

Second Target Station Project: System Verification Plan for the Moderator Reflector Assembly (MRA)



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Second Target Station Project

**SYSTEM VERIFICATION PLAN FOR THE MODERATOR REFLECTOR ASSEMBLY
(MRA)**

Jim Janney

July 2026

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Approvals

System Verification Plan for the Moderator Reflector Assembly (MRA)		ISSUE DATE: 8/3/2026
PREPARED BY Jim Janney	PROJECT Second Target Station	DOCUMENT NUMBER: S03040000-SRD10000

	Signature / Date					
	Rev. 00	Date	Rev. 01	Date	Rev. 02	Date
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Revision	Description					
00	Initial Release					
01	Update for Final Design Review					

1. PURPOSE

This document serves to establish the plan for verification of Moderator Reflector Assembly system requirements [1]. The verification plan is simply a table of the MRA requirements with the verifications at Final Design and planned verifications at factory acceptance testing, installation, and commissioning in the future. The status of verification at the Final Design Review is included with white and light grey indicating successful verification and yellow indicating no verification has been completed. White denotes primary MRA requirements and grey indicates MRA requirements derived from primary MRA requirements. Note that the status of a primary verification will match the status of any unverified derived requirements.

2. 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.

3. REFERENCES

Ref	Document Title	Document Number
[1]	System Requirements Document for Target Systems Moderator Reflector Assembly (MRA)	S03040000-SR0001

Requirement

Verification

Summary	Description	FDR	PRR	FAT	Pre Ops	Ops
MRA Neutron Brightness Requirement	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 5Å.	Analysis	Inspection	Inspection		Test
		S03040000-DAC10010	Drawings	Dim. Insp. and MTRs		Measurement
MRA Moderator Hydrogen Density Requirement	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		
MRA Moderator Hydrogen Maximum	The hydrogen temperature shall at no point in the moderators exceed 32 K.	Analysis	Inspection	Inspection		
		S03040000-DAC10011	Drawings	Dim. Insp. and MTRs		
MRA Moderator Alignment	The MRA shall position the moderator viewed faces within +/- 1 mm of their ideal locations		Inspection	Inspection	Inspection	
			Drawings	Dim. Insp.	MRA S&A	
MRA Moderator Operational Displacement	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 Proton Beam Port Size Requirement	The MRA proton beam port shall be 262.8 mm wide by 80.8 mm tall or greater in order to allow for >99.9% of the nominal proton beam profile to pass through to the target.	Inspection	Inspection	Inspection		
		0000064880	Drawings	Dim. Insp.		
MRA Temperature Requirement	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		
MRA Aluminum Temperature Requirement	The MRA aluminum 6061-T6 structures shall have a maximum operating temperature of 100 C.	Analysis	Inspection	Inspection		
		S03040000-DAC10011	Drawings	Dim. Insp. and MTRs		

MRA Stainless Steel Temperature	The MRA stainless steel structures shall have a maximum operating temperature of 200 C.	Analysis	Inspection	Inspection		
		S03040000-DAC10011	Drawings	Dim. Insp. and MTRs		
MRA Beryllium Temperature Requirement	The MRA beryllium shall have a maximum operating temperature of 100 C.	Analysis	Inspection	Inspection		
		S03040000-DAC10011	Drawings	Dim. Insp. and MTRs		
MRA Water Temperature Requirement	The MRA cooling water shall have a maximum temperature of 100 C.	Analysis	Inspection	Inspection		
		S03040000-DAC10011	Drawings	Dim. Insp. and MTRs		
MRA Temperature	The MRA shall include thermocouples for monitoring the temperature of the MRA through	Inspection	Inspection	Inspection	Test	
		0000064880	Drawings	C of C	ICS Test	
MRA Lifetime Requirement	The MRA design shall allow for a lifetime of at least 5 years of operation.	Derived Requirement Verification	Derived Requirement Verification	Derived Requirement Verification		
MRA Material Lifetime Requirement	The MRA materials shall allow for a lifetime of at least 5 years.	Analysis	Inspection	Inspection		
		S03040000-DAC10010	Drawings	Dim. Insp. and MTRs		
MRA Cyclic Loading Requirement	The MRA shall be designed for a lifetime of 5 years (25000 hours of 700 kW beam power operation) or more with respect to cyclic loading. The hydrogen boundaries are expected to experience 50 full pressure cycles during commissioning and 10 full pressure cycles per year during operation. Hydrogen pressure is expected to fluctuate 2 bar or less during beam trips and ramps. The water boundaries are expected to experience 20 pump start cycles during commissioning and 4 pump start cycles per year during operation. A pump start cycle is expected to produce an MRA water pressure change of 1 bar or less. No full pressure cycles are expected for the water boundaries. 10000 beam trips are expected to occur each year.	Analysis	Inspection	Inspection		
		S03040000-DAC10012, S03040000-DAC10013, S03040000-DAC10014	Drawings	Dim. Insp. and MTRs		

