RPT-24-80803
Revision B

DOME RSS Preliminary Design Review Report

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Greg Lewis
Enercon

Chance Price
Idaho National Laboratory

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Title:	DOME RSS Preliminary Design Review Report	**PROJECT REPORT NO.**		**BEA2302-RPT-01**	
		REV.		**B**	
Client:	BEA	**Project Identifier:**	BEA2302		

Item	Cover Sheet Items	Yes	No
1	Does this Project Report contain any open assumptions, including preliminary information, that require confirmation? (If **YES**, identify the assumptions.)	☒	☐
2	Does this Project Report supersede an existing Project Report? (If **YES**, identify the approved Project Report.) **Superseded Project Report No.** ______	☐	☒

Scope of Revision:

Incorporation of 60% Preliminary Design Comments. Removal of Trade Studies reports and incorporation of their content into main report.

Revision Impact on Results:

Reactor Supplemental Shielding (RSS) modular shielding layout updated to reduce streaming paths, roof penetrations revised and doghouse roof shielding developed, cast-in place foundation pedestal layout and penetration configuration developed to reduce streaming paths, aluminum tank revised to a two-tank system, and removal of thermal insulation on the roof based on revised temperature maximums.

☐ **Safety-Related** ☐ **Augmented Quality** ☐ **Non-safety Related**
☒ **Safety Class** ☐ **Safety Significant** ☐ **General Services** ☐ **Production Support**

(Print Name and Sign)

Preparer: Greg Lewis, PE	**Date:**
Design Verifier (Design Reviewer[1]): Curt Angstadt, PE	**Date:**
Approver: Rick Ahrens, PE, SE	**Date:**

Note 1: For Non-safety Related, DOE General Services, or DOE Production Support Project Reports, design verification can be substituted by review.

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PROJECT REPORT REVISION STATUS

REVISION	DATE	DESCRIPTION
A	3/28/2024	60% of Preliminary Issue
B	8/22/2024	90% of Preliminary Design

APPENDIX/ATTACHMENT REVISION STATUS

APPENDIX NO.	NO. OF PAGES	REVISION NO.	ATTACHMENT NO.	NO. OF PAGES	REVISION NO.
8.1		B	9.1		B
8.2		B	9.2		B
8.3		B	9.3		B
8.4		B			
8.5		B			
8.6		B			
8.7		B			
8.8		B			
8.9		B			
8.10		B			
8.11		B			
8.12		B			
8.13		B			
8.14		B			

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1.0 Purpose and Scope

The National Reactor Innovation Center (NRIC) is developing the Demonstration of Microreactor Experiments (DOME) test bed at the Idaho National Laboratory (INL) Materials and Fuels Complex (MFC). The DOME test bed will allow for testing of advanced reactors in support of future licensing and commercial operations. As part of this development a neutron and photon radiation shielding system is required to protect personnel and equipment from the harsh neutron and photon fluxes anticipated during reactor operations and post shut down operations, disassembly, and decommissioning.

ENERCON's initial task was to evaluate the conceptual design proposed by MPR Associates, Inc., as described in 1129-0298-RPT-001, Rev 1 "DOME Reactor Supplemental Shielding Conceptual Design". This was accomplished through the development of several Trade Studies. ENERCON's Trade Study results were used as justification for determining how the conceptual design could be optimized and/or improved.

With the completion of the Trade Studies, ENERCON began the second task of developing the preliminary reactor supplemental shielding (RSS) system design. The RSS design required the system to be modular, control temperature, and limit radiation. To meet modularity requirements, the RSS walls, roof, tank and other elements need to be able to be disassembled without destructive methods. This modularity allows these components to be reconfigured and removed to accommodate various reactor types and layouts. As the RSS is a re-usable shielding system, the maximum temperature limit inside the shield enclosure is set at 200°C (392°F) (per RFI-011). This is to prevent the degradation of shielding materials due to excessive heat. The shielding layout, composition, and thickness needed to be configured to limit does rates to less than 0.05 mrem/hr at 50 ft from the exterior wall of the Dome. These limits are for the safety of those working on or around the site.

At the completion of this phase, all primary systems, to include shielding, cooling, structural, mechanical, and electrical shall be sufficiently developed to confirm the suitability of the RSS System for final development. These results will be used to provide accurate information for cost estimating to included developing estimates for material requirements as well as identifying further engineering work. The completion of this phase will support construction planning and provide reactor vendors with reliable information for the development of their designs.

This report documents the concepts evaluated and/or developed as part of the 90% of preliminary design. This includes the Functional Classification identification of major RSS elements. Items designated as Safety Class (SC) or Safety Significant (SS) will require QA processes meeting the requirements of ASME NQA-1 program as outlined in SPC-70646 (Ref 3.1.1). Further, the remaining work required within the Dome structure, needed to support the RSS assembly and execution of the DOME project, is identified and discussed.

2.0 Summary of Result and Conclusions

ENERCON's design utilizes two L-shaped aluminum water tanks, along each of the interior walls, for radiation shielding and temperature control. The use of these tanks is sufficient to limit the interior RSS temperature to a maximum of 200°C (392°F) (per RFI-011). Temperature limits were checked for both the operational and accident condition. Operational conditions evaluated the reactor heat output while the cooling system was operational. Accident conditions evaluated the reactor's transitive heat output while the cooling system was inoperable. In both cases, the maximum temperature limit was not exceeded.

Outside of the RSS the temperature limit on systems, equipment, and existing concrete structures was limited to 100 °C (212 °F). The RSS floor, which is not protected by a water tank, uses a combination of insulation and 0.635 cm (0.25 in) thick aluminum plates to prevent excessive heat from radiating through the floor and heating the existing DOME Test Bed floor to temperatures exceeding this limit.

The primary body of the RSS; walls and roof, are comprised of both normal weight and high-density magnetite concrete. In conjunction with the water tanks, sufficient shielding is provided to limit dose rates around the DOME to less than 0.05 mrem/hr at 50 feet from the exterior wall of the Dome and ALARA. Evaluation determined that the walls, when accounting for the water tank, would need to be 137 cm (54 in) thick, the roof 183 cm (72 in) thick, and the floor 92 cm (36 in) thick.

As the RSS has various penetrations through the roof, floor, and the primary opening, supplemental shielding is required around these penetrations. The opening of the RSS utilizes a remotely operated shield door. During reactor shutdown, this door will provide adequate protection to workers within the DOME. During reactor operations, the door will be supplemented with additional shielding block around the front and sides of the opening to block streaming paths and meet the 0.05 mrem/hr at 50 feet requirement. Throughout the foundation pedestal, small conduit penetrations are installed for developer use in routing electrical cable and sensor wiring needed for testing. Due to the size of these penetrations, a labyrinth path is used to limit streaming though these openings. The top of the RSS includes the larger 46 cm (18 in) square and 61 cm (24 in) and 92 cm (36 in) diameter penetration locations. These penetrations utilize high-density magnetite doghouses to enclose these pipes and ducts and create an exterior labyrinth path on the roof. The use of these doghouses help reduce streaming dose rates but due to the associated penetration sizes, dose rates potentially exceed requirements at higher elevations. Due to this, the doghouses are configured so as to direct any streaming to locations or areas where no other buildings are located.

