ISIS Target Station One Upgrade Project – An overview of the development work being undertaken to improve the Target, Reflector and Moderator (TRaM) support systems

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Abstract. ISIS Spallation source is currently undergoing a new project to develop the Target, Reflector and Moderators (TRAM) of its existing Target Station One (TS1) facility. This project is being undertaken with a view to improve the neutronic performance combined with a gain in output and at the same time, engineered to increase flexibility for upgrades and easier remote operations. The second ISIS target Station (TS2) was completed in 2008. Its design enables the remote handling operator to access the methane moderator in minutes, without having to handle the target with the requirement to drain and split water circuits. With the opportunity to replace much of the structure within TS1, some of the design features of TS2 could be incorporated in the development of the TS1 TRAM.

1. Background
TS1 has been in operation from 1984 and has undergone multiple target changes, the reflector had been replaced in 2004, a replacement hydrogen moderator in 2007 numerous ambient moderator changes and 47 methane moderators. The TRAM is situated at the front of a long trolley system that consists of shielding plugs and services that provide cryogens and cooling for the moderators, reflector and target as shown in Figure 1.1.

Figure 1.1, ISIS TS1 Target trolley, The services are located on the yellow trolley to the left. The TRAM is located to the right end of the trolley in front of the forward shielding plug.
The trolley travels to and from the centre of the target station to the remote handing hot cell for maintenance. The TRAM is too active for human intervention and therefore maintenance operations must be carried out remotely using manipulators while using a zinc bromide window and CCTV cameras as visual aids. The methane moderator is regularly changed twice a year due to clogging. The procedure to change this moderator involves draining down the entire cooling system into holding tanks and drying out the system. The reflector and target are disconnected and handled to their storage locations to enable access to the moderator. The moderator connections are located out of sight below the support beam; this location can make remote handling operations tricky. The entire procedure can take two weeks to change the moderator with risks of damage to the reflector, target, leakages and contamination. The aim is to try to minimise the handling procedures and to reduce the risks.

2. The Neutronic Spec

The new TRAM specification was developed by the ISIS neutronics group and was supplied as a MCNPX file converted to import into Computer Aided Design software (CAD). The latest design being developed for manufacture is the Mark 7. The internal geometry is restricted by the requirements and the positions of the existing beamlines. As shown in Figure 2.1, the sizes and positions of the ambient water moderators are unchanged from the current TRAM. The target has been developed to reduce the stainless inventory. The hydrogen moderator head and moderator position has been developed for 99% para operation. The methane moderator has gone from a single poison foil to a dual foil, but is located in the same position. Both the cryo-moderators have the addition of the pre-moderator with a view to extend the moderator life time. Construction of the reflector has progressed from a stainless box filled beryllium structure to a solid beryllium unit.

- Dual water moderators.
- Stainless cased. Tantalum cladded tungsten plate target.
- Water pre-moderator for hydrogen moderator.
- Water pre-moderator for methane moderator.
- Hydrogen moderator.
- Dual poison methane moderator.
- Surrounded by a solid Beryllium reflector

**Figure 2.1, ISIS TS1 Project TRAM MCNPX Model.**

3. Engineered for Remote Handling

The current TS2 TRAM has a clever support frame system that divides the reflector and positions it away from the target and moderators without splitting the water circuits. An attempt to develop the same system for the TS1 project wasn’t achievable as it was difficult to overcome the problem of the target being fixed to the interface door blocking moderator access. Therefore, a solution to this problem was to remove the current target support from the door and mount the target directly within
the reflector. This then offers enough space to divide the reflector to reveal the cryo-moderators. See Figure 3.1 for details.

**Figure 3.1**, The TRAM concept to illustrate a method of splitting the reflector to access the cryo-moderators.

However, this generated a new problem of providing flexible services adequate to supply sufficient cooling for the target. Figure 3.2 illustrates the complexity of delivering services to the target, reflector and moderators. This concept also highlighted the limitations of the current cantilevered support structure, a new support structure is required.

