S01020500-IST10148-R01

SECOND TARGET STATION (STS) PROJECT

Interface Sheet for Cryogenic Moderator System and Moderator Reflector Assembly

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3/12/2024

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE US DEPARTMENT OF ENERGY

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Approvals

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PREPARED BY Jim Janney	PROJECT Second Target Station	DOCUMENT NUMBER: S01020500-IST10148

	Signature / Date					
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Revision	Description
00	Initial Release
01	Update expected supplied and moderator hydrogen states for single hydrogen loop

TABLE OF CONTENTS

1. PURPOSE

This document defines the interfaces between Cryogenic Moderator System and Moderator Reflector Assembly. The hydrogen state delivered to the MRA and the hydrogen state expected in the moderators is described as well as the expected proton beam loads imposed on the hydrogen and surrounding structures. The interface described in this document will provide guidance to the design of the Cryogenic Moderator System and Moderator Reflector Assembly.

2. SCOPE

The scope of this document is the interface between Cryogenic Moderator System and Moderator Reflector Assembly. No parent Interface Control Document exists since both systems are within Target Systems. The hydrogen state supplied to the MRA and expected in the moderators is described as well as the expected proton beam loads imposed on the hydrogen and surrounding structures. Further description of the physical interface between the systems will be provided in future revisions of this document.

2.1 INTERFACING PARTS OR COMPONENTS

No.	Components (Cryogenic Moderator System)		Components (Moderator Reflector Assembly)	
	Name	Functional reference Number	Name	Functional reference Number
1	Cryogenic Moderator System	S03030000-M8U-8800-A10000	Moderator Reflector Assembly	S03040000-M8U-8800-A10000

3. ACRONYMS AND DEFINITIONS

CMS	Cryogenic Moderator System
ICD	Interface Control Document
IS	Interface Sheet
MRA	Moderator Reflector Assembly
MAWP	Maximum Allowable Working Pressure
SSC	Structure, System or Component
STS	Second Target Station
WBS	Work Breakdown Structure

4. REFERENCES

4.1 DOCUMENTS APPLICABLE TO THE INTERFACING SSCS

Ref	Document Titles	Document Control System Location
[1]	S03030000-SR0001-R00 System Requirements Document for CMS	/Neutron Sciences/Second Target Station (STS)/S03 – Target Systems/S0303 – Cryogenic Moderator Systems
[2]	S03040000-SR0001-R00 System Requirements Document for MRA	/Neutron Sciences/Second Target Station (STS)/S03 – Target Systems/S0304 – Moderator Reflector Assembly
[3]	Preliminary Moderator Optimization Report	Unreleased
[4]	Preliminary Hazard Analysis Report	/Neutron Sciences/Second Target Station (STS)/S01 – Project Management/S0103 – ES&H - QA

5. INTERFACE DEFINITION

5.1 TECHNICAL DESCRIPTION OF THE INTERFACE

The purpose of the Second Target Station (STS) Cryogenic Moderator System (CMS) [1] is to supply liquid hydrogen to the 2 moderators such that the hydrogen state within the moderator is maintained for acceptable neutronics performance from the Moderator Reflector Assembly (MRA) [2] given the neutronic heating of the hydrogen and surrounding structures by the proton beam. This document describes the hydrogen state supplied to the MRA, the hydrogen states expected in the moderators, and calculated neutronic heating for both moderators and serves as a basis for design of the CMS and MRA.

The CMS will aim to maintain the hydrogen state within the moderators as near as possible to the parameters used in the preliminary Moderator Reflector Assembly (MRA) neutronics analyses – temperature of 20 K, density of 72.9 kg/m3, and parahydrogen fraction of 100% [3]. Previous neutronics analyses have shown the moderator performance to be much less sensitive to the moderator hydrogen temperature and density compared to the sensitivity to the parahydrogen fraction. The expected hydrogen states are listed in Table 1.

Previous neutronics analyses have shown the moderator performance to be very sensitive to the moderator para hydrogen fraction, especially for the lower tube moderator, as seen in Figures 1 and 2. The equilibrium parahydrogen concentration is a function of temperature and at 18 K is 99.95%. Back conversion of parahydrogen to orthohydrogen by neutron interactions in the moderator will drive the parahydrogen concentration to be slightly less than the equilibrium concentration. Expected parahydrogen fraction is listed in Table 1.

Potential deviations from the expected parameters listed in Table 1 will be established in a future revision of this document.

The neutronic heat loads to the hydrogen and surrounding structures from the proton beam must be removed by the CMS while maintaining stable hydrogen state and operation. The neutronic heat loads were calculated based on MCNP analysis of the MRA preliminary design, as seen in Table 2. The heat loads are divided into heating directly in the hydrogen and heating to the aluminum moderator vessels and invar piping. The heating directly in the hydrogen is directly proportional to the parahydrogen to orthohydrogen back conversion rate and will be used to determine expected parahydrogen fractions.

