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1.1 Status of Spallation Neutron Source Program in High Intensity Proton Accelerator Project

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Abstract

Japan Atomic Energy Research Institute and High Energy Accelerator Organization are jointly designing a 1MW spallation neutron source as one of the research facilities planned in the High Intensity Proton Accelerator Project. The spallation neutron source is driven by 3GeV proton beam with a mercury target and liquid hydrogen moderators. The present status of design for these spallation source and relevant facility is overviewed.

1. Introduction

In the Joint Project Team organized in 1999 from Japan Atomic Energy Research Institute (JAERI) and High Energy Accelerator Research Organization (KEK), the Neutron Group was also organized under the joint team for designing Spallation Neutron Source. [1-3] The neutron group consists of several teams that are of target station, instrumentation (spectrometer), advanced device, scientific demand and proton beam transport. Scientific demand team is seeking attractive proposals, and the last one works jointly with the muon team. The instrumentation team was organized with more than 100 researchers of Japan.

The scope of spallation neutron source design includes target-moderator-reflector system, bio-shield-shutter-neutron line, system utility&safety, remote handling, proton beam transport and facility building layout.

The target station team has been continued extensively to develop a conceptual design of target-moderator-reflector (TMR) system, handling and safety schemes, facility layout, proton beam transport line. [4] The spallation source is designed for 1MW proton beam injection with 3GeV of proton energy and 333μA of current. Pulse duration is 25 Hz in which two 100ns bunches are injected with 400ns interval. At the front of the neutron source two muon targets will be placed and then a proton beam passes through those targets before reaching the spallation neutron target. This arrangement produces extra technical issues of a scraper for beam spill due to muon targets and shield for neutrons from the spill. Operation requirement for this facility is 4500 hrs beam time in a year, so that an exchange period of the TMR system is desired to be a half of a year at least. For neutron beam lines, the number of beam lines is desired as many as possible from users, although shield design will limit the number. Thus the design team is strongly communicating with the instrumentation team that will make necessary concept and specifications for the target station design.

A conceptual design study is being performed to complete by March 2001, and then the detailed design will start at the mid of 2001. The research and development is also performed in parallel to the design study. These R&D are the target experiment using AGS at BNL(ASTE) and material irradiation by SINQ at PSI by international collaboration, and experiments of mercury flow, corrosion, erosion, cavitation, and remote handling by mockup test devices installed at JAERI-Tokai site. Most of the R&D items are expected to be concluded by the mid of 2002.

2. Target-Moderator-Reflector Design

The target station designed for the present spallation neutron source is shown in Fig. 1. The

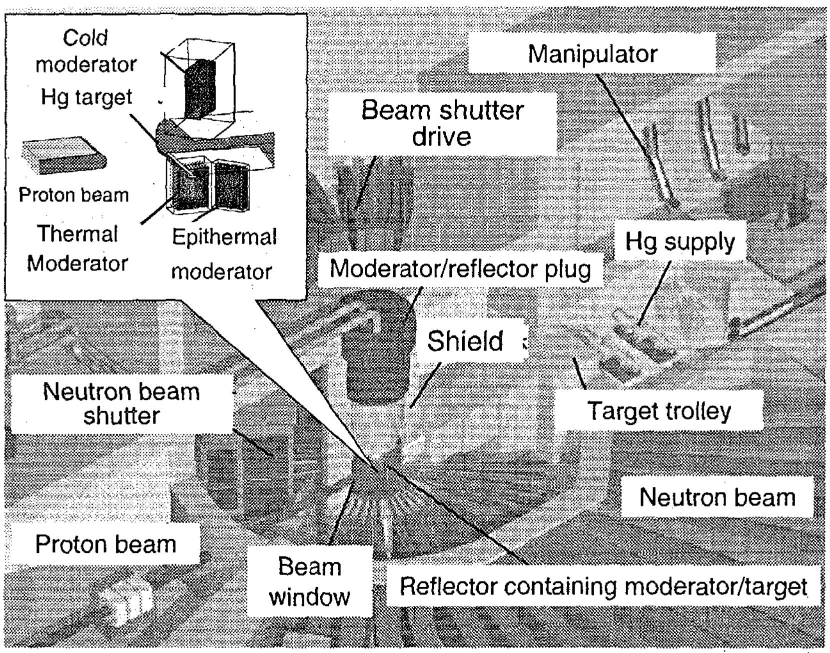

Fig. 1 Target Station and Target-Moderator-Reflector system

Target-Moderator-Reflector design are now being focused on the following items.

