



August 11, 2026 | Oak Ridge, TN

MRA System Verification Plan

Jim Janney

MRA Lead Engineer



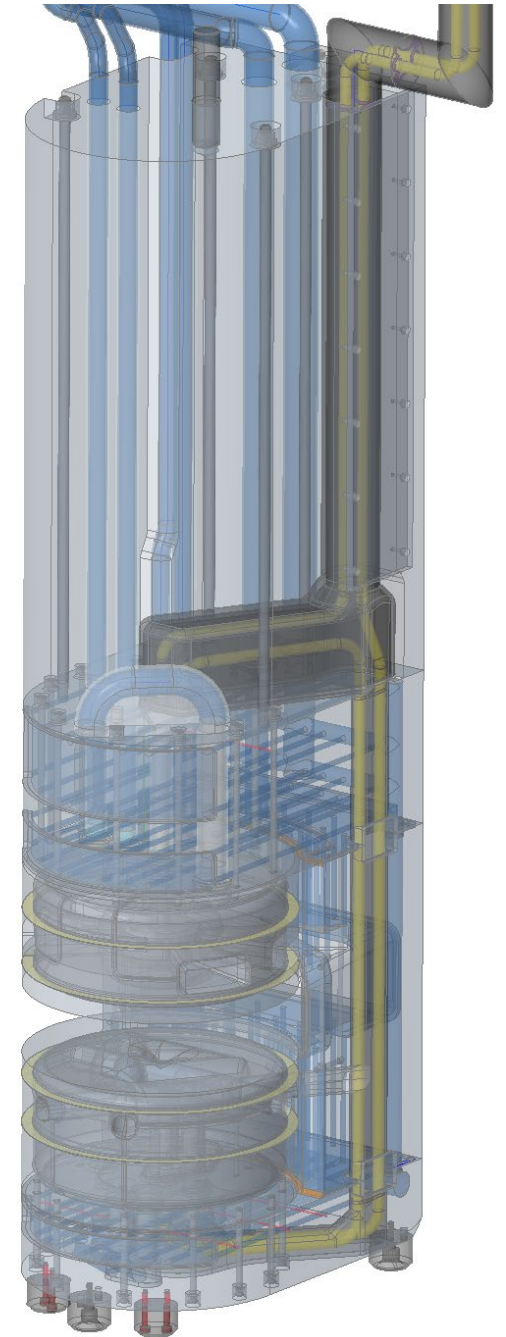
U.S. DEPARTMENT
of **ENERGY**

ORNL IS MANAGED BY UT-BATTELLE LLC
FOR THE US DEPARTMENT OF ENERGY



MRA System Verification Plan Overview

- Verification Plan tracks requirement verification at FDR stage and shows plan for verification at later project stages
- Decomposed requirements are verified by verification of their child requirements
- Color coded for easy visibility
 - White/grey – Verified at FDR
 - Yellow – Has yet to be verified at FDR
 - Red – Requirement verification failed



MRA Verification Plan Definitions

- Analysis – The critical and careful evaluation of a situation or problem. Documented in a DAC or analysis report (can also be part of a system description if verification uncomplicated and is completed in design).
- Demonstration – Verification by witnessing an actual operation in the expected or simulated environment, without need for measurement data or post demonstration analysis. (I.e. clear pass or fail. Yes/no.)
- Inspection – Conformity evaluation by observation and judgment accompanied as appropriate by measurement, testing or gauging.
- Test – Determination of one or more characteristics according to a procedure.