While effective at reducing does rates, the large roof-mounted doghouses create additional weight on the RSS and the RSS was found to exceed the Dome floor's allowable capacity by approximately 40% (See Section 6.6). Additional floor analysis was performed by the Client and ECAR-8009 (Ref 3.1.153.1.14) was developed. ECAR-8009 determined that the existing Dome floor is adequate based on the proposed RSS foundation. The current foundation pedestal design has sufficient strength to span any voids or weak spots in the underlying Dome floor and thus the allowable bearing capacity of the floor, as outlined in SPC-70646 (Ref 3.1.1), to be exceeded.

To meet the modularity requirements, the RSS utilizes bolted connections to attach the RSS roof to the RSS walls and the RSS walls to the pedestal foundation. The water tank is also attached inside the RSS though the use of bolted connections. The reactor base, which is a cast-in-place concrete pedestal, is not considered part of the RSS but rather a permanent part of the DOME Test Bed. Reactor developers will anchor to this slab using post-installed anchors as required by their design. The pedestal foundation, with the RSS attached, was checked for rocking and sliding due to the anticipated seismic loads for the site. Based on this analysis, the RSS was determined to be self-anchored and not mechanical anchoring to the DOME floor is required.

Regarding the size of the RSS, this design is based on the requirements of SPC-70646 Revision 2 (Ref 3.1.1). Per the specification, the size of the RSS referenced herein is 29'-0" W x 29'-0" L x 23'-0" H with an interior clear space of 16'-0" W x 27'-0" L x 12'-0" H. It is understood that the next revision of the specification will increase the size of the RSS to provide an interior clear space of 16'-0" W x 30'-0" L x 13'-0" H. These changes are already reflected in the RSS model being developed for this project.

3.0 References

3.1 Code and Standards

3.1.1 SPC-70646, Rev 2, Specification for Reactor Supplemental Shielding for use in DOME, 9/20/23

3.1.2 COR-0006, Rev 2, Demonstration of Microreactor Experiments (DOME) Code of Record, 9/15/22

3.1.3 DOE-STD-1020-2016, Natural Phenomena Hazard Analysis and Design Criteria for DOE Facilities, U.S. Department of Energy, 2015

3.1.4 DOE-STD-1090-2020, Hoisting and Rigging, U.S. Department of Energy, 2015

3.1.5 International Building Code, International Code Council, 2015

3.1.6 ASCE/SEI 7, Minimum Design Loads for Building and Other Structures, American Society of Civil Engineers, 2010

3.1.6.1 Supplement No. 1, Effective 3/31/2013

3.1.7 ASCE/SEI 43, Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities, American Society of Civil Engineers, 2005

3.1.8 ACI 318-19, Building Code Requirements for Structural Concrete, American Concrete Institute, 2019

3.1.9 ACI 349-13, Code Requirements for Nuclear Safety-Related Concrete Structures, American Concrete Institute, 2019

3.1.10 AISC 325-17 Steel Construction Manual, 15th Edition

3.1.11 AISC 360-16, Specification for Structural Steel Buildings, American Institute of Steel Construction, 2015

3.1.12 AISC N690-18, Specification for Safety-Related Steel Structures for Nuclear Facilities, American Institute of Steel Construction, 2018

3.1.13 ASCE/SEI 4, Seismic Analysis of Safety-Related Nuclear Structures and Commentary, American Society of Civil Engineers, 2016

3.1.14 ASME NQA-1/1a, Nuclear Quality Assurance, American Society of Mechanical Engineers, 2008/2009

3.1.15 ECAR-8009 MFC NRIC Dome Floor Analysis, Rev 0

3.1.16 DOME Shield System Conceptual Design 1129-0298-RPT-001, Rev 1.

3.1.17 Chiung-Huei Ke, Hwa-Sheng Cheng, “Activation Analysis of Trace Impurities in Aluminum,” Journal of the Chinese Chemical Society, Volume 12, Issue 1-2, June 1965.

3.2 Acronyms and Abbreviations

AIL	Action Item List
ALARA	As low as reasonably achievable
BEA	Battelle Energy Alliance - the Management and Operating Company contracted to the DOE and charted with INL operations.
C	Celsius
cm	centimeters
COR	Code-of-Record
DOME	Demonstration of Operational Microreactor Experiments
DOE	Department of Energy
EDS	Electrical Distribution System
EFS	Enercon Federal Services Inc.
ESI	Enercon Services, Inc. - the A&E Owner of the EFS subsidiary
F	Fahrenheit

FDC	Flooding Design Category
ft	feet
g	gravity
gpm	gallons per minute
H	height
HRS	Heat Removal System
HVAC	Heating, Ventilation and Air Conditioning
in	inch
in w.g	inches of water gauge
INL	Idaho National Laboratory
ISRS	In-Structure Response Spectra
I&C	Instrumentation & Control
kg	kilogram
kPa	kilopascal
L	length
L	liter
lb	pounds force
LS	Limit State
m	meter
MFC	Materials and Fuels Complex
min.	minute
mm	millimeter
MCMP	Monte Carlo N-Particle
NPH	Natural Phenomenon Hazard
NRIC	National Reactor Innovation Center
pcf	pound per cubic foot
PDL	Project Design Lead
PM	Project Manager
PPD	Project Planning Document
psf	pounds per square foot
psig	pounds per square inch gauge

QA	Quality Assurance
RAMI	Reliability, Availability, Maintainability, Inspectability
RFI	Request for Information
RSS	Reactor Supplemental Shielding
s	second
SC	Safety Class
SDC	Seismic Design Category
SDD	System Design Description
SS	Safety Significant
SSC	Structure, System, Component
SOW	Statement of Work
VFD	Variable Frequency Drive
W	width
WBS	Work Breakdown Structure

4.0 Assumptions

4.1 Item: Air Activation

4.1.1 Owner: Safety Analysis – Nuclear

4.1.2 Assumption: Design assumes that neutron activation of air outside the shield is negligible. The RSS shield will be designed for lower dose and neutron flux rates outside of the shield.

4.1.3 Status: Closed. The RSS shielding calculation demonstrates that the shielding design is well shielded and dose and neutron fluence that would lead to activation of air outside the RSS is an order of magnitude lower than the activation flux on the inside of the RSS.

