EQUIPMENT AND TECHNIQUES FOR THE REPLACEMENT OF THE ISIS PROTON BEAM TO TARGET WINDOW

Stephen David Gallimore, Stephen Jago (STFC/RAL/ISIS, Chilton, Didcot, Oxon, UK)

Abstract

The ISIS Spallation Neutron Source has been in operation at the Rutherford Appleton Laboratory for over 25 years. Much of the original equipment installed during the construction of the facility is still in operation. The window separating the proton beam transfer line from the neutron target is a key component in the accelerator complex. During the operational life of the Beam Entry Window it has absorbed a considerable amount of energy deposited from the proton beam as it passes from the accelerator vacuum to the target area. Due to the difficulties in accessing and handling the window assembly, a decision was made to replace this component in a planned maintenance period. This paper describes the specialist remote handling equipment and techniques that were developed during the 3 year build up to the removal and replacement of the highly active Beam Entry Window.

BACKGROUND

The Beam Entry Window (BEW) is situated in the lower downstream extracted proton beam (EPB) for target station 1 at the ISIS facility. It is constructed from two long (3.4m) coaxial flanged pipes, each with one end closed by an inconel window. Cooling water flows between the two pipes and down in the gap between the two windows. The outer window sits approximately 600mm from the front face of the neutron target, while the rest of the assembly passes through the monolith shielding and attaches to a flange built into the shielding wall just inside the EPB tunnel. Figure 1 shows the location of the BEW assembly in relation to the target void vessel and monolith shielding.

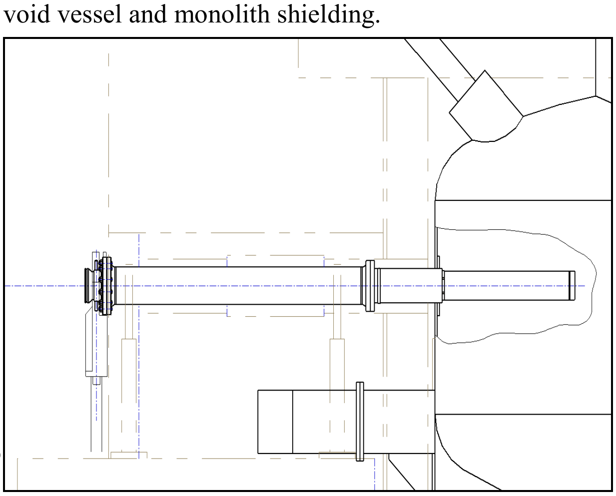

Figure 1: A schematic showing the Beam Entry Window assembly with regards to the target void vessel.

Access to the area is closely controlled due to the radiation levels from activated equipment and particle 'spray' from the up-stream muon target. The location of magnets, monitors and other equipment limited both physical and visual observation of the BEW assembly.

The accuracy of original drawings following unrecorded operational modifications was questionable and the lack of records of how the BEW assembly was installed, an element of the 'unknown' remained until the work itself began in earnest. Photographs and tape-measured dimensions were employed to confirm key information.

THE BEAM ENTRY WINDOW

The BEW and the spare used to replace it were produced in 1984, from stainless steel (Gr 304L) with the inner and outer beam windows made from Inconel (718). Table 1 details some of the key information about the BEW.

Table 1: Beam Entry Window Details

Property	Measurement
Mass	130 Kg
Centre of gravity	1502mm (from upstream flange seal face)
Downstream tube diameter	Ø168
Upstream flange diameter	Ø203
Centre line height above EPB floor	1905mm
Contact dose on upstream flange	42.000 µSv/hr
Contact dose on outside inconel window	7.800.000 µSv/hr

REMOTE TOOLING EQUIPMENT AND OPERATIONS

Upon analysis and investigation of the tooling objectives set out in the project specification and following initial conceptual design work, it was decided that three main assemblies could be designed to meet the performance and operational requirements. Initial efforts had been made to combine all the functionality necessary into one assembly, but it quickly became apparent that the level of complication would require greater resources and time than those available.

The tooling assemblies were all mounted on top of a movable trolley, which provided a flat and level surface from which to operate. The trolley also brought the working height for the BEW centre line to 1.3m instead of the 1.9m above the floor in the EPB. The reduction in working height thus simplified, quickened and made safer the tooling operations.