MRA Neutron Brightness Requirement Verification

Summary	Description	FDR	PRR	FAT	Pre Ops	Ops
<u>MRA Neutron Brightness Requirement</u>	The MRA shall deliver 18 neutron beams with the characteristics and locations described in the MRA-Instrument Systems Interface Sheet, S01020500-IS0023. The peak brightness of all neutron beams shall be greater than $2 \times 10^{14} \text{ n/cm}^2/\text{sr}/\text{\AA}/\text{s}$ at the neutron wavelength $5 \text{\AA}$.	Analysis	Inspection	Inspection		Test
		S03040000-DAC10010	Drawings	Dim. Insp. and MTRs		Measurement
<u>MRA Moderator Hydrogen Density Requirement</u>	The hydrogen in both moderators shall have a minimum average density of 72.0 kg/m^3 .	Analysis	Inspection	Inspection		
		S03040000-DAC10011	Drawings	Dim. Insp. and MTRs		
<u>MRA Moderator Hydrogen Maximum Temperature Requirement</u>	The hydrogen temperature shall at no point in the moderators exceed 32 K.	Analysis	Inspection	Inspection		
		S03040000-DAC10011	Drawings	Dim. Insp. and MTRs		
<u>MRA Moderator Alignment Requirement</u>	The MRA shall position the moderator viewed faces within +/- 1 mm of their ideal locations during installation.		Inspection	Inspection	Inspection	
			Drawings	Dim. Insp.	MRA S&A	
<u>MRA Moderator Operational Displacement Requirement</u>	The MRA moderators shall have a displacement of 0.3 mm or less relative to the MRA mounting points from installation to 700 kW operation.	Analysis	Inspection	Inspection		
		S03040000-DAC10013	Drawings	Dim. Insp. and MTRs		

MRA Temperature Requirement Verification

Summary	Description	FDR	PRR	FAT	Pre Ops	Ops
<u>MRA Temperature Requirement</u>	The MRA shall be capable of maintaining temperature of the assembly such that structural integrity is unaffected at 700 kW beam power.	Derived Requirement Verification	Derived Requirement Verification	Derived Requirement Verification		
<u>MRA Aluminum Temperature Requirement</u>	The MRA aluminum 6061-T6 structures shall have a maximum operating temperature of 100 C.	Analysis S03040000-DAC10011	Inspection Drawings	Inspection Dim. Insp. and MTRs		
<u>MRA Stainless Steel Temperature Requirement</u>	The MRA stainless steel structures shall have a maximum operating temperature of 200 C.	Analysis S03040000-DAC10011	Inspection Drawings	Inspection Dim. Insp. and MTRs		
<u>MRA Beryllium Temperature Requirement</u>	The MRA beryllium shall have a maximum operating temperature of 100 C.	Analysis S03040000-DAC10011	Inspection Drawings	Inspection Dim. Insp. and MTRs		
<u>MRA Water Temperature Requirement</u>	The MRA cooling water shall have a maximum temperature of 100 C.	Analysis S03040000-DAC10011	Inspection Drawings	Inspection Dim. Insp. and MTRs		

MRA Structural Integrity Requirement Verification

Summary	Description	FDR	PRR	FAT	Pre Ops	Ops
<u>MRA Structural Integrity Requirement</u>	The MRA shall maintain structural integrity under all expected loading conditions.	Derived Requirement Verification	Derived Requirement Verification	Derived Requirement Verification		
<u>MRA Hydrogen Transfer Line Requirement</u>	The MRA hydrogen transfer lines shall be designed and fabricated to 2019 ASME B31.12. Applied seismic loads shall be derived from the NPH BOD.		Analysis	Test		
			Piping Analysis, Drawings	Pressure Test		
<u>MRA Water Piping Requirement</u>	The MRA water piping shall be designed and fabricated to 2020 ASME B31.3. Applied seismic loads shall be derived from the NPH BOD.		Analysis	Test		
			Piping Analysis, Drawings	Pressure Test		
<u>MRA Hydrogen Vessel Requirement</u>	The MRA hydrogen vessels shall be designed to the intent of the 2023 ASME BPVC. Applied seismic loads shall be derived from the NPH BOD.	Analysis	Inspection	Test		
		S03040000-DAC10012	Drawings	Pressure Test		
<u>MRA Vacuum Vessel Requirement</u>	The MRA vacuum vessels shall be designed to the intent of the 2023 ASME BPVC. Applied seismic loads shall be derived from the NPH BOD.	Analysis	Inspection	Test		
		S03040000-DAC10013	Drawings	Pressure Test		
<u>MRA Reflector Vessel Requirement</u>	The MRA reflector vessels shall be designed to the intent of the 2023 ASME BPVC. Applied seismic loads shall be derived from the NPH BOD.	Analysis	Inspection	Test		
		S03040000-DAC10013	Drawings	Pressure Test		
<u>MRA Backbone Requirement</u>	The MRA Backbone shall be designed to the intent of the 2023 ASME BPVC. Applied seismic loads shall be derived from the NPH BOD.	Analysis	Inspection	Test		
		S03040000-DAC10013	Drawings	Pressure Test		
<u>MRA Fastener Requirement</u>	The fasteners employed within the MRA shall have a factor of safety of 3 or greater against yielding for all expected loading conditions including lifting and seismic. Applied seismic loads shall be derived from the NPH BOD.	Analysis	Inspection	Inspection		
		S03040000-DAC10014	Drawings	MTRs		

