							Fire Protection System	FPS	The fire protection system detects fires, alarms on detection, and provides fire suppression.
Issue-006	Seismic Monitoring	Determine whether the existing MFC seismic monitoring system can be used or if the ETB requires additional seismic instrumentation	Technical Decision	Open	Moderate		Seismic Detection	3.4.6.5	The EBR-II containment must have instrumentation or other means to detect and record the occurrence and severity of seismic events.
							Seismic Detection System	SDS	The seismic detection system detects seismic activity and provides a signal to the overall I&C network.
							Detect Seismic Events	ETB.2.9	
Issue-007	Module Installation Strategy	A system to bring modules into the dome needs to be identified. Some options include a low profile track, heavy duty container cart, or a cart rail system. A trade study should be performed to evaluate the options.	Trade-Off Study	Open	Moderate		Move Modules Into ETB	ETB.2.7.2	
							Reactor Handling System	RHS	The reactor handling system provides all equipment necessary (lifts, cranes) to move demonstration reactor modules into, out of, and within the ETB containment.

Project Issues							Caused by		
Number	**Name**	**Description**	**Type**	**Status**	**Priority**	**Resolution**	**Name**	**Number**	**Description**
							Installation Equipment	3.2.2.4	A loading platform and associated equipment shall be provided, inside and outside containment, allowing the equipment modules to be installed into the containment with permanently installed equipment.
Issue-008	Reactor/containment Cooling Strategy	The reactor / containment cooling strategy needs to be looked at in more detail and options evaluated.	Trade-Off Study	Open	Moderate		Remove Thermal Energy from Containment	ETB.2.1	The facility needs a system to cool the demonstration reactor and the cell.
							Heat Removal System	HRS	The heat removal system removes demonstration reactor and ETB containment heat and rejects it to the atmosphere.
							Remove ETB Containment Heat	ETB.2.1.2	
							Containment HVAC System	CHS	The containment ventilation system provides fresh, conditioned air to the ETB dome area and subsequently filters and exhausts air to the atmosphere.
Issue-009	System Control Stratey	A system control strategy needs to be developed identifying the following: How will the reactor be controlled? What will be controlled from NRIC control room? What will be controlled from demonstrator control room? What needs to be tied into the NRIC control room?	Informal Evaluation	Open	Moderate		Monitor and Control ETB Systems	ETB.2.6	
							Instrumentation & Control System	ICS	The instrumentation & control system monitors data received from various system instruments and provides control functions for the systems within the ETB.
Issue-010	Module Floor Restraint	The modules placed in the dome will need to be secured to the floor of the containment. A quick connect type system that could be remotely operated is preferable. Options on how to restrain the modules need to be studied.	Trade-Off Study	Open	Moderate		Installation Equipment	3.2.2.4	A loading platform and associated equipment shall be provided, inside and outside containment, allowing the equipment modules to be installed into the containment with permanently installed equipment.
							Demonstration Reactor Package Installation	3.1.2.7	A method for installation of a demonstration reactor package shall be provided in the EBR-II containment structure.
Issue-011	Heat Dissipation	The majority of heat generated by the reactors will be transferred to a working fluid to ultimately produce electricity. How much heat will be dissipated through the reactor and	Demonstrator Action Item	Open	Moderate		Reactor Dissipation System	RDS	The Reactor Dissipation System dissipates the electrical energy produced by any demonstration reactor projects.