4.2 Item: Air Flow Rate

4.2.1 Owner: Safety Analysis – Nuclear

4.2.2 Assumption: Design assumes an unrestricted flow through the RSS of approximately 198 m^3/min. (7,000 ft^3/min.) This equates to a flow rate equal to two air exchanges per minute inside the assumed RSS free volume of 99 m^3/min. (3,500 ft^3).

4.2.3 Status: Open. Waiting for BEA confirmation of flow rates.

4.3 Item: Argon Isotopic Concentration

4.3.1 Owner: Safety Analysis – Nuclear

4.3.2 Assumption: All activation calculations assume a 100% isotopic concentration in elemental argon. This adds a slight conservatism to design since Ar-40 is approximately 99.65% of the elemental mix of argon in the air.

4.3.3 Status: Open. Waiting for BEA confirmation regarding assumption within DOME.

4.4 Item: Cobalt Impurity in Aluminum Alloys

4.4.1 Owner: Safety Analysis – Nuclear

4.4.2 Assumption: When cobalt impurity is added to aluminum alloys, it is assumed that the Co-59 impurity level is at 1 ppm. Due to little information being available regarding trace impurities in aluminum alloys, this assumption is based on information found in Ref 3.1.17

4.4.3 Status: Open. Waiting on vendor documentation

4.5 Item: Dose Unit

4.5.1 Owner: Safety Analysis – Nuclear

4.5.2 Assumption: Design assumes one absorbed dose unit for photons (rad) is equal to 1 equivalent dose unit for photons (rem). This assumption is consistent with 10 CFR 835.2 weighting factor for photons of one.

4.5.3 Status: Closed. Assumption consistent with appropriate reference.

4.6 Item: Dilution Occurrence

4.6.1 Owner: Safety Analysis – Nuclear

4.6.2 Assumption: In the calculation of the equilibrium concentration of activation products in air, it is assumed that no dilution occurs from intake of fresh air from the environment. This assumption is conservative and accounts for conditions where effluent release may be in the vicinity of the intake.

4.6.3 Status: Closed. Assumption consistent with appropriate design methodologies.

4.7 Item: Thermal Impacts to Concrete Strength

4.7.1 Owner: Structural

4.7.2 Assumption: High-temperature concrete testing plans are in progress to qualify shielding concrete to around 250 to 325°C (482 to 617°F). As no test results are currently available, an assumed reduction factor shall be applied to preliminary concrete designs for both normal weight and high-density magnetite concrete. Based on RFI-011, a thermal reduction factor of 0.50 shall be used in the design to account for concrete exposed to a temperature of 200 °C (392 °F)

4.7.3 <u>Status: Open. Waiting BEA sample testing results.</u>

4.8 Item: Density of High-Density Concrete

4.8.1 Owner: Structural

4.8.2 Assumption: The density of the high-density magnetite concrete is assumed to be 3.63g/cm^3 (230 pcf). This is based Burns Concrete, Inc. A regional supplier of high-density concrete to BEA for projects at the MFC. Normal weight concrete has a density of 2.3g/cm^3 (150 pcf).

4.8.3 Status: Open. Waiting selection of Concrete Supplier.

4.9 Item: Reactor Weight

4.9.1 Owner: Structural

4.9.2 Assumption: The reactor is assumed to be 68,000 kg (75 tons) in the development of the RSS weight and the determination of bearing pressure. This is based on the maximum lifting capacity of the crane.

4.9.3 Status: Open. Waiting for BEA to provide Developer reactor weights.

4.10 Item: Shielding Overburden

4.10.1 Owner: Structural

4.10.2 Assumption: The shielding overburden weight (the required additional shielding necessary at penetrations) is assumed to be the equivalent of a 152 cm (60 in) thickness over the entire roof of the RSS. This corresponds to an overburden pressure load of 1150 psf based on the density of high-density magnetite concrete. This assumption is used in the development of the RSS weight and the determination of bearing pressure. This will be revised as analysis develops.

4.10.3 Status: Open. To be closed with completion of preliminary design.

5.0 Design Inputs

5.1 Safety Function and Safety Classifications

Per Ref 2 Part 2.C.t., ENERCON is to provide safety function and safety classification of DOME shielding structures, systems, and components (SSCs). Per RFI-003 the following functions were confirmed for the RSS.

RSS Item	Proposed Safety Function (SC/SS)
Floor	Safety Class
Roof	Safety Class
Walls	Safety Class
Tank	Safety Class
Shield Door (automated)	Safety Significant
Shield Door (blocks)	Safety Significant

For the automated shield door, the door and support frame are safety significant. The motor and any system or components necessary for door operation are General Service. For the tank, the drain piping and drain piping components will also be safety class, but all other associated piping and components will be general services. Instrumentation monitoring the water level and temperature will be safety class. Refer to Appendix 8.12 *Instrument Index* for safety classification of individual instruments.

5.2 Code of Record

Appendix 9.3, Code-of-Record (COR), identifies codes and standards identified thus far for the development of the preliminary design. The COR has been developed by discipline (Mechanical, Civil, Structural, and Electrical/I&C), and specific system assignments for each entry are made within DOORS. Refer to Appendix 9.3, for the Codes and Standards associated with the DOME test bed.

5.3 NPH Design Category:

Primary Natural Phenomenon Hazard for the DOME RSS is Seismic Design Category (SDC) 3 for seismic. The Limit State (LS) of structures within the Dome are based on their requirements. Non-airtight structures, like the RSS, are LS-C while any pressure tight or airtight systems are LS-D. As a result, the RSS is SDC-3 LS C.

Due to the Dome structural providing protection for the RSS; wind, snow, and rain loads do not affect the RSS and are not included in the design. Per Ref. 3.1.1 Flooding (FDC-3) is a concern but due to the elevated floor of the Dome, exterior flooding loads are not considered as part of the RSS design.

6.0 Detailed Discussion

6.1 RSS Risk Register

The RSS Risk Register is outlined in Appendix 8.1. This appendix covers potential risks resulting from component failure, design issues, fabrication and equipment problems, physical risks, and radiological risks. The register outlines the consequence of the risk as well as the mitigation step proposed to reduce or eliminate the risk.

6.2 RSS Cost Estimate

The RSS Cost Estimate is included in Appendix 8.2. This estimate covers the costs associated with the initial design, fabrication, and assembly of the RSS configuration shown in the current project drawings. This estimate does not cover future work associated with reconfiguration design or disassembly and movement of the RSS modular components associated with reactor switch-out.

6.3 Fire Protection

The RSS System will have limited impact on Fire Protection Systems. Inside the RSS the usage of primary non-flammable building materials will provide low concern of fire and good housekeeping should be maintained during the various developments of reactor testing. Cable routed into the RSS shall be installed in the appropriate non-combustible metallic conduit. Areas outside RSS, including the DOME and MFC-769 are being evaluated by others.

6.4 RSS Reliability and Maintainability Analysis

The reliability and maintainability considerations are integrated throughout the development process to create the RSS, from conceptual design through and during operations. The integration of these considerations is discussed and identified in Appendix 8.4.