The physical interface between the MRA and the CMS is at the top of the MRA transfer line within the core vessel. Both sections of transfer line feature two parallel 16 mm OD, 1mm thick Invar tubes (hydrogen boundary) extending 25 mm from a 76.2 mm OD, 1.65 mm thick stainless steel tube (vacuum boundary). Upon MRA installation, the Invar tubes will be welded together before the gap in the vacuum boundary is closed with a stainless steel sleeve, sized to just slide over the vacuum tubes, which is welded to both vacuum tubes.

The CMS is also responsible for over pressure protection of the MRA hydrogen and vacuum spaces by providing relief valves and rupture disks which vent over pressure hydrogen through the hydrogen safe vent. The maximum allowable working pressure (MAWP) of the hydrogen vessel is 19 bara, while the maximum allowable working pressure of the vacuum vessel is 2 bara. The limiting case for over pressure protection for the hydrogen vessel is a rapid loss of insulating vacuum resulting in a sudden large heat in leak to the hydrogen system. The limiting case for over pressure protection for the vacuum vessel is a large liquid hydrogen leak into the vacuum vessel.

Both of these venting cases involve vessels within the MRA and the hydrogen transfer lines within the MRA and CMS and both require transient non-linear analyses. Instead of attempting to divide the allowable pressure drop in the venting scenarios between the systems for separate analysis, we will instead analyze the venting scenarios as a whole for the MRA and CMS portions of the hydrogen and vacuum boundaries. The CMS project will be responsible for performing these analyses, although the MRA project is responsible for ensuring that the hydrogen line and vacuum space design of the MRA allow for venting of hydrogen in these scenarios without exceeding the MAWP of the vessels.

According to the STS Preliminary Hazard Analysis Report [4], the hydrogen transfer lines shall be designed to the requirements of ASME B31.12, including evaluation of seismic loads. Again, rather than attempting to divide the analysis into the MRA and CMS portion of the hydrogen transfer lines, the stress analysis shall consider the whole of the transfer lines. The CMS project will be responsible for performing these analyses, although the MRA project is responsible for ensuring the hydrogen transfer line design of the MRA meets the requirements of ASME B31.12.

5.2 INTERFACE DATA

Table 1. STS CMS/MRA Expected Parameters

Location	Inlet Temperature (K)	Inlet Pressure (bara)	Hydrogen Flowrate (g/s)	Inlet Parahydrogen Fraction	Average Temperature (K)	Average Density (kg/m3)	Average Parahydrogen Fraction
Supply to MRA	18.34	14.08	37.35	0.99947			
Upper, Cylinder	18.35	14.06	37.35	0.99947	19.65	73.100	0.99946
Lower, Tube	19.67	14.02	37.35	0.99945	20.63	72.101	0.99944
Return to CMS	21.00	13.98	37.35	0.99943			

Table 2. STS Moderator Heat Loads

Moderator	Hydrogen Heat Load (W)	Structure Heat Load (W)	Total Heat Load (W)
Upper, Cylinder	166.39	244.73	411.12
Lower, Tube	228.04	218.62	446.67