Project Issues							Caused by		
Number	Name	Description	Type	Status	Priority	Resolution	Name	Number	Description
		reactor module to the containment?					Ambient Temperature Limit	3.1.3	The heat radiated from the demonstration reactor during operation shall not challenge the ability of the ETB to maintain a maximum room temperature of 40 degrees Celsius.
							Dissipate Reactor Produced Electricity	ETB.2.8	
							Electrical Dissipation	3.1.5.8	A method to dissipate up to 3MWe shall be provided, either temporarily or permanently.
Issue-012	Activation of Materials	During reactor testing activation of materials will take place. How will the following items be affected and what time is necessary to allow workers to reenter the containment: Reactor module Dome Floor	Demonstrator Action Item	Open	Moderate	Develop interface requirement(s) for residual activation limits.			
Issue-013	Reactor Module Shielding	How much shielding will be required to move the module after testing and to ship the tested reactor?	Demonstrator Action Item	Open	Moderate	Potentially develop interface requirement(s) for the demonstrator			
Issue-014	ETB module access	A security fence is located approximately 40' outside the module access to the dome. The fence may make it difficult to place modules into the dome.	Informal Evaluation	Open	Moderate				
Issue-015	Demonstrator module configuration	Demonstrator modules could be of various sizes and configurations. Should a requirement be placed on demonstrators to have the module the reactors are shipped and constructed in be of a specific design, i.e. a standard connex box configuration? This would simplify the ETB module handling system.	Technical Decision	Open	Moderate	Generate an interface requirement for the demonstrator reactor size.			
Issue-016	Equipment door into the dome	A detailed study and analysis of the largest door size need to be completed along with a detailed cost estimate to determine the door size.	Trade-Off Study	Open	Moderate		Containment Dome Hatch Size	3.1.2.1	The EBR-II Containment dome equipment hatch shall be modified to allow a 15.5 ft tall × 13 ft wide rectangular object to be placed in the containment.
							Containment Access	2.3.	ETB shall have access to the containment that is as a minimum of 10-ft wide x 12-ft high based on structural analysis to allow for installation of reactor modules.
Issue-017	Module Weight	Determine the requirement for the maximum module weight. Shielding may impact the maximum allowable.	Technical Decision	Open	Moderate		Module Weight	3.1.2	Each demonstration reactor module shall weigh less than [100,000] lbs.

Project Issues							Caused by		
Number	**Name**	**Description**	**Type**	**Status**	**Priority**	**Resolution**	**Name**	**Number**	**Description**
Issue-018	eVinci Test in 2023	Determine whether its feasible to host a demonstration reactor by 2023	Technical Decision	Open	Critical				
Issue-019	Identify Critical Penetrations	Identify which penetrations are critical and must be installed for the test bed to function and which penetrations could be postponed until the future.	Informal Evaluation	Open	Minor				
Issue-020	Containment Pressure Testing	How will the pressure testing of the dome be done?	Technical Decision	Open	Moderate				
Issue-021	What should be done with the power generated at ETB?	Power will be generated during testing at ETB. What should be done with this power? Should the power be placed back onto the grid? Should the power be dumped? Does this need to be a requirement in the FOR?	Informal Evaluation	Open	Serious				
Issue-022	Individual penetration pressure testing	If penetrations are added later will the entire dome need retested or can just the penetrations that are added be tested?	Technical Decision	Open	Moderate	There are two things that are being tested when the dome is pressurized with the original/currently proposed requirements. One is pressure retaining capability of the vessel as a whole and the second is the leak rate of the vessel as a whole. I think it is possible to create custom fixtures that would allow leak testing to be done on individual penetrations, but the cost of making them and installing them will not be cheap (could be close to the cost of the making and installing the penetration itself). I have done some things like this on small scale penetrations, but not for penetrations that are measured in feet. DWG 773684 shows a concept of one of these that was done for a 1" hole in hot cell piping, but the ones we need would be more complicated and much bigger. Regarding pressure testing, this will be a potential can of worms. There isn't really a way (that is practical, meaning less costly or difficult than just pressing the dome up) to pressure test the penetrations individually (i.e., develop the hoop stress and longitudinal stress locally that result from the entire dome being pressurized). The real question is can you skip the pressure test altogether when adding new penetrations. My thoughts: 1)Initial response is that some type of pressure test is required. This is based on the original design discussing how they made the penetration inserts separately leak testable so they weren't required to re-do the pressure test of the dome. It is also based on what I think would be required by the codes if we were following them and my engineering judgement. Big holes in a big vessel need to be tested to ensure the construction was adequate. Analysis shows the			
Issue-023	Code of Record	What codes will be used for the design modifications? Can the original design code be used or will new code have to apply?	Informal Evaluation	Open	Moderate				