MRA Availability Requirement	The MRA design shall allow for greater than 95% availability for greater than 5000 hours of proton beam on target per year with accommodation for maintenance intervals in accordance with the STS operating schedule.	Derived Requirement Verification	Derived Requirement Verification	Derived Requirement Verification		
MRA Maintenance	The MRA shall be designed to require no maintenance during its lifetime.	Inspection	Inspection			
		CAD Model	Drawings			
MRA Joining Requirement	The MRA design shall use all welded construction (including friction welds and explosion bonds) on all pressure boundaries.	Inspection	Inspection	Inspection		
		CAD Model	Drawings	Weld Insp.		
MRA Replacement Requirement	The MRA shall be capable of being replaced in a 1400 hour maintenance outage.	Analysis				
		S0310500-TDO10001				
MRA Leak Rate Requirement	The MRA shall maintain leak rates less than what would cause degradation of the core vessel environment or the insulating vacuum surrounding the hydrogen boundary.	Derived Requirement Verification	Derived Requirement Verification	Derived Requirement Verification	Derived Requirement Verification	
MRA Hydrogen Leak Rate Requirement	All MRA hydrogen boundaries shall have a leak rate of 1×10^{-9} mbar-l/s or less.	Inspection	Inspection	Test	Test	
		CAD Model	Drawings	Helium Leak Check	Helium Leak Check	
MRA Water Leak Rate Requirement	All MRA water boundaries shall have a leak rate of 1×10^{-6} mbar-l/s or less.	Inspection	Inspection	Test		
		CAD Model	Drawings	Helium Leak Check		
MRA Vacuum Leak Rate Requirement	All MRA vacuum boundaries shall have a leak rate of 1×10^{-9} mbar-l/s or less.	Inspection	Inspection	Test		
		CAD Model	Drawings	Helium Leak Check		

MRA Structural Integrity Requirement	The MRA shall maintain structural integrity under all expected loading conditions.	Derived Requirement Verification	Derived Requirement Verification	Derived Requirement Verification		
MRA Hydrogen Transfer Line Requirement	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		
MRA Water Piping Requirement	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		
MRA Hydrogen Vessel Requirement	The MRA hydrogen vessels shall be designed to the intent of the 2023 ASME BPVC. Applied seismic loads shall be derived from the NPH	Analysis	Inspection	Test		
		S03040000-DAC10012	Drawings	Pressure Test		
MRA Vacuum Vessel Requirement	The MRA vacuum vessels shall be designed to the intent of the 2023 ASME BPVC. Applied seismic loads shall be derived from the NPH	Analysis	Inspection	Test		
		S03040000-DAC10013	Drawings	Pressure Test		
MRA Reflector Vessel Requirement	The MRA reflector vessels shall be designed to the intent of the 2023 ASME BPVC. Applied seismic loads shall be derived from the NPH	Analysis	Inspection	Test		
		S03040000-DAC10013	Drawings	Pressure Test		
MRA Backbone Requirement	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		
MRA Fastener Requirement	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	Requirements derived from the MRA-CMS Interface Sheet, S01020500-IST10148	Derived Requirement Verification	Derived Requirement Verification	Derived Requirement Verification	Derived Requirement Verification	
MRA Hydrogen Loop Pressure Drop	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	
MRA Hydrogen Boundary Pressure	The MRA hydrogen boundary MAWP shall be 19 bara.	Analysis S03040000-DAC10012	Inspection Drawings	Test Pressure Test		
MRA Vacuum Boundary Pressure	The MRA vacuum boundary MAWP shall be 2 bara.	Analysis S03040000-DAC10013	Inspection Drawings	Test Pressure Test		
MRA Vacuum Space Requirement	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		
MRA Vacuum Venting Requirement	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.		
MRA Hydrogen Venting Requirement	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-Process Systems Interface Requirements	Requirements derived from the MRA-Process Systems Interface Sheet, S01020500-IST10186	Derived Requirement Verification	Derived Requirement Verification	Derived Requirement Verification	Derived Requirement Verification	
MRA Water Boundary Pressure	The MRA water boundaries shall have a MAWP of 5 bara.	Analysis S03040000-DAC10013	Inspection Drawings	Test Pressure Test		