6.5 RSS Concept of Operations

The RSS Water Tank System provides shielding and cooling. Flow through the system is provided by an RSS pump with VFD. Automatic flow control valves are located at the inlet of each tank to maintain RSS water tank temperatures. Additionally, an automatic flow control valve is provided on the Heat Removal System (HRS) side of the HRS/RSS heat exchanger to adjust chilled water flow.

The RSS Shield Door provides shielding from radiation sources within the RSS during operation and post-shutdown. The door is remotely operated and can be opened/closed from outside the Dome Test Bed. The door system will include status signal/light to confirm door closure. The door may be disconnected from power during operation of the experiment in the RSS or a system interlock may be used to shut down the experiment if the door closure signal is lost.

6.6 Structural Evaluation Outline/Results

The preliminary structural evaluation of the RSS covered the design of the primary structural elements to include the walls, roof, and bearing load on the Dome floor. These elements were checked using Code-based design Dead and Live loads. The RSS seismic loads were developed based on a time history analysis using five sets of accelerations compatible with the DOME Test Bed in-structure response spectra (ISRS). Based on these results a maximum horizontal design acceleration was determined and used in the design of the RSS. The design of the RSS was controlled by the loads associated with supplemental roof shielding (i.e. doghouses) required for the various roof penetrations. The inclusion of these penetrations resulted in both reduced structural performance and increased loads, owing to the supplemental shielding weight. However, as the roof and wall element sizes are governed by neutron and photon shielding requirement, this has resulted in generally large members with substantial reserve capacity and these primary elements were found to be adequate for the anticipated gravity and seismic loads.

Accounting for the supplemental shielding loads the overall weight of the RSS has increased relative to the conceptual design. The DOME Shield System Conceptual Design Report (Ref 3.1.16) estimated the floor loads to be 173 kPa (3621 psf). This meets the requirements outlined in the project specification, SPC-70646 (Ref 3.1.1). However, the conceptual design only included the basic RSS layout and had limited penetrations and supplemental shielding shown. With these simplifications, the conceptual RSS was at 96.5% of the maximum allowable floor bearing capacity. Per ENERCON's evaluation and better refinement of the necessary shielding requirements, the RSS bearing load was found to have increased. This increased bearing pressure was determined to be 190 kPa (3960 psf) without supplemental roof shielding and 245 kPa (5110 psf) with the inclusion of supplemental roof shielding. A bearing pressure of 245 kPa (5110 psf) exceeds the Dome floor's allowable capacity by 36%. The inclusion of seismic overturning loads would result in additional increases to the listed bearing pressure.

Based on this exceedance, BEA re-evaluated the floor capacity. As the RSS foundation pedestal is heavily reinforced, it functions as a rigid structural plate element. The bearing capacity outlined in SPC-70646 (Ref 3.1.1) is conservatively low owing to the potential for voids and weak-spots in the grout used to the backfill the Dome test bed. ECAR-8009 (Ref 3.1.15) approximate the stiffness of the proposed RSS pedestal in order to determine an acceptable span distance. This analysis determined the pedestal could span an 8ft x 8ft void and thus, the current foundation bearing pressure was determined to be acceptable.

Environmental hazard loads within the Dome are limited to seismic loads. Per Ref 3.1.1, the seismic design category of the site is SDC-3 Limit State C. Based on ENERCON's analysis ISRS for the RSS, the acceleration used to evaluate the RSS was = 0.83g. This is the peak acceleration using a 4% damping for reinforced concrete structures, as outlined in ASCE 43-05 (Ref 3.1.7). Accounting for the sheer amount of weight associated with the high-density concrete structure, this results in a significant lateral load requirement. Lateral load needs to be accounted for through the full range of anticipated temperatures, normal and accident. During an accident, where the cooling system is inoperative, temperatures will increase. Based on the thermal analysis (see Section 6.12) the maximum anticipated temperature within the RSS is 200°C (392°F). Per RFI-002 a strength reduction factor of 50% was applied to the concrete compressive strength as part of the design. The RSS was still found to be structurally adequate during these accident conditions with this factor applied.

The seismic lateral loads are resisted by the RSS walls which require them to be anchored to the RSS pedestal slab to resist transverse loads. Further, connections between individual RSS structural elements are needed to stabilize the structure against racking due to lateral loads applied parallel to the wall face. While connectivity of structural elements is needed, the seismic loads were not found to exceed the coefficient-of-friction between cast-in-place RSS floor and the existing dome floor, nor did they result in mass overturning forces sufficient to topple the overall RSS structure. The improved frictional resistance of the floor is accomplished by roughening the existing Dome floor to a 0.64 cm (1/4 in) amplitude prior to pouring concrete. Due to this roughening, no anchors are required between the RSS pedestal slab and the Dome floor.

Various anchoring options were evaluated for anchoring of the reactor. The current design assumes reactor developers will utilize post installed anchors to connect to the 3-ft thick pedestal foundation. The foundation design itself uses bundled bars to increase spacing between reinforcing thus allowing for more options for anchor placement.

Regarding the current design of the RSS, this design is based on the requirements of revision 2 of SPC-70646 (Ref 3.1.1). As a result, the current RSS design is shorter in length than the anticipated revision 3 design requirement. The current design uses three 10-foot-wide wall segments on each side. These segments weigh approximately 66 tons. While the design is based on revision 2, the RSS model was provided by BEA and depicts the larger RSS. To account for the size difference, the provided model assumed three 11-ft wide wall segments. However, these 11-ft wide wall segments each weigh 73 tons a piece and when accounting for lifting hardware, they exceed the polar crane's capacity. As a result, once the specification revision is issued, the RSS walls will need to be redesigned to four 8.25-ft wide wall segments with updates made to the calculations, drawings, and model.

6.7 Mechanical Evaluation Outline/Results

The purpose of the RSS Water Tank System is to provide shielding and cooling for the DOME test bed. The preliminary design of the RSS contains two "L" shaped tanks, two circulation pumps, a heat exchanger, an expansion tank, and an ion exchanger. Drawing numbers BEA2302-M-0001 through BEA2302-M-0004 are P&IDs of this system and can be found in Attachment 9.1.

The RSS water tanks specification can be found in Attachment 9.2. Due to the modular constraints, this limits the ability to route piping through the side of the RSS structure. If piping was routed through the side of the RSS structure, it would prevent easy access to dissemble flange connections between RSS water tank and RSS concrete shielding and thus require demolition and destruction. The current design requires all penetrations for the water tanks to go through the roof of the RSS structure except for the tanks' drain lines. The RSS water tanks are safety class and will be designed to SDC-3 seismic forces to prevent failure during a design basis earthquake event. In the event of a pipe shearing from the drain line inside the RSS cavity, the RSS floor has four drains to prevent internal flooding of the RSS. Maximum flooding rate was calculated at 479.3 gpm based on a 2" pipe shear from drain line. The floor drains will be sized to prevent water level from reaching the lowest level of the reactor.