MRA-CMS Interface Requirements Verification

Summary	Description	FDR	PRR	FAT	Pre Ops	Ops
<u>MRA-CMS Interface Requirements</u>	Requirements derived from the MRA-CMS Interface Sheet, S01020500-IST10148	Derived Requirement Verification	Derived Requirement Verification	Derived Requirement Verification	Derived Requirement Verification	
<u>MRA Hydrogen Loop Pressure Drop Requirement</u>	The MRA hydrogen loop pressure drop shall be less than 0.15 bar @ 0.5 l/s and 20 K.	Analysis S03040000-DAC10011	Inspection Drawings	Inspection Dim. Insp.	Test CMS Test	
<u>MRA Hydrogen Boundary Pressure Requirement</u>	The MRA hydrogen boundary MAWP shall be 19 bara.	Analysis S03040000-DAC10012	Inspection Drawings	Test Pressure Test		
<u>MRA Vacuum Boundary Pressure Requirement</u>	The MRA vacuum boundary MAWP shall be 2 bara.	Analysis S03040000-DAC10013	Inspection Drawings	Test Pressure Test		
<u>MRA Vacuum Space Requirement</u>	The MRA vacuum space shall be designed to provide insulating vacuum surrounding all MRA hydrogen boundaries. The vacuum space shall be designed for vacuum service.	Inspection 0000064880	Inspection Drawings	Test Dim. Insp., Cleaning Report and Helium Leak Check		
<u>MRA Vacuum Venting Requirement</u>	The MRA vacuum space shall be designed to support venting of hydrogen leaks without exceeding the MAWP.		Analysis CMS Venting Analysis, Drawings	Inspection Dim. Insp.		
<u>MRA Hydrogen Venting Requirement</u>	The MRA hydrogen lines shall be designed to support venting of hydrogen after loss of transfer line vacuum without exceeding the MAWP.		Analysis CMS Venting Analysis, Drawings	Inspection Dim. Insp.		