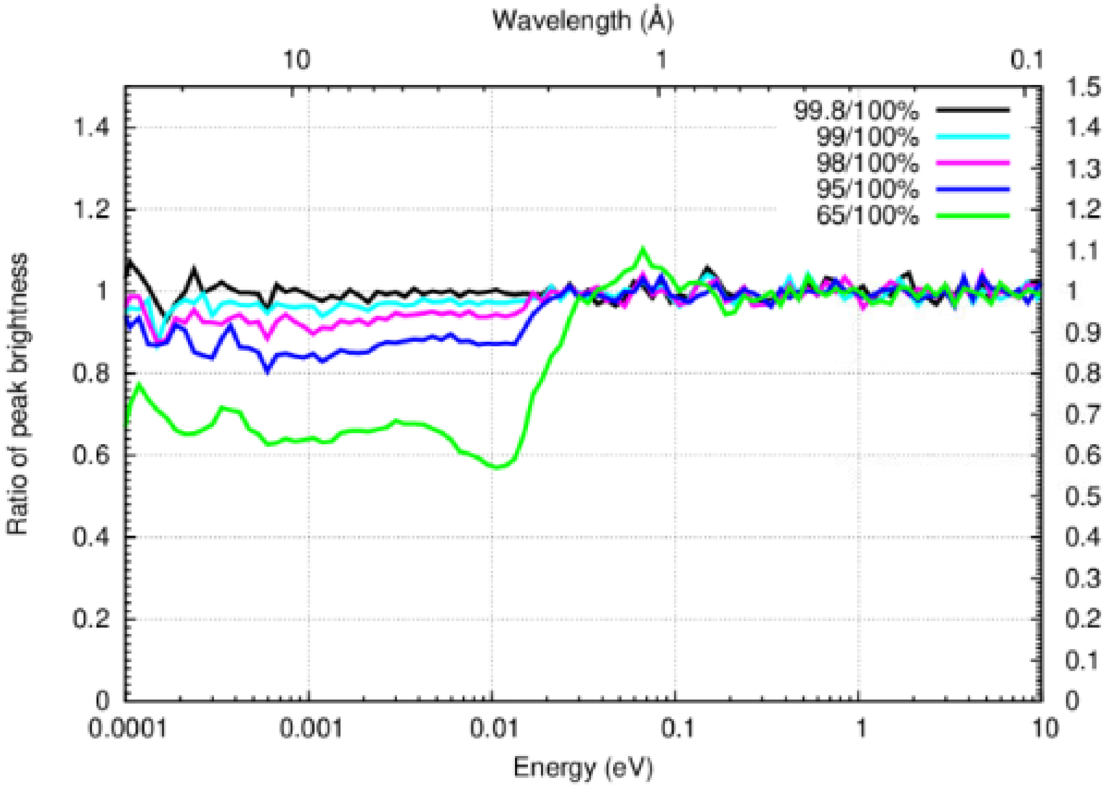

Figure 1. Cylindrical Moderator Peak Brightness Ratio vs. Energy for Various Parahydrogen Fractions

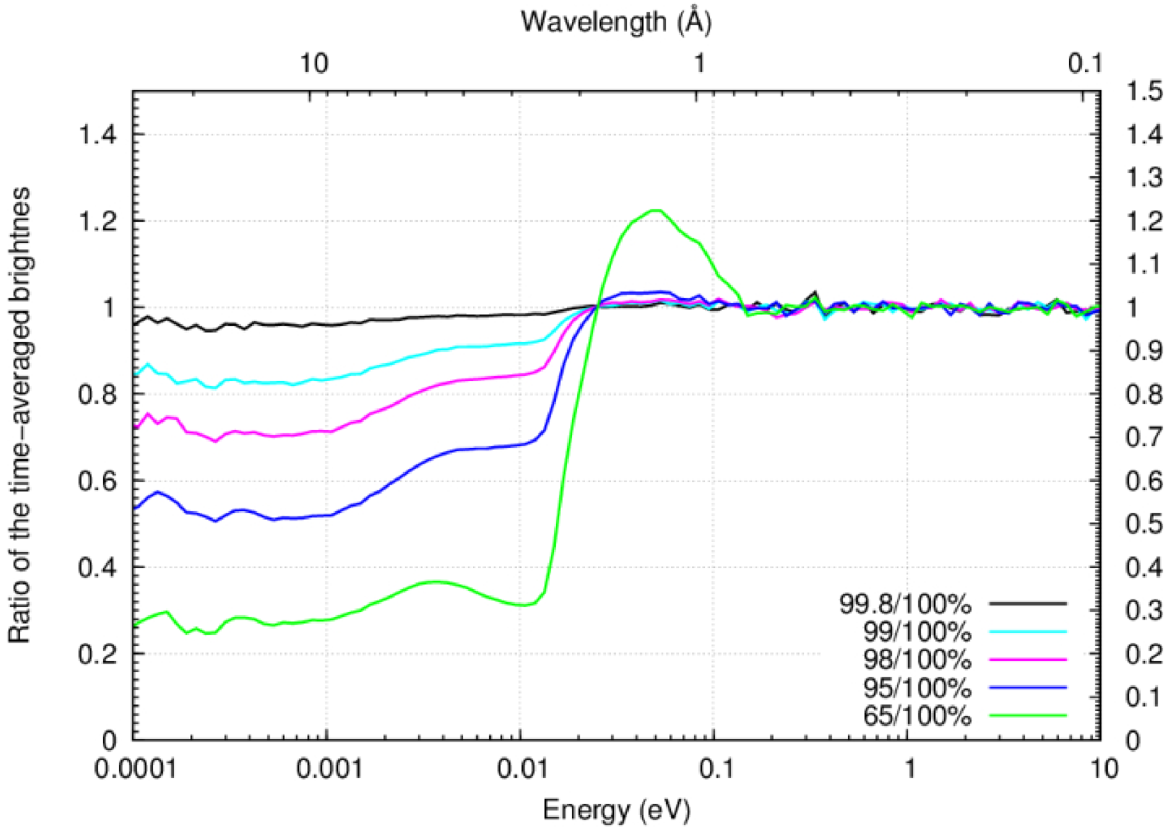

Figure 2. Tube Mod. Time-Averaged Brightness Ratio vs. Energy for Various Parahydrogen Fractions