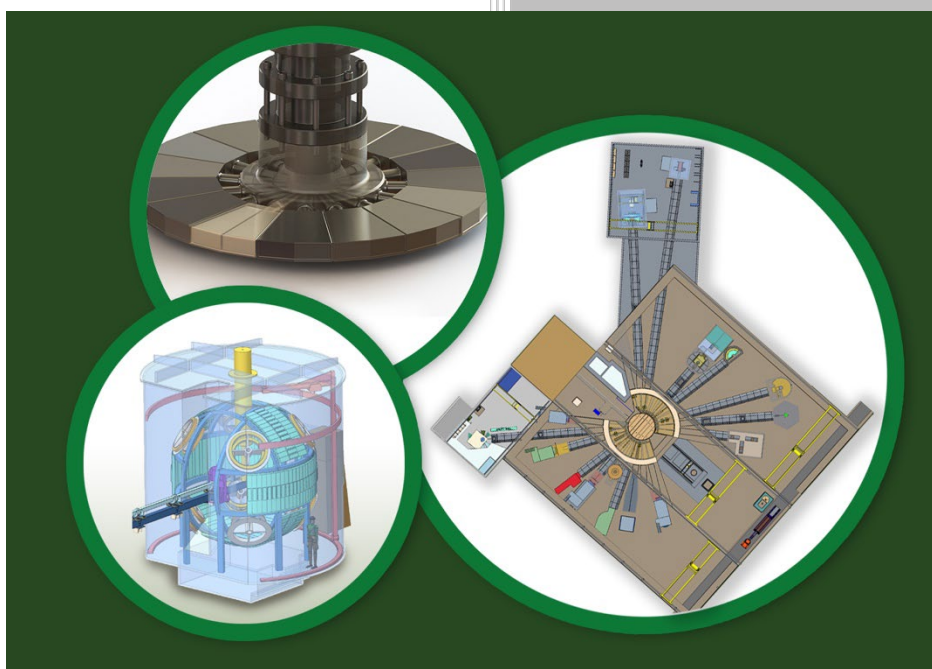


SECOND TARGET STATION (STS) PROJECT

System Verification Plan for the Moderator Reflector Assembly (MRA)



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March 22, 2024

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SECOND TARGET STATION (STS) PROJECT

SYSTEM VERIFICATION PLAN FOR THE MODERATOR REFLECTOR ASSEMBLY

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1. PURPOSE

This document serves to establish the plan for verification of Moderator Reflector Assembly system requirements [1]. The verification plan is simply a list of the MRA requirements with the planned verifications at Preliminary Design and Final Design, and will be expanded to include verifications during fabrication, installation, and commissioning in the future. The status of verification at the Preliminary Design review is included with yellow indicating no verification has been completed and red indicating that the design did not meet the requirement. 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	PDR	FDR
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
MRA Structural Integrity 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
MRA Aluminum Temperature Requirement	The MRA aluminum 6061-T6 structures shall have a maximum operating temperature of 100 C.	Analysis	Analysis
MRA Stainless Steel Temperature Requirement	The MRA stainless steel structures shall have a maximum operating temperature of 200 C.	Analysis	Analysis
MRA Beryllium Temperature Requirement	The MRA beryllium shall have a maximum operating temperature of 100 C.	Analysis	Analysis
MRA Water Temperature Requirement	The MRA cooling water shall have a maximum temperature of 100 C.	Analysis	Analysis
MRA Remote Handling Requirement	The MRA design shall include features to allow for remote handling and replacement	Derived Requirement Verification	Derived Requirement Verification
MRA Ziplift Requirement	The MRA shall include a Ziplift stud located over the assembly CG.	Inspection	Inspection
MRA Pipe Cutting Requirement	The MRA piping shall be designed for cutting above the upper shield block with a hydraulic shear.	Inspection/ Analysis	Inspection/ Analysis
MRA Blowdown Requirement	The MRA shall be capable of blowdown of water passages such that the subsequent water level is below the upper shield block.		Analysis
MRA Removal Requirement	The MRA shall be capable of vertical removal from core vessel after the removal of 3 target segments.	Inspection	Inspection
MRA Installation Requirement	The MRA shall be capable of vertical installation after the removal of 3 target segments.	Inspection	Inspection
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
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.	Inspection	Inspection

MRA Mass Requirement	The mass of the MRA shall be less than 3000 kg after removal of piping above the upper shield block and subsequent drying of water passages.	Inspection	Inspection
MRA Shipping Requirement	The MRA shall meet the radiological requirements for shipping in the TN-RAM cask after operation and decay time of 1 year or less.		Analysis
MRA Disposal Classification Requirement	The MRA shall meet the requirements for classification as class C nuclear waste after operation and decay time of 1 year or less.	Analysis	Analysis
MRA Temperature Monitoring Requirement	The MRA shall include thermocouples for monitoring the temperature of the reflector vessels and backbone through the integrated control system per S01020500-IST10126.	Inspection	Inspection
MRA Lifetime Requirement	The MRA design shall allow for a lifetime of at least 5 years of operation.	Derived Requirement Verification	Derived Requirement Verification
MRA Material Lifetime Requirement	The MRA materials shall allow for a lifetime of at least 5 years.	Analysis	Analysis
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.		Analysis
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
MRA Maintenance Requirement	The MRA shall be designed to require no maintenance during its lifetime.	Inspection	Inspection
MRA Joining Requirement	The MRA design shall use all welded construction (including friction welds and explosion bonds) on all pressure boundaries.	Inspection	Inspection
MRA Replacement Requirement	The MRA shall be designed to be replaced in a 3 month maintenance outage.	Inspection	Inspection
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
MRA Hydrogen Transfer Line Requirement	The MRA hydrogen transfer lines shall be designed and fabricated to ASME B31.12		Analysis