The RSS pump is designed to provide a total of 170 L/min (45 gpm) of flow, meeting the minimum required flow rate of 151 L/min (40 gpm) (Ref. 3.1.1). The pump is sized based on calculation BEA2302-CALC-002 (Appendix 8.7). A Bell and Gossett 1.5x1.5x7C, 1750 RPM, 6.5" impeller is capable of meeting required flow rates. Flow will be equally split between each tank. Automatic control valves are located on the inlet to each tank to balance flow and maintain temperatures as required.

Only one pump is required due to this portion of the system not being classified as safety significant. However, based on the initial Reliability and Maintainability Analysis, it is recommended to have a second pump as a backup due to the 8,000 hours of continuous operations requirement. The second pump is shown in the model and drawings in Attachment 9.1.

The expansion tank is designed to hold 4,542 L (1,200 gallons) of water and is located on top of the RSS structure. The 4,542 L (1,200 gallon) tank provides adequate margin for thermal expansion (from 104 to 414°C (40 to 212°F)).

The normal operating pressure of the RSS tank is 63 to 85 kPa (9.1 to 12.4 psig) as shown in Appendix 8.7. The overpressure protection for each tank is a common open path vent line as shown on drawings in Attachment 9.1. Calculation BEA2302-CALC-002 (Appendix 8.7) provides hydraulic analysis to verify the vent line provides adequate protection. The design pressure of the RSS water tanks is 124 kPa (18 psig) which provides a 25% margin in an overpressure condition (Attachment 9.2.1).

The HRS/RSS heat exchanger is used to remove heat from the RSS Water Tank System. An automatic Flow Control Valve (FCV) is used to adjust flow rate to the heat exchanger. The minimum required flow rate through the chilled water side is 303 L/min. (80 gpm) (Ref. 3.1.1).

The HRS Secondary Chilled water pump needs to be capable of providing 1,647 L/min (435 gpm) of flow at 30.6 m (100.5 ft) of head to maintain full flow to each AHU unit and the HRS/RSS Heat Exchanger as shown in BEA2302-CLC-004 (Appendix 8.7).

6.8 Electrical Evaluation Outline/Results

Preliminary values for the anticipated electrical loads that will be added to the DOME facility are documented within BEA2302-DWG-S-00002, *RSS Electrical Panel Schedules*. Further electrical study is expected to be performed as part of final design of the RSS as the design of the RSS and the design of the DOME facility progresses.

6.9 Lifting and Load Handling System

An evaluation of the requirements necessary for lifting and loading components of the RSS and requirement for the test reactor both into and within the Dome structure found the following:

- A Hydra-Slide track system provides a low-profile way to move heavy components through the Dome access hatch and into the Dome proper.
- Space constraints within the Dome limit the use of forklifts and crawlers while the vertical height of the RSS exceeds the height of available gantry cranes. Additionally, gantry cranes are limited in their movement and lack the flexibility to move RSS components as is anticipated for installation and removal. Repair of the existing polar crane back to a maximum load capacity of 68,000 kg (75 tons) will be an integral component of the interior load handling system.

See Appendix 8.11 for additional information on the Lifting and Load Handling System

6.10 RSS Remote Operated Shield Door [16610]

Per the specifications in SPC-70646 (Ref 3.1.1), the RSS requires a remotely operated shield door system. Based on weight constraints resulting from the Dome floor's maximum allowable bearing pressure, a door option was selected in which an operable door would provide shielding during reactor shut-down times. During reactor operation, this door would be supplemented by additional high-density concrete shielding blocks. The blocks would be moved into and out of position using a crane while the door would be remotely controlled. The remotely operated door uses a 625 cm x 452 cm x 91 cm (246 in x 178 in x 36 in) wide normal weight concrete shield door. The concrete shield would be supported with a steel frame system. A procurement specification for this shield door system can be found in Attachment 9.2.2.

6.11 RSS Design Verification Matrix

Appendix 8.12 contains the RSS Design Verification Matrix. This matrix outlines the DOORS items that are applicable to the design of the DOME RSS as well as ENERCON's response to each item and how these requirements have been preliminarily incorporated into the design.

6.12 Thermal Evaluation Results

The RSS heat removal system includes two L-shaped water tanks that provide the primary means of heat removal during operation and shutdown. During normal operation, cooling water will be circulated through the tank to remove as much as 100 kW of heat from the shield. The heat gained by the water in the tank will be transferred to the primary heat sink by a heat exchanger located outside of the RSS. Heating of the RSS due to gamma radiation from the reactor is included for normal operating condition.

During shutdown, the RSS heat removal system will operate in passive mode (i.e., without forced water convection). The system is designed such that the thermal mass of the water in the tank is sufficient to remove the decay heat during accident conditions for 72 hours without boiling.

Thermal analysis for steady-state normal condition and transient accident condition of the DOME RSS is performed with the ANSYS general purpose finite element program, Version 2022 R2, including ANSYS Workbench Mechanical. The feasibility of keeping the new concrete temperatures below the required limit of 200°C (392°F) and existing concrete temperature below the required limit of 100°C (212°F) during normal operation and shutdown condition are documented in BEA2302-RPT-006 (Appendix 8.14).

Report BEA2302-RPT-006 shows that 30 cm (12 in) of clearance under the reactor with 1.27 cm (0.5 in) aluminum plate on floor is required to mitigate the raised concrete temperature and restore the concrete temperature to less than 200°C (392°F) for the new concrete and 100°C (212°F) for the existing concrete under the floor slab. With the addition of 1.27 cm (0.5 in) aluminum plates to the floor, the design can tolerate aluminum tank emissivity as low as 0.7. The unpainted emissivity of the aluminum tank is 0.76. A black paint will be applied to the aluminum tank in order to increase its emissivity and improve heat transfer, but the paint is not being credited and therefore does not need to be qualified for performing a design function. The floor will also have a 2.54 cm (1 in) layer of alternating 0.635 cm (0.25 in) layers of reflective (emissivity 0.05) and low-conductivity insulation to minimize heat transfer to these areas, consistent with the conceptual design.

The preliminary results of the steady state and transient analyses for normal and shutdown operation for multiple designs are summarized in the below table. The detailed discussion and figures are presented in Report BEA2302-RPT-006.