1) TMR configuration optimization
   - neutronics comparative study of configuration and shape
   - material combination of reflector and moderator type
   - method for fabrication
2) Mercury target system design
   - heat removal to assure steady flow (flow control)
   - confirm pressure wave related phenomena (cyclic stress, cavitation)
   - chemical reactions of mercury with container material(erosion, corrosion)
3) Moderator system design
   - remove heat generated by nuclear heating (several W/cm^3 at maximum)
   - assembling and piping scheme
4) Maintenance scenario
   - disassembling/assembling scenario
5) Safety consideration
   - system scenario for off-normal event

To fix a basic design concept, neutron energy and time spectra from moderators were calculated by changing their size and configuration, with the combined Monte Carlo simulation code system of NMTC/JAERI and MCNP. [5-7] The uniqueness of the present design is adoption of concepts of cross flow target and pre-moderator. The cross flow concept assure the mercury flow to distribute ideally, and the pre-moderator increases cold neutron intensity from the cold moderator and decreases nuclear heat inside the moderator at the same time. The premoderator can increase neutron intensity by extending to neutron view window. It is so called the extended pre-moderator. The calculations also show that, adopting the extended pre-moderator, two moderators can be replaced by one moderator

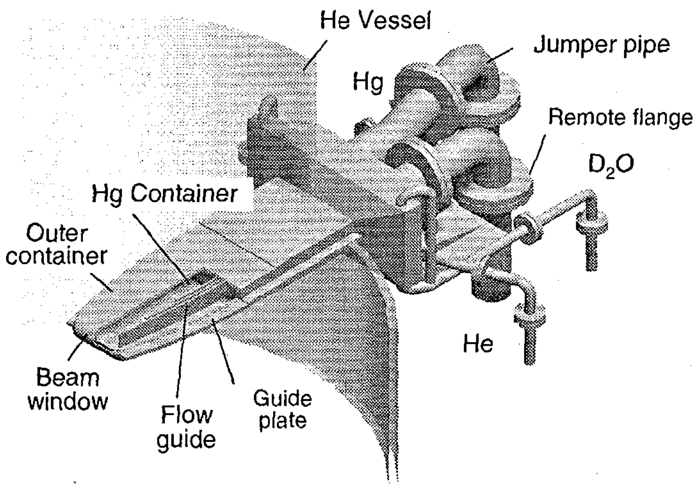

Fig. 2 Target assembly

with neutron view windows attached to the both sides. It makes significant benefit that the moderator cost and hydrogen inventory become lower.

The concept of the target assembly is shown in Fig.2 and the inner structure of the cross flow target shown in Fig.3. [8] Thermo-hydraulics design showed it could be persistent to 3GeV-1MW beam power with 1 m/s mercury flow. The present design showed the temperature distribution inside mercury is less than 115 degree C and the maximum temperature at the front window of the container is 176 degree C by adopting cross flow scheme. Now the design effort is focused to decrease inventory of mercury and simplify the structure of flow distributors. [9]

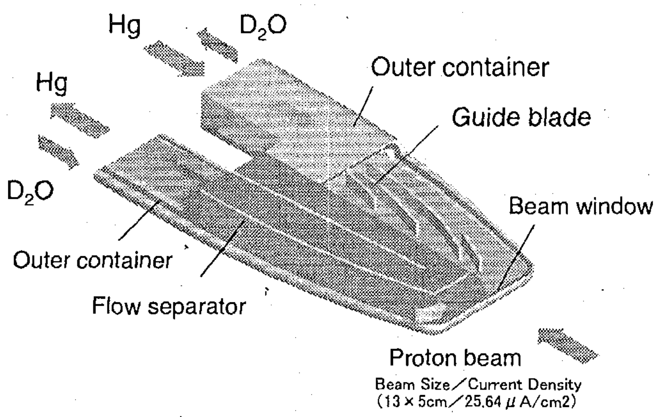

Fig. 3 Cross flow target

Pressure wave is one of most important issue in mercury target concept. The design calculation indicated that the maximum pressure of around 200 MPa takes place at front end of target container and it is lower than the design limit of 414 MPa for 316LN stainless steel. Another issue is the generation of cavitation at inside of the container wall. This was being studied by Hopkins method.