MRA Water Piping Requirement	The MRA water piping shall be designed and fabricated to ASME B31.3		Analysis
MRA Hydrogen Vessel Requirement	The MRA hydrogen vessels shall be designed to the intent of the ASME BPVC	Analysis	Analysis
MRA Vacuum Vessel Requirement	The MRA vacuum vessels shall be designed to the intent of the ASME BPVC	Analysis	Analysis
MRA Reflector Vessel Requirement	The MRA reflector vessels shall be designed to the intent of the ASME BPVC	Analysis	Analysis
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
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
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
MRA-CMS Interface Requirements	Requirements derived from the MRA-CMS Interface Sheet, S01020500-IST10148	Derived Requirement Verification	Derived Requirement Verification
MRA Hydrogen Loop Pressure Drop Requirement	The MRA hydrogen loop pressure drop shall be less than 0.1 bar @ 0.5 l/s and 20 K.	Analysis	Analysis
MRA Hydrogen Boundary Pressure Requirement	The MRA hydrogen boundary MAWP shall be 19 bara.	Analysis	Analysis
MRA Vacuum Boundary Pressure Requirement	The MRA vacuum boundary MAWP shall be 2 bara.	Analysis	Analysis
MRA Vacuum Space Requirement	The MRA vacuum space shall be designed for vacuum service.	Inspection	Inspection
MRA Vacuum Venting Requirement	The MRA vacuum space shall be designed to support venting of hydrogen leaks without exceeding the MAWP.		Analysis
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

MRA-Process Systems Interface Requirements	Requirements derived from the MRA-Process Systems Interface Sheet, S01020500-IST10186	Derived Requirement Verification	Derived Requirement Verification
MRA Water Boundary Pressure Requirement	The MRA water boundaries shall have a MAWP of 5 bara.	Analysis	Analysis
MRA Upper Premoderator Pressure Drop Requirement	The MRA upper premoderator water loop shall have a pressure drop of less than 15 psi at 7.5 gpm and 35 C inlet temperature	Analysis	Analysis
MRA Lower Premoderator Pressure Drop Requirement	The MRA lower premoderator water loop shall have a pressure drop of less than 15 psi at 7.5 gpm and 35 C inlet temperature	Analysis	Analysis
MRA Upper Reflector Pressure Drop Requirement	The MRA upper reflector water loop shall have a pressure drop of less than 15 psi at 7.5 gpm and 35 C inlet temperature	Analysis	Analysis
MRA Lower Reflector Pressure Drop Requirement	The MRA lower reflector water loop shall have a pressure drop of less than 15 psi at 7.5 gpm and 35 C inlet temperature	Analysis	Analysis
MRA Backbone Pressure Drop Requirement	The MRA backbone water loop shall have a pressure drop of less than 15 psi at 15 gpm and 35 C inlet temperature	Analysis	Analysis
MRA-TVP Interface Requirements	Requirements derived from the MRA-TVP Interface	Derived Requirement Verification	Derived Requirement Verification
MRA TVP Slot Requirement	The MRA shall provide a clear path through the MRA for the optical path shown in S03050230_L-M8U-8800-A001-SKEL.PRT.	Inspection	Inspection
MRA-Target Assembly-Core Vessel Interface Requirements	Requirements derived from the MRA-Target Assembly-Core Vessel Interface Sheet, S01020500-IST10205	Derived Requirement Verification	Derived Requirement Verification
MRA Boundary Requirement	The MRA nominal boundary shall match the boundary defined in the MRA-Target Assembly-Core Vessel Interface Sheet	Inspection	Inspection
MRA Profile Tolerance Requirement	The MRA shall have an overall profile tolerance of +/- 1mm to the ideal boundary after installation.	Analysis	Analysis
MRA Deflections Requirement	The MRA outside surfaces shall not deflect more than +/- 1mm from their installed locations under any expected loading conditions.	Structural Analysis	Structural Analysis

MRA-Instrument Systems Interface Sheet	Requirements derived from the MRA-Instrument Systems Interface Sheet, S01020500-IS0023.	Derived Requirement Verification	Derived Requirement Verification
MRA Neutron Beam Requirement	The MRA shall deliver 18 neutron beams with the characteristics and locations described in 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\AA.	Analysis	Analysis
MRA Moderator Hydrogen Density Requirement	The hydrogen in both moderators shall have a minimum average density of 72.0 kg/m ³ .	Analysis	Analysis
MRA Moderator Hydrogen Maximum Temperature Requirement	The hydrogen temperature shall at no point in the moderators exceed 32 K.	Analysis	Analysis
MRA Moderator Alignment Requirement	The MRA shall position the moderator viewed faces within +/- 1 mm of their ideal locations during installation.	Analysis	Analysis
MRA Moderator Operational Displacement Requirement	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	Analysis
MRA Seismic Requirement	The MRA shall be capable of withstanding the loads outlined in ASCE 7 within the limits defined by the ASME BPVC, ASME B31.12, and ASME B31.3		Analysis
MRA Shielding Requirement	The MRA shielding and pipe routing design shall not impact radiation transport through the vessel systems shield stack to an extent which would require additional shielding in the target drive room roof.	Analysis	Analysis