Mobile Tooling Assembly

The mobile tooling assembly (MTA) was designed to carry out the main remote tooling operations involving the removal of the nuts from the studs holding the BEW to the flange in the monolith wall. It also included tools to polish the sealing face on the wall mounted flange and to rectify foreseeable damage caused by seizing or shearing of nuts or studs. Figure 2 shows a 3D CAD model of the MTA produced using Solid Edge.

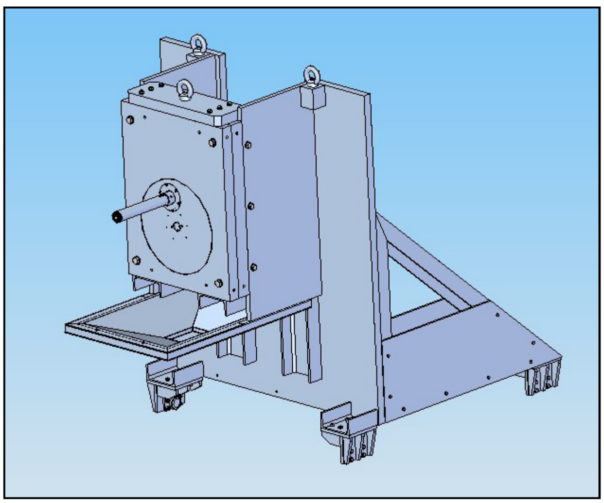

Figure 2: A 3D CAD model of the mobile tooling assembly.

It consisted of counterbalanced steel shielding blocks (190mm thick) which housed a rotatable tooling disc, through which could be operated a wide array of tools, such as an extension socket, drills, jigs and a polishing disc. Mounted to the front of the steel block were cameras that fed their signal back to a switcher box and monitor position behind the steel blocks for use by the operator. The assembly also had a capture tray below the area where operations would be carried out that could capture activated components such as the nuts and potential metal swarf, in an appropriate waste bag for easy and safe disposal.

The MTA was mounted on a further set of rails on top of the trolley that allowed for easy manual movement and initial alignment.

BEW Extraction Assembly

This assembly which became known as the ‘Trojan horse’ was designed to extract the BEW and place it in the shielded casket once it was unattached from the wall flange and then to refit the new BEW.

It did this by straddling the lower half of the casket and using a long probe arm to pick-up the BEW just past its centre of gravity. Then ‘C’ shaped jaws were used to clamp around the ‘throat’ of the exposed pipe. The top half of the assembly had 500mm of vertical adjustability driven from a leadscrew and with lateral adjustment achieved via large adjustment screws. The probe arm had a rounded (rugby ball shaped) end which reduced the chances of it jamming inside the bore of the BEW. The ‘Trojan horse’ too mounted on the rails on top of the trolley and connected into a drive system that allowed for the remote driving of the assembly axial with regards to the BEW. Figure 3 shows a 3D CAD model of the BEW extraction assembly mounted on its drive system.

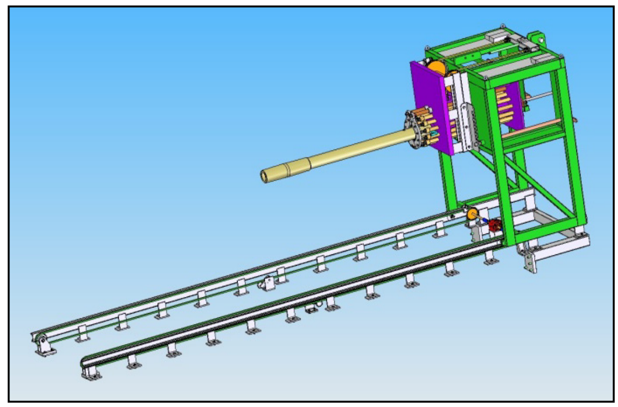

Figure 3: A 3D CAD model of the mobile tooling assembly.

Shield Housing Assembly

The shield housing assembly was a large fabricated steel ‘U’ shaped structure design to reduce the radiation of exposure to personnel working inside it to the γ and x-rays coming from the walls, ceiling and BEW flange. It was produced from 50mm steel plate and had guided slots at the front, into which could be put a selection of shielding plates depending on the application. It was also used to remove active equipment bolted into the ceiling of the EPB tunnel.

THE ‘MOCK-UP’

In order to provide a more realistic environment in which to test equipment, techniques and procedures as well to allow more accurate personnel dose rates to be calculated, a full-size replica of the lower downstream EPB was designed and constructed. Figure 4 is a photograph of the mock up during its construction on site.