Material persistence against radiation damage is also an issue to keep the life of target container longer. A stainless steel of SS316 is adopted at the present. This is expected to be confirmed by a radiation damage study using SINQ. [10]

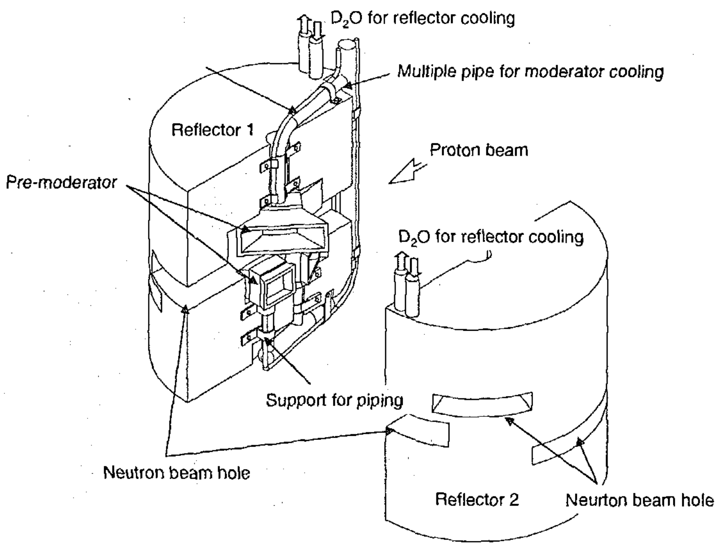

Fig.4 Assembling of Target-Moderator-Reflector system

For a cold moderator, a coupled moderator of liquid hydrogen at 20 K was adopted with pre-moderator of H_2O. Thermal- and epithermal moderators were extensively studied for a decoupled moderator with respect to background tail in the emitted neutron time spectrum. Thermo-hydraulics of super-critical liquid hydrogen flow under nuclear heat generation was investigated by computation. The flow distribution was tested by mockup model with water instead of hydrogen. The present design with 1.5 litter/sec can be used up to 2MW target within 3 degree K increase.[11]

3. Handling and Safety Scheme

Assembling and disassembling concept of piping structure and flow systems with safety hull, as shown in Fig. 4, should be investigated by fabricating a scaled model. Remote disassembling scheme for handling with manipulator is being developed by full-scaled mockup test bench. Various schemes and procedures for assembling and disassembling the TMR system will be tested by using this bench. [9]

Radio-activities were estimated by the Monte Carlo codes including all types of solid, liquid and gas phase. This estimation is a base of scenario making for exhausting system, removal system and shielding structure to reduce them. Consideration of waste management and storage scenario include transport path, disassembling and packing of used targets.