MRA Upper Premoderator Pressure Drop	The MRA upper premoderator water loop shall have a pressure drop of less than 15 psi at 7.5 gpm and 32.2 C inlet temperature	Analysis	Inspection	Inspection	Test	
		S03040000-DAC10011	Drawings	Dim. Insp.	Process Systems Test	
MRA Lower Premoderator Pressure Drop	The MRA lower premoderator water loop shall have a pressure drop of less than 15 psi at 7.5 gpm and 32.2 C inlet temperature	Analysis	Inspection	Inspection	Test	
		S03040000-DAC10011	Drawings	Dim. Insp.	Process Systems Test	
MRA Upper Reflector Pressure Drop	The MRA upper reflector water loop shall have a pressure drop of less than 15 psi at 7.5 gpm and 32.2 C inlet temperature	Analysis	Inspection	Inspection	Test	
		S03040000-DAC10011	Drawings	Dim. Insp.	Process Systems Test	
MRA Lower Reflector Pressure Drop	The MRA lower reflector water loop shall have a pressure drop of less than 15 psi at 7.5 gpm and 32.2 C inlet temperature	Analysis	Inspection	Inspection	Test	
		S03040000-DAC10011	Drawings	Dim. Insp.	Process Systems Test	
MRA Backbone Pressure Drop Requirement	The MRA backbone water loop shall have a pressure drop of less than 15 psi at 15 gpm and 32.2 C inlet temperature	Analysis	Inspection	Inspection	Test	
		S03040000-DAC10011	Drawings	Dim. Insp.	Process Systems Test	
MRA-AIC Interface Requirement	The MRA design shall provide a clear path through the MRA for the optical path from the TVP mirror to the target assembly face as shown in S03050230_L-M8U-8800-A001-SKEL.PRT as specified in the MRA-AIC Interface Sheet, S03000000-IST10000.	Inspection	Inspection	Inspection	Test	
		0000064880	Drawings	Dim. Insp.	AIC Test	
MRA-Target Assembly-Core Vessel Clearance Requirements	The MRA shall not contact the target assembly and shall not contact the core vessel shielding, except for the alignment features and the seismic restraint, by meeting the requirements of the MRA-Target Assembly-Core Vessel Clearance Budget Document.	Derived Requirement Verification	Derived Requirement Verification	Derived Requirement Verification	Derived Requirement Verification	
MRA Boundary Requirement	The MRA nominal boundary shall match the boundary defined in the MRA-Target Assembly-	Inspection	Inspection			
		CAD Model	Drawings			
MRA Profile Tolerance Requirement	The MRA shall have an overall profile tolerance of +/- 1mm to the ideal boundary after installation.	Inspection	Inspection	Inspection	Inspection	
		CAD Model	Drawings	Dim. Insp.	MRA S&A	

MRA Deflections Requirement	The MRA outside surfaces shall not deflect more than +/- 1.5mm from their installed locations under any expected loading conditions.	Analysis	Inspection	Test		
		S03040000-DAC10013	Drawings	Dim. Insp., MTRs, and Pressure Test		
MRA Shielding Requirement	The MRA design shall support the Target Systems Monolith meeting the Target Systems Radiation Shielding Requirement. Note: The MRA design must be carefully coordinated with surrounding structures to minimize the impact of streaming gaps.	Analysis	Inspection	Inspection		Test
		S03120100-TRT10017	Drawings	Dim. Insp. And MTRs		Radiation Monitoring
MRA Remote Handling Requirement	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	
MRA Lifting Stud Requirement	The MRA shall include a 1.5"-8 UN threaded stud located over the assembly CG.	Inspection	Inspection	Inspection	Demonstration	
		0000064880	Drawings	Dim. Insp.	MRA Installation	
MRA Pipe Cutting Requirement	The MRA piping shall be designed for cutting above the upper shield block.	Analysis	Inspection	Inspection		
		S0310500-TDO10001	Drawings	Dim. Insp.		
MRA Blowdown Requirement	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	Inspection		
			Analysis, Drawings	Dim. Insp.		
MRA Removal Requirement	The MRA shall be capable of vertical removal from core vessel after the removal of 3 target segments.	Analysis	Inspection	Inspection		
		S0310500-TDO10001	Drawings	Dim. Insp.		
MRA Installation Requirement	The MRA shall be capable of vertical installation after the removal of 3 target segments.	Analysis	Inspection	Inspection	Demonstration	
		S0310500-TDO10001	Drawings	Dim. Insp.	MRA Installation	

MRA Utilities Dose Rate Requirement	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	Analysis	Inspection	Inspection		
		S03120100-TRT10015	Drawings	Dim. Insp. and MTRs		
MRA Disposal Requirement	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		
MRA Size Requirement	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	Inspection	Inspection		
		S0310500-TDO10001	Drawings	Dim. Insp.		
MRA Mass Requirement	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	Inspection	Inspection		
		0000064880	Drawings	Dim. Insp. and MTRs		
MRA Shipping Requirement	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		
MRA Disposal Classification Requirement	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 Assembly Structure Requirement	The hydrogen vessels shall be located within the vacuum vessels, which are located in the central region of the reflector vessels and surrounded by premoderator water and beryllium, providing 2 layers of aluminum and the beryllium reflector around each hydrogen vessel to prevent potential contact.	Inspection	Inspection	Inspection		
		CAD Model	Drawings	Dim. Insp.		