**Figure 3.2**, Diagram to illustrate the various cooling circuits throughout the TRAM.

### 4. Hydrogen Moderator Development

The hydrogen moderator design utilises the current coupling and stem design, but with an optimised moderator head designed for the required 99% para hydrogen, as shown in Figure 4.1.

**Figure 4.1**, Hydrogen moderator design

**Figure 4.2**, FEA plots of the hydrogen moderator head optimisation
The moderator head is constructed from Aluminium 5083 alloy and has been optimised to withstand the operating pressure of 8 Bara and a temperature of 20K. The surrounding vacuum and tertiary vessels have been developed for both pressure and vacuum situations as shown in Figure 4.2.

5. Methane Moderator
The proposed methane moderator as shown in Figure 5.1 has been developed with a dual gadolinium poison layer. The pressure vessel to be manufactured from Aluminium 5083 alloy, has been designed to contain liquid methane at 3 Bara and 110k. The pressure vessel is surrounded by a vacuum vessel to provide thermal insulation. The vessel have been accessed by using FEA modelling as shown in Figure 5.2, to produce a robust design without compromising the thickness of the can that can reduce neutronic performance.

![Figure 5.1 Dual Foil Methane moderator development](image)

Figure 5.1 Dual Foil Methane moderator development, The cryo-coupling is shown to the left of the image, the moderator pressure and vacuum vessels are shown to the right. The pressure clamp is shown around the moderator in the middle of the image.

The cryo-coupling for this moderator has been designed to position the pressure clamp from beneath, to above the cantilever support frame to provide better access and visibility to aid remote handling during moderator change.

![Figure 5.2](image)

Figure 5.2, illustrates the effect of internal pressure on the methane vessel and external pressure acting on the vacuum vessel.

6. Reflector Development
The technical advancement of a solid beryllium reflector as fitted to the ISIS second target station, is a feature that would be beneficial on the TS1 project to replace the current stainless box filled with beryllium rod design. However, this does have its challenges as TS2 reflector is subjected to 4kw of thermal load whereas TS1 is around 11kw. The reflector is divided into multiple components to provide flexibility to accommodate future upgrades rather than a complete reflector replacement to reduce waste, costs and remote handling operations. The reflector is also designed to support the target, ambient water moderators and pre-moderators. Access to these components is also provided. The design requirement was to maintain the reflector core temperature to below 100°C to protect the aluminium moderators and prevent the deterioration of the neutronic performance. Cooling to the
reflector is provided by conduction to the outer edges using water flowing through cooling pads. As shown in Figure 6.1, FEA analysis was carried out to optimise the structure and by addition of more cooling pads a core temperature of less than 100°C was achieved. As shown in Figure 6.2 the reflector is broken down into 13 component parts. The size of the entire reflector is 800 X 700 x 700mm and will be manufactured from Beryllium S200FH.

Figure 6.1, FEA plots of the thermal analysis of the reflector halves. The maximum expected temperature measured is 97.5°C.

Figure 6.2, Illustration of the reflector breakdown, The complete reflector assembly as shown on the right.

7. Conclusion
Although the neutronic design is not too different to the current TRAM. A lot of development has already been undertaken to produce a design that will improve remote handling during moderator changes with the advantages of reducing down time along the risks of contamination and damage. The design has taken more focus towards the eventual decommissioning utilising structures that can be broken down to fit into standard flasks to eliminate cutting radioactive material. The solid beryllium reflector has been successfully optimised with a sectional construction for upgrade flexibility while maintaining a critical internal temperature of less than 100°C. Water pre-moderators have been successfully incorporated into the reflector to reduce the damaging effect of the high energy neutrons acting on the cryo-moderators which should improve moderator life.

References
[1] G. Skoro, S. Lilley and R. Bewley, ‘Neutronics analysis of target, moderators and reflector design for the ISIS TS-1 project, Physica B, (submitted)