Table 6-1:Maximum Concrete Temperature

Case	Condition	Water Tank Emissivity	Reactor Clearance (in)	1" Insulation	Additional Aluminum Plate on Floor	Max new concrete temperature on Floor		Max existing concrete temperature on Floor	
						(°C)	(°F)	(°C)	(°F)
1	Normal operation	0.98	6	floor-roof-door	No	222.0	431.5	145.4	293.7
2	Normal operation	0.98	12	floor-roof-door	No	184.2	363.6	122.7	252.9
3	Normal operation	0.98	12	floor-roof-door	0.5 inches	136.6	277.8	93.7	200.7
	Shutdown	0.98	12	floor-roof-door	0.5 inches	139.1	282.3	93.7	200.7
	Normal operation	0.76	12	floor-roof-door	0.5 inches	142.7	288.8	97.8	208.0
	Shutdown	0.76	12	floor-roof-door	0.5 inches	145.3	293.5	97.8	208.0
4	**Normal operation**	**0.98**	**12**	**floor**	**0.5 inches**	**135.6**	**276.1**	**93.3**	**199.9**
	Shutdown	**0.98**	**12**	**floor**	**0.5 inches**	**138.1**	**280.6**	**93.3**	**199.9**
	Normal operation	**0.76**	**12**	**floor**	**0.5 inches**	**142.7**	**288.8**	**97.9**	**208.2**
	Shutdown	**0.76**	**12**	**floor**	**0.5 inches**	**145.3**	**293.5**	**97.9**	**208.2**
	Normal operation	**0.7**	**12**	**floor**	**0.5 inches**	**145.1**	**293.1**	**99.5**	**211.0**
	Shutdown	**0.7**	**12**	**floor**	**0.5 inches**	**147.8**	**298.0**	**99.5**	**211.0**
5	Normal operation	0.98	12	floor	0.75 inches	121.3	250.4	84.7	184.4
	Shutdown	0.98	12	floor	0.75 inches	123.6	254.4	84.7	184.4
	Normal operation	0.76	12	floor	0.75 inches	127.6	261.6	88.7	191.7
	Shutdown	0.76	12	floor	0.75 inches	129.9	265.8	88.7	191.7
	Normal operation	0.45	12	floor	0.75 inches	143.1	289.5	98.9	209.9
	Shutdown	0.45	12	floor	0.75 inches	145.8	294.4	98.9	209.9

Case	Condition	Water Tank Emissivity	Reactor Clearance (in)	1" Insulation	Additional Aluminum Plate on Floor	Max new concrete temperature on Floor		Max existing concrete temperature on Floor	
						(°C)	(°F)	(°C)	(°F)
6	Normal operation	0.98	12	No	1.5 inches	134.5	274.0	92.0	197.5
	Shutdown	0.98	12	No	1.5 inches	138.8	281.9	92.0	197.5
	Normal operation	0.76	12	No	1.5 inches	141.3	286.3	96.4	205.5
	Shutdown	0.76	12	No	1.5 inches	145.9	294.6	96.4	205.5
7	Normal operation	0.98	12	No	No	214.6	418.3	147.7	297.9

6.13 Material Review and Piping Penetration Routing

The trade study (Attachment 8.11.3 in the 60% preliminary design report) was conducted to review alternate photon and neutron shielding materials that may be used to replace the water, light concrete, or magnetite concrete in the conceptual design of the RSS. It was determined that water and the mixture of light and magnetite concrete provides a cost-effective combination for the shielding of neutrons and photons from the demonstration reactor. Alternate materials that are better at shielding photons often are less effective for neutrons. Additionally, better photon shielding materials have a higher density which may have a negative impact on the structural requirements of the RSS. This part of the study comparing materials is therefore focused on the addition of neutron shielding materials (boron) towards the inner layers of the RSS. MCNP calculations show that adding neutron absorption can reduce doses to the exterior of the RSS by approximately 20%. However, the additional costs for these materials are unlikely to offset the cost reduction in magnetite concrete from an approximate 2.5 cm (1 in) thickness reduction.

Secondly this evaluation modeled several alternate configurations of penetrations through the shield necessary to allow wiring, piping and the interchange of air with the DOME atmosphere. These studies confirmed that penetrations up to 61 cm x 61 cm (24 in x 24 in) or 3721 cm^2 (4 ft^2) can be shielded through the roof if the penetration length is sufficient to cross the width of the RSS. Although shorter penetrations would simplify the design of a modular roof, the study shows higher dose rates that would challenge the operational dose requirements. A study on the 91 cm x 157 cm (36 in x 50 in) penetration showed a significant increase in the dose at the penetration exit of greater than 30 rem/hr. It was concluded that a complicated labyrinth would be needed for the design of a penetration of this size. Such a labyrinth could be incorporated into one of the RSS walls or into the ceiling. It is believed that a ceiling labyrinth for this penetration increases structural complexity of the RSS while a wall labyrinth would increase complexity of the wall and overall cost. Other studies in this attachment show that a crack type penetration along the edge of the RSS would be possible for allowing air flow and only a small cap shield would be needed to shield the collimated beam of radiation exiting the penetration. The evaluation also demonstrated that the size and location of the source has a significant impact on the dose rates that are calculated at the exit of the penetrations.

6.14 RSS Shielding Evaluation

Calculation BEA2302-CALC-008 evaluated the following requirement in SPC-70646: 1) dose rates outside of the DOME structure during operation, 2) dose rates outside of the RSS from a shutdown and 90-day decayed source term from the core of the experiment. 3) neutron fluence values in various RSS materials that is subsequently used in the material activation analysis in BEA2302-CALC-010, 4) Energy deposition in RSS materials for the thermal analysis, and 5) lifetime neutron fluence to RSS materials and DOME equipment dose limits.

6.15 RSS Air Activation

Calculation BEA2302-CALC-009 evaluated the production rate and potential dose impacts from the activation products of Ar-41 and N-16 in air by allowing additional air flow through the RSS. While additional air flow is possible to allow at least partial cooling by natural convection a production rate limit inside the RSS would need to be implemented on each developer to make sure dose contribution from activation of air does not challenge operation requirements for dose rates outside of the DOME structure. RFI-DOME-004 indicated that the flow rate restriction through the RSS would be removed from the SPEC-70646 and replace with 75 µCi/second limit to the production of Ar-41. RFI-DOME-004 also required that production rate of N-16 be analyzed inside the RSS.

6.16 RSS Material Activation

The material activation and dose rates from the inside of the RSS were evaluated in calculation BEA2302-CALC-010. Due to the large uncertainties in material impurities, dose rates determined for each case in this calculation were determined for no impurities and for average impurities found in Aluminum, concrete and steels from published sources. Only Co-59 impurity was considered. The calculation demonstrated that dose rates at 90 days after 6 months of operation are in the range of 10 – 40 mrem/hr. These dose rates are higher than the 5 mrem/hr ALARA goal in SPC-70646. With consideration of impurities dose rates exceed 1 rem/hr due to activation with the majority of the source term coming from activation of the concrete floor and ceiling. Inclusion of a boron absorber in the final design of the RSS would limit dose rates to 2-10 mrem/hr for the case without impurities but will still result in dose rates greater than 1 rem/hr with consideration of impurities in materials. Calculation BEA2302-CALC-010 made the following considerations to further reduce dose rates inside the RSS due to activation of impurities.