MRA Remote Handling Requirement Verification

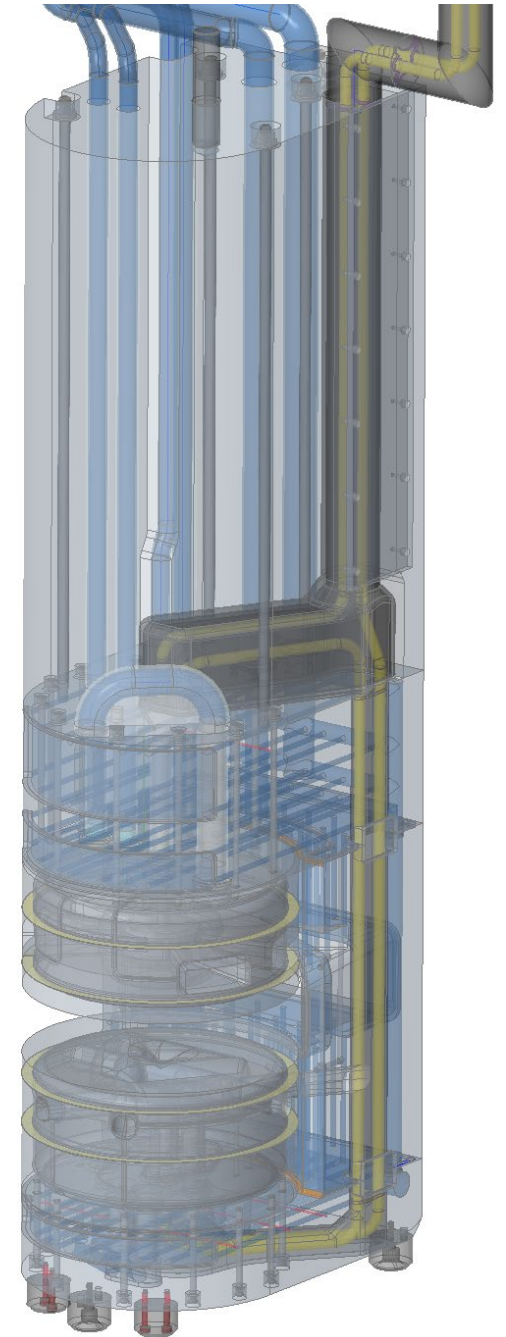
Summary	Description	FDR	PRR	FAT	Pre Ops	Ops
<u>MRA Remote Handling Requirement</u>	The MRA design shall include features to allow for remote handling and replacement	Derived Requirement Verification	Derived Requirement Verification	Derived Requirement Verification	Derived Requirement Verification	
<u>MRA Lifting Stud Requirement</u>	The MRA shall include a 1.5"-8 UN threaded stud located over the assembly CG.	Inspection 0000064880	Inspection Drawings	Inspection Dim. Insp.	Demonstration MRA Installation	
<u>MRA Pipe Cutting Requirement</u>	The MRA piping shall be designed for cutting above the upper shield block.	Analysis S0310500-TDO10001	Inspection Drawings	Inspection Dim. Insp.		
<u>MRA Blowdown Requirement</u>	The MRA shall be capable of blowdown of water passages such that the subsequent water level is at or below the top of the MRA shield block.		Analysis Analysis, Drawings	Inspection Dim. Insp.		
<u>MRA Removal Requirement</u>	The MRA shall be capable of vertical removal from core vessel after the removal of 3 target segments.	Analysis S0310500-TDO10001	Inspection Drawings	Inspection Dim. Insp.		
<u>MRA Installation Requirement</u>	The MRA shall be capable of vertical installation after the removal of 3 target segments.	Analysis S0310500-TDO10001	Inspection Drawings	Inspection Dim. Insp.	Demonstration MRA Installation	
<u>MRA Utilities Dose Rate Requirement</u>	The dose rates at 30 cm from the MRA hydrogen transfer line connection and water line connections shall be 100 mrem/hour or less after MRA operation and decay time of 8 hours to allow for hands on replacement of these connections with the target station in nominal operating configuration with the exception of the removal of the Core Vessel MRA hatch.	Analysis S03120100-TRT10015	Inspection Drawings	Inspection Dim. Insp. and MTRs		

MRA Disposal Requirement Verification

Summary	Description	FDR	PRR	FAT	Pre Ops	Ops
<u>MRA Disposal Requirement</u>	The MRA shall be capable of shipping to and disposal at a waste facility at the end of life.	Derived Requirement Verification	Derived Requirement Verification	Derived Requirement Verification		
<u>MRA Size Requirement</u>	The MRA shall fit within a liner designed to fit in the TN-RAM shipping cask after removal of piping above the upper shield block.	Analysis S0310500-TDO10001	Inspection Drawings	Inspection Dim. Insp.		
<u>MRA Mass Requirement</u>	The mass of the MRA shall be less than 2400 kg after removal of piping above the upper shield block and subsequent drying of water passages.	Inspection 0000064880	Inspection Drawings	Inspection Dim. Insp. and MTRs		
<u>MRA Shipping Requirement</u>	The MRA shall meet the radiological requirements for shipping in the TN-RAM cask after operation of 6 years and decay time of 2 years or less.		Analysis	Inspection		
			Analysis, Drawings	Dim. Insp. and MTRs		
<u>MRA Disposal Classification Requirement</u>	The MRA shall meet the waste acceptance criteria for Nevada National Security Site after operation of 6 years and decay time of 2 years or less.		Analysis	Inspection		
			Analysis, Drawings	Dim. Insp. and MTRs		