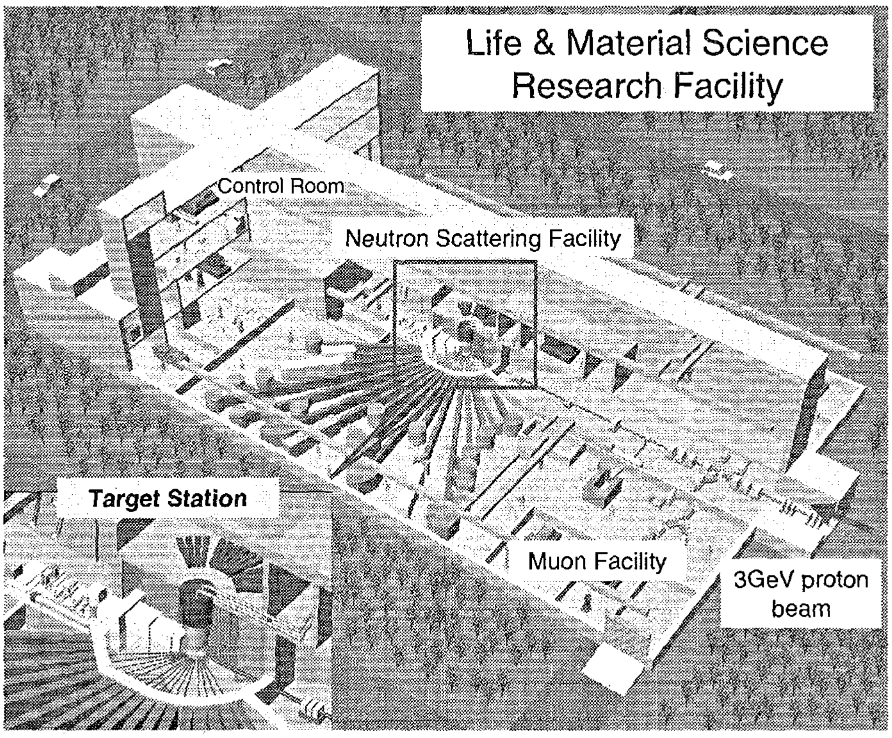

Fig. 5 Facility Layout

For safety consideration, a concept of multiple barriers with three barriers is adopted to contain the radio-activities estimated by the above calculation. Effects of off-normal operations, such as mercury container destruction, vacuum window destruction, etc. are to be considered by combining the estimated radio-activities.

4. Facility Layout

The facility concept is shown Fig. 5. Two muon targets will be placed finally at the front space of the neutron target station. Radioactive-control area located at center zone of the building is commonly used for maintenance of both the facility. This center zone includes proton beam transport line, spallation neutron target, handling and supporting cell for the neutron target, and muon target.

Neutron beam lines are distributed to booth sides of the central area. The areas are 60m x 35m and 60m x 25m each. The height of the measurement hall is 14m. Beam scraper for beam spread due to the muon targets is placed just behind the muon target. This scaraper arises the most crucial problem in proton beam transport because more than 100kW beam power deposits there. There must be much effort to be paid for countermeasure of radioactive gas production.

Bio-shield is designed as 5m iron and 1 m concrete shield. For beam shutter, we are considering an up-down type with at least 2 m thickness of Fe or W. A shutter and beam line shielding study is now under way. The beam line shield design is also strongly connected to interface devices with spectrometers such as t_0-chopper and mirror guide tubes that affect the number of possible lines.[12]

Typical energy and time spectra for moderators that will be the candidates were provided as the initial condition for instrumentation design as shown in Fig. 6. On the basis of these conditions, instrumentation groups organized from all researchers in Japan who have interest in the present SNS program have started conceptual designs of spectrometers and development of necessary technology for them as shown in Table 1.

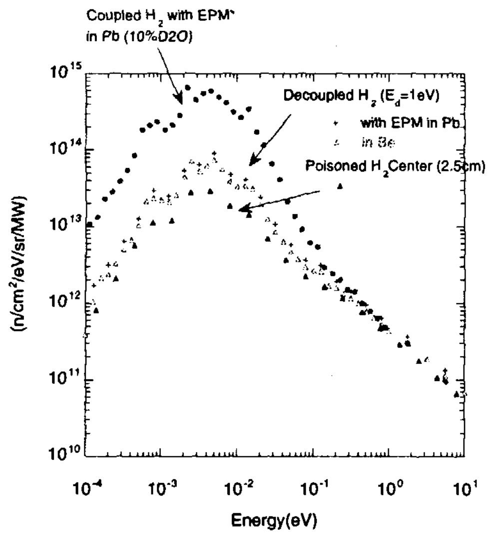

Fig. Neutron spectral intensities from various moderators
*EPM : extended PM

Fig. 6 Typical energy spectra expected to be obtained from the moderator

Table 1 Organization for development of spectrometer and devices

Spectrometer concept / Device development	Diffractometer Group (Powder crystal)	Total Scattering Group	Inellastic Scattering Group (Chopper Spin echo)	Small Angle Scattering Group	Biology Group	Radiography Goup	Fundamental Physics Goup	Promt Gamma Spectros-copy Group
Computer simulation Group		Cooperation with moderator design						
Data Analysis Group								
Neutron beam line group		Cooperation with Shielding dsign						
Chopper Group								
Mirror Group								
Polarizer Group								
Detector Group								

* Colored columns show the groups already established.

5. Summary

The conceptual design of the TMR system in the Japanese spallation neutron source was almost completed. The facility, handling and safety analysis are under investigation. The R&D for the target and moderator are continued and the mockup test for confirming remote maintenance scheme will start 2001.

Proton beam transport line is being designed with developing concept of scraper for the muon target. Neutron beam line shielding study has started together with beam shutter. For instrumentation, a large team of concept development has been organized and computer simulations started for designing neutron optics and detector with the initial energy and time spectrum conditions calculated by neutronics design team.

The concept development will be continued by April in 2001 and then move to the detailed design work before a fabrication starts in 2002.

Acknowledgments

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