- Reduce the operational time or power of the experiment inside the RSS.
- Actual modeling of activation with the experimental reactor source and equipment to account for self-shielding inside the RSS.
- Identify actual impurity levels and limit impurity levels that may occur in the shielding materials.
- Consider the use of a sacrificial layer of concrete on the floor and top shield blocks that can be removed after each experiment to limit dose rates on the inside at 90 days post shutdown.
- Consider alternate timing to all credit for additional decay of activated shield materials between experiments.

6.17 Neutron and Photon Source Term Spectra

Since the energy distribution of the neutron and photon flux spectra in the preliminary design are based on older references, a study was completed to see if spectra generated using more recent nuclear data files would result in any significant changes. Overall, the spectra are similar between the preliminary and more recent data with only slight variations in each energy group. It was concluded that the preliminary data are slightly conservative for the design of the RSS and no update to the fraction of neutron and photon flux in each energy group is needed.

6.18 Fluence to Dose Conversion Factors

A dose conversion factors evaluation (Attachment 8.11.7 of the 60% preliminary design report) looked at the benefit that can be gained when using flux-to-dose coefficients, based on an effective dose equivalent from ICRP 116, are used instead of the ANSI/ANS-6.1.1-1977 coefficients. The analysis showed that, for the bounding exposure geometry in ICRP

116 (anterior to posterior), the calculated dose rates at 15.24 m (50 ft) from the DOME were approximately 20% less. For the preliminary design of the RSS, the thickness of the high-density concrete on the sides and back could be reduced by approximately 2.5 cm (1 in) and still maintain the same dose rate results. Even with the use of the ICRP 116 dose coefficients for dose limits outside of the DOME, conservatism can be maintained due to the use of the limiting exposure geometry. RFI-DOME-006 approved the use of the ICRP 116 dose coefficients for doses calculated outside of the DOME. However, calculation BEA2302-CALC-008 calculated dose rates outside of the DOME using the conservative ANSI/ANS-6.1.1-1977 coefficients.

6.19 Door Shielding for Post-Shutdown Source Terms

Preliminary calculations (Attachment 8.11.9 of the 60% preliminary design report) were completed to determine the thickness of a remotely operated door that would shield personnel outside of the RSS after a decay of 90 days post-shutdown. This analysis used a source term previously used for the evaluation of inhalation doses from releases of microreactor experiments in the DOME. The attachment demonstrates it would be possible to shield post-shutdown doses with 122 cm (48 in) of normal concrete. If a mix of normal and high-density magnetite concrete are used, the door thickness can be refined further during preliminary design. These source terms are used in the calculation of shutdown dose rates from the RSS in calculation BEA2302-CALC-008.

6.20 Chemistry Control of the RSS Water Tank System

A chemical and radiological analysis is required for the Reactor Supplemental Shielding (RSS) water tanks due to the significant radiation exposure that can impact water chemistry and result in gaseous radiolytic byproducts such as hydrogen. Hydrogen is generated inside the water tanks due to the radiolysis of water as well as the induced hydrogen production due to the aluminum material of the water tank. Additionally, pH will naturally lower during irradiation and at higher temperatures. A pH range of 5-6 is desired because it significantly decreases hydrogen production (Ref 3.1.1).

Per BEA2302-CALC-007 (Appendix 8.15.1), the containment volume, containment ventilation system, and RSS water system vent should be designed to maintain a non-flammable atmosphere given a hydrogen flow rate of 1.26 mL/s of hydrogen and 0.63 mL/s of oxygen emitted by the RSS water from radiolysis.

Per BEA2302-CALC-007, nitric acid production from radiolysis of the RSS water will result in a pH of less than 5 within 10.5 days if no action is taken, assuming an unbuffered starting pH of 6. A minimum flow of 0.72 L/s through 14.0 L of ≥ 0.80 eq/L (OH- form) anion exchange resin will maintain the system pH between 5 and 6 for a period of 6 months. Longer durations may be obtained by a proportional increase in anion exchange resin volume. It is recommended that a mixed cation/anion exchange resin be used to remove other impurities in addition to nitric acid. Additionally, the vendor should be consulted for resin selection considering the resin material and the oxidizing chemical environment.

BEA2302-CALC-007 also explored the use of a boric acid/alkali hydroxide to maintain the RSS water pH. Assuming a boric acid concentration at its solubility limit at 0°C, this buffer solution could maintain the pH within the 5 to 6 range for a 6.7-month duration. However, a mixed cation/anion exchange resin bed is recommended for pH control as it can be easily scaled to a larger volume for a larger capacity.