MRA Verification Plan in the Future

- 53/64 MRA Requirements have been verified at FDR
- MRA Requirements verification status will continue to be tracked through the remainder of the STS Project
- Most MRA Requirements are verified by analysis in design and then confirmation at PRR and FAT that drawings, materials, and dimensional inspection matches what was analyzed
- Only a few MRA requirements can be verified with tests/demonstrations at FAT, Pre Ops, and during Ops
 - Plans for these tests will continue to be further developed

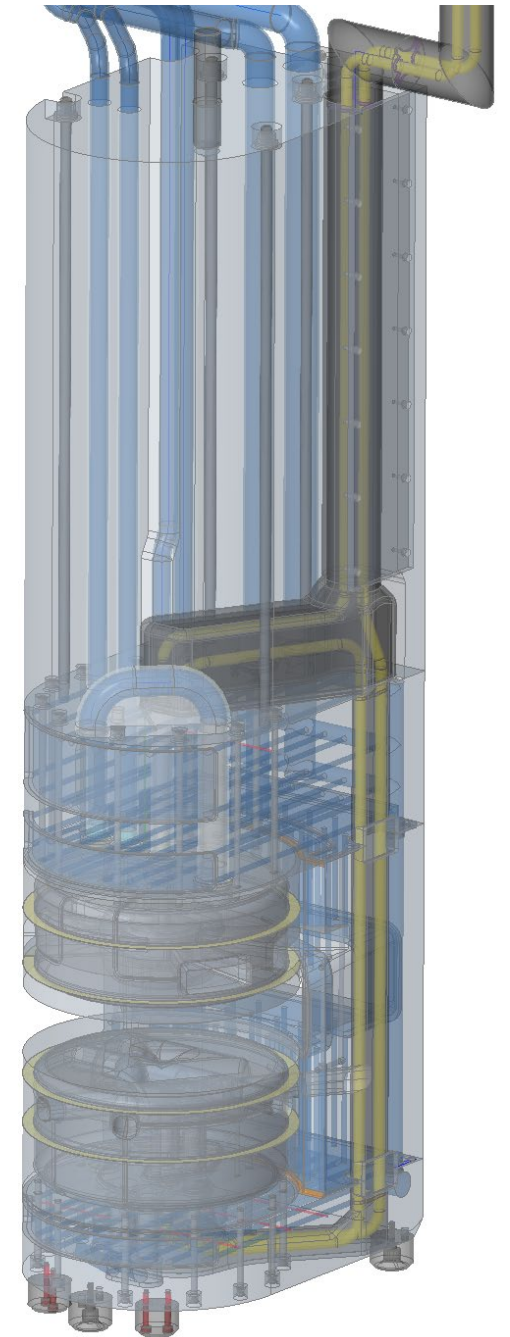


Conclusions

- The final MRA design meets STS neutron performance requirements as defined through the project KPPs and MRA-Instrument Systems Interface Sheet
- While not an explicit requirement, design for manufacturability has been a priority for MRA design resulting in reduced risk during fabrication and cost savings
- MRA requirements and interfaces have been appropriately defined
- The majority of MRA requirements have been verified at Final Design Review and those that are unverified will be verified prior to the procurement readiness review

The Path to Procurement Readiness

- Complete analysis to verify currently unverified requirements
 - Piping Structural Analysis (within CMS Scope)
 - Hydrogen Venting Analyses (within CMS Scope)
 - MRA Blowdown Analysis
 - Further Evaluation of MRA Shipping/Disposal Criteria
- Implement any pipe supports required by piping analysis
 - Update MRA-Core Vessel Interface Sheet as required
- Complete Procurement Package
 - Complete Drawing Package
 - Complete Fabrication Specifications
 - Complete Statements of Work
 - Complete Acceptance Criteria List



Thank You