Construction of this mock-up began a year before the operational shutdown, in which the BEW assembly was to be replaced, allowing for a robust testing and commissioning regime to be implemented. Following this, a four week period was allocated to offline trials. These trials were planned to be as close to carrying out the work in the EPB as possible. They were videoed and timed for further analysis into possible areas for improvement. It was imperative that the personnel who performed the trials were also those who worked on the real BEW assembly.

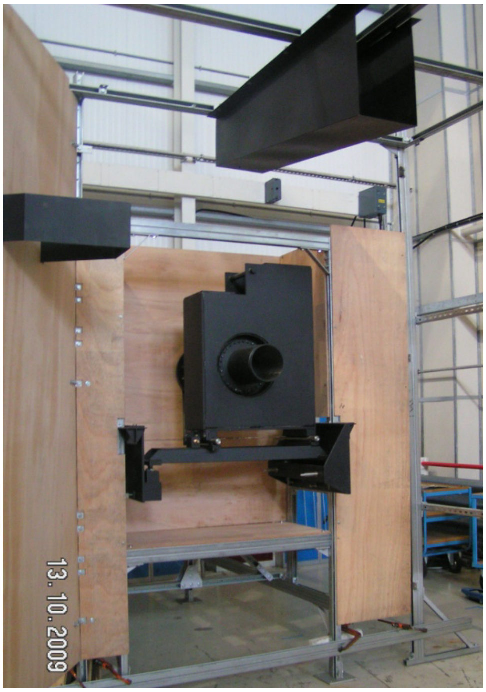

Figure 4: The 'mock-up' in construction clearly showing the representative equipment.

Situated under a separate crane from the main part of the building it enabled the testing and commissioning of all of the equipment to be used in the project without a major impact on the daily operation of the facility.

The mock-up was an invaluable resource in enabling the practice, timing and improvement of the planned work for the removal and refit of the BEW assembly and associated tasks, outside of a controlled radiation environment. Following the successful use and positive feedback received, the construction of a mock-up is a technique that will exploited again in similar future projects for the Accelerator Group of the ISIS Design Division.

EXPECTED DOSE RATES & SHIELDING

Radiation surveys carried out by the on-site health physics team provided a good indication of the expected levels for the up-stream flange of the BEW assembly but the inability to directly access the key areas of BEW meant we relied on estimations and analogy for the expected dose levels on the window itself and thus the level of required shielding. The casket designed for the transport and storage of the old BEW was a 10T 'dog-bone' shaped steel vessel with two large 800mm diameter ends providing over 240mm of shielding in every direction to both the flange and window ends of BEW.

THE USE OF CAMERAS

It was essential to have a clear view of all the operations to be carried out and any potential problems that might occur, in order to minimise the radiation exposure of personnel. Previous experience with using lead glass or other similar products highlighted issues such as the extra thickness required to maintain the same level of shielding as the surrounding steel and the lack of flexibility a fixed-position viewing window offers. Utilising this knowledge and with the opportunity for experimentation offered by the mock-up, the decision was taken to use cameras and monitors to provide the visuals required for successful completion of the work.

With the lifespan of the electronic equipment in the expected radiation environment an unknown and the short duration of their use, the methodology employed was to use low-cost 'off-the-shelf' cameras that could be easily, quickly and cheaply replaced should a failure occur. As it turned out, the cameras performed very well in the radiation levels, without a single failure. The only problem encountered was when a cable was damaged by a piece of equipment.

The low cost of the cameras meant that several could be installed at once giving the operator the chance to choose between various viewing angles. Another advantage to using cameras was that the signal could be spit and shared with observers external to the working area and could be recorded for reference and analysis.

The cameras employed were low-light *202BW bullet cameras* supplied by *Henrys Electronics Ltd* [1]. In comparison to using a lead glass window, the cameras offered greater flexibility, more options in terms of people able to see the work being carried out (both at the time and for future reference) and there was also significant cost savings and reductions in delivery times.

SUMMARY AND CONCLUSIONS

The Beam Entry Window for ISIS's target station 1 was successfully extracted and replaced by the use of remote tooling equipment that had been rigorously trialled and tested prior to use. Despite the very high levels of radiation encountered (7.8 Sv/hr on contact with the beam window) doses to personnel were kept to an acceptable level. The use of low cost cameras instead of lead glass window produced cost, functionality and flexibility improvements.

REFERENCES

[1] Henrys Electronics ltd., http://www.henrys.co.uk/