7.0 Computer Software

7.1 Mech/Thermal: ANSYS Mechanical

7.2 Safety Analysis/Radiation: MicroShield

7.3 Safety Analysis/Radiation: MCNP

7.4 Safety Analysis/Radiation: SCALE

7.5 Civil/Structural: STAAD.PRO

7.6 Civil/Structural: AutoPIPE

7.7 Civil/Structural: ANSYS

7.8 Civil/Structural: RSPMATCH09

8.0 Appendices

8.1 RSS Risk Register

8.2 RSS Cost Estimate

8.3 NOT USED

8.4 DOME RSS Reliability and Maintainability Analysis, BEA2302-RPT-002

8.5 NOT USED

8.6 Structural Calculations

8.6.1 BEA2302-CALC-001 RSS Structural Design

8.6.2 BEA2302-CALC-005 Development of Acceleration Time Histories Compatible with DOME Slab ISRS

8.6.3 BEA2302-CALC-006 Development of DOME RSS In-Structure Response Spectra

8.7 Mechanical Calculations

8.7.1 BEA2302-CALC-002 RSS Shield Cooling Tank Pressure Drop

8.7.2 BEA2302-CALC-004 Heat Removal System

8.8 Electrical Calculations

8.8.1 BEA2302-CALC-003 Electrical Load and Arc Flash Analysis

8.9 Safety

8.9.1 BEA2302-CALC-008 Shielding Calculation for Normal Operation and Reactor Shutdown

8.9.2 BEA2302-CALC-009 DOME Air Activation Analysis

8.9.3 BEA2302-CALC-010 RSS Material Activation Analysis

8.10 Mechanical Equipment List

8.11 Lifting and Load Handling System, BEA2302-RPT-005

8.12 RSS Design Verification Matrix

8.13 Instrument Index

8.14 DOME RSS Thermal Analysis, BEA2302-RPT-006

8.15 Chemistry Calculations

8.15.1 BEA2302-CALC-007 RSS Water System Chemistry Calculation

8.16 Input/Output List

9.0 Attachments

9.1 DOME RSS Project Drawings

9.2 Specifications

9.2.1 BEA2302-DSPEC-001 Aluminum Tank

9.2.2 BEA2302-PSPEC-002 Procurement Specification for Radiation Shield Doors and Frames

9.2.3 Section 01 91 13 General Commissioning Requirements

9.3 Demonstration of Microreactor Experiments (DOME) Code of Record, COR-006, Rev 2

10.0 Project Report Preparation Checklist	PROJECT REPORT NO.	BEA2302-RPT-01
	REV.	B

CHECKLIST ITEMS[1]	YES	NO[2]	N/A
GENERAL REQUIREMENTS			
1. Are the latest procedure revisions being used?	☒	☐	☐
2. Are the proper forms being used and are they the latest revision?	☒	☐	☐
3. Have the appropriate review forms/checklists been completed?	☒	☐	☐
4. Are all pages properly identified with a Project Report number, report revision and page number consistent with the requirements of the applicable procedure?	☐	☐	☐
5. Is all information legible and reproducible?	☐	☐	☐
6. Is the Project Report presented in a logical and orderly manner?	☐	☐	☐
7. Is there an existing Project Report?	☐	☐	☐
8. Is it possible to alter an existing Project Report instead of preparing a new Project Report for this situation?	☐	☐	☐
9. If an existing Project Report is being used for design inputs, are the key design inputs, assumptions, and engineering judgments used in that Project Report valid and do they apply to the Project Report revision being performed?	☐	☐	☐
10. Is the format of the Project Report consistent with applicable procedures and expectations?	☐	☐	☐
11. Were design input/output documents properly updated to reference this Project Report?	☐	☐	☐
12. Can the Project Report logic, methodology, and presentation be properly understood without referring back to the Originator for clarification?	☐	☐	☐
OBJECTIVE AND SCOPE			
13. Does the Project Report provide a clear concise statement of the problem and objective of the Project Report?	☐	☐	☐
14. Does the Project Report provide a clear statement of quality classification?	☐	☐	☐
15. Is the reason for performing and the end use of the Project Report understood?	☐	☐	☐
16. If the Project Report provides the basis for information found in the plant's license basis, is it clearly documented in the Project Report?	☐	☐	☐
17. If the Project Report provides or supports the basis for information found in the plant's design basis documentation, is it clearly documented in the Project Report?	☐	☐	☐

10.0 Project Report Preparation Checklist	PROJECT REPORT NO.	BEA2302-RPT-01
	REV.	B

CHECKLIST ITEMS[1]		YES	NO[2]	N/A
18.	Has the appropriate design or license basis documentation been revised, or has the change notice or change request documents being prepared for submittal?	☐	☐	☐
DESIGN INPUTS				
19.	Are design inputs clearly identified?	☐	☐	☐
20.	Are design inputs retrievable or have they been added as attachments?	☐	☐	☐
21.	If Attachments are used as design inputs or assumptions are the Attachments traceable and verifiable?	☐	☐	☐
22.	Are design inputs clearly distinguished from assumptions?	☐	☐	☐
23.	If the Project Report relies on Attachments for design inputs or assumptions, are the attachments properly referenced in the Project Report?	☐	☐	☐
24.	Are input sources (including industry codes and standards) appropriately selected and are they consistent with the quality classification and objective of the Project Report?	☐	☐	☐
25.	Are input sources (including industry codes and standards) consistent with the plant's design and license basis?	☐	☐	☐
26.	If applicable, do design inputs adequately address actual plant conditions?	☐	☐	☐
27.	Are input values reasonable and correctly applied?	☐	☐	☐
28.	Are design input sources approved?	☐	☐	☐
29.	Does the Project Report reference the latest revision of the design input source?	☐	☐	☐
30.	Were all applicable plant operating modes considered?	☐	☐	☐
ASSUMPTIONS				
31.	Are assumptions reasonable/appropriate to the objective?	☐	☐	☐
32.	Is adequate justification/basis for all assumptions provided?	☐	☐	☐
33.	If engineering judgements are used, are they clearly identified as such?	☐	☐	☐
34.	If engineering judgments are used as design inputs, are they reasonable and can they be quantified or substantiated by reference to site or industry standards, engineering principles, physical laws or other appropriate criteria?	☐	☐	☐

10.0 Project Report Preparation Checklist	PROJECT REPORT NO.	BEA2302-RPT-01
	REV.	B

CHECKLIST ITEMS[1]		YES	NO[2]	N/A
SOFTWARE/COMPUTER CODES				
35.	If computer codes or software languages used in the preparation of the Project Report, have the requirements of QENG-101, including verification of accuracy and applicability been met?	☐	☐	☐
36.	If computer codes have been used, are they properly identified along with source vendor, organization, and revision level?	☐	☐	☐
37.	If a computer code is being used, is it applicable for the analysis being performed?	☐	☐	☐
38.	If applicable, does the computer model adequately consider actual plant conditions?	☐	☐	☐
39.	If applicable, are the inputs to the computer code clearly identified and consistent with the inputs and assumptions documented in the Project Report?	☐	☐	☐
40.	If applicable, is the computer output clearly identified?	☐	☐	☐
41.	If applicable, does the computer output clearly identify the appropriate units?	☐	☐	☐
42.	If applicable, are the computer outputs reasonable when compared to the inputs and what was expected?	☐	☐	☐
43.	If applicable, was the computer output reviewed for ERROR or WARNING messages that could invalidate the results?	☐	☐	☐
RESULTS AND CONCLUSIONS				
44.	Is adequate acceptance criteria specified?	☐	☐	☐
45.	Are the stated acceptance criteria consistent with the purpose of the Project Report, and intended use?	☐	☐	☐
46.	Are the stated acceptance criteria consistent with the plant's design basis, applicable licensing commitments and industry codes, and standards?	☐	☐	☐
47.	Do the Project Report results and conclusions meet the stated acceptance criteria?	☐	☐	☐
48.	Are the results represented in the proper units with an appropriate tolerance, if applicable?	☐	☐	☐
49.	Are the Project Report results and conclusions reasonable when considered against the stated inputs and objectives?	☐	☐	☐
50.	Is sufficient conservatism applied to the outputs and conclusions?	☐	☐	☐
51.	If the Project Report results and conclusions affect other reports or documents, have the affected documents been revised and cross referenced?	☐	☐	☐

10.0 Project Report Preparation Checklist	PROJECT REPORT NO.	BEA2302-RPT-01	
	REV.	B	
CHECKLIST ITEMS[1]	**YES**	**NO[2]**	**N/A**
52. Have any conceptual, unconfirmed or open assumptions requiring later confirmation been properly identified?	☐	☐	☐

Note 1: Where required, provide clarification/justification for answers to the questions in the space provided below each question.

Note 2: An explanation is required for any questions answered as "No".

Preparer: Greg Lewis – See Coversheet for Signature

Print Name and Sign   Date