RADIATION SAFETY ISSUES ASSOCIATED WITH OPERATING AND MAINTAINING INTENSE BEAM ACCELERATORS

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Abstract

One of the issues that face all high-energy beam accelerators is that of active component replacement. This can arise through failure of components, the need to carry out maintenance, or upgrading of systems to increase output efficiency. During the year 2001/2 RAL undertook a major upgrade on the most active area of the ISIS accelerator ring, "Straight 1". This section of the ISIS accelerator contains a collector system for containing lost beam during injection and some beam extraction components. The case for carrying out this work was driven by several aspects of machine operation: - Component failure, lack of purpose built shielding, high downstream activity levels, original design restrictions causing beam clipping and the need for re-designing several components to meet the needs of future intensity upgrades

1 INTRODUCTION

ISIS is the most intense pulsed neutron source for condensed matter materials research in the world. Operational from December 1984, the fast cycling (50 Hz) proton synchrotron is now running close to it's design intensity of 200 µA and routinely delivers mean proton currents in excess of 180 µA to a tungsten target. Calculations during the machine design phase indicated that operational beam loss would need to be carefully minimised on a machine wide basis if the required regime of "hands-on" maintenance was to be supported. A further requirement was that total beam loss (under fault conditions) should result in a beam trip within one machine pulse, if catastrophic damage to machine components was to be prevented. During the design phase of ISIS a global beam loss monitoring system, using long argon filled ionization chambers of the Brookhaven type was considered to be most suitable. This system of beam loss monitoring (BLM's) is composed of three subsystems divided by the time dependant nature of beam loss. 70 MeV H- linac and transport line, the 800 MeV proton synchrotron, and the 800 MeV proton transport line. The B.L.M. system is complemented by a toroidal beam monitoring system allowing the actual beam current to be measured from the source, through the linac, at entry to the ring, after bunching, during acceleration and final beam to target. Computer monitoring of this system allows real time efficiency monitoring and data collection for our management information system. For the crew, it also provides trend warnings to be given for several cycles or immediate beam trips under poor machine efficiency conditions. The crew have access to all of the detector signals in both systems thus providing a good source of diagnostic information for setting up, running and during fault conditions

2 REASONS FOR STRAIGHT 1 REPLACEMENT

Despite operating the machine as efficiently as possible and minimizing beam loss, component irradiation still occurs. After some 17 years of machine operation a business case was put forward to decommission and replace "straight1", (see figure 1) the hottest (in radiological terms) section of the synchrotron ring. The business case outlined the following categories and items as justification for the work to be carried out

2.1 DAMAGED COMPONENTS

Extract septum cooling circuits and bus bar failures, failed vacuum ion pumps. high prompt beam loss downstream of the collector system giving probable cause for observed beam loss on the R.F. screen of dipole 2.

2.2 PERSONNEL SAFETY.

A lack of purpose built shielding severely restricted general access making modifications and replacement of existing failed components hazardous to personnel.

2.3 FUTURE UPGRADES

The extract septum magnet was not compatible with a proposed 300µA beam upgrade, due to beam aperture restrictions. And a new collector design for localising capture of lost beam had been designed. The aim of which was to reduce irradiation in other areas and components of the synchrotron by improving loss containment with the new straight 1.

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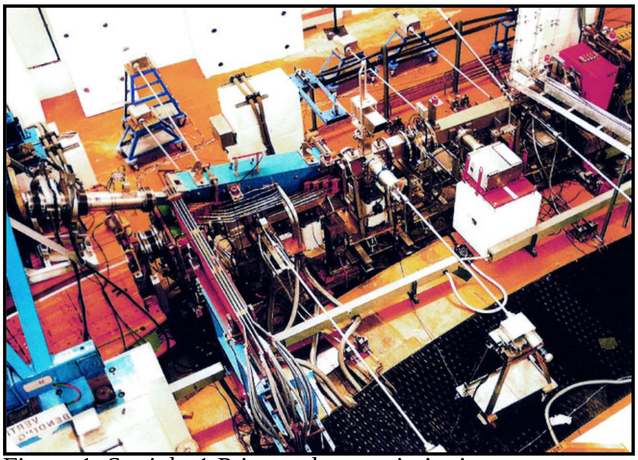

Figure 1, Straight 1 Prior to decommissioning

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4.0 LIMITING EXPOSURE

The straight 1 section of the ISIS synchrotron contains a collector system which was designed to capture non-trapped beam during the beam bunching process, and localise the subsequent loss. By capturing and absorbing this lost beam the collectors protect the remainder of the ring from damage and in so doing takes the brunt of beam irradiation. It was therefore vital to minimise personnel exposure during de-commissioning.

As always, when working in active areas it is essential to understand the risks involved. In the case of straight 1 this was accomplished by a comprehensive risk assessment study, which lead on to the planning and implementation phases. As would be expected, the prime risk identified was that of personnel radiation dose limits during the de-commissioning and removal of the active machine components. For the project planning team this issue became the subject of many hours work for those involved.

5.0 PLANNING

In order to reduce personnel exposure one area of the planning process focussed on getting to know every component and connection involved. And a major concern identified in this process was a lack of knowledge. No one had carried significant amounts of work in this section of the machine for the last 17 years. Archived drawings when studied, did not always match up to what had been installed in the machine. In such cases further studies and surveys had to be conducted using time limiting techniques such as digital photography.

The conducted radiation survey revealed high levels of activity in all of the components concerned and lead to a three month cooling down process prior to any "hands on" work commencing. Even after this period significant dose levels would be present in the components and from the upstream "straight 0" section of the ring.

The project team identified one approach to minimising the installation time exposure would be by Pre-building the new straight 1 in a dedicated clean area (see figure 2). This allowed for the build, alignment and testing of the modules and components thus eliminating any problems that may have otherwise been discovered only at the time of installation in the ring.

Figure 2 Pre-build area

Looking back this process worked well, a six month build and test of the new straight 1, reduced the actual installation time to two weeks. The team responsible for carrying out the hands on work were selected from practical, knowledgeable and experienced personnel. This team was divided into dedicated task responsibilities, in order to share and reduce exposure to radiation. Each person was then familiarised with their task and where possible practice runs were conducted in the pre-build area. Our Health Physics team provided detailed protocols and work programs highlighting the necessary controls and procedures to be adhered to. They also took responsibility for the removal and safe disposal/storage of the active items removed.

Prior to the commencement of hands on work within the ring the total collective dose rate for the tasks involved was given at an estimated 5000 µSv. With personnel often working in fields of up to 1000 µSv/h.

6.0 IMPLEMENTATION

After the 3 month cooling down period during which the pre-build had been conducted. Health Physics surveyed the area again and installed concrete blocks, finger and lead shielding where appropriate. The de-commissioning team embarked on the program of component removal. At this stage the opportunity was taken to conduct a more accurate mechanical survey for the placement of the new modules and to look for any new problems that had not been identified during the planning stages.

With the old components removed and safely stored, work on the installation of the new components commenced.

Radiation levels in the work area had now been greatly reduced. New plinths were installed to take the modules of the new components. The new modules were then fitted onto their bases and connected up to the ring and electrical and mechanical services.

Once the major components had been connected new concrete shielding blocks were fitted into place. (figure 3) These now provide good protection from radiation for personnel working in this area of the machine. Vacuum pumps and where possible collector control systems are now mounted outside this shielding, allowing future component failures to be managed easily within the Radiation Regulations at ISIS. The entire project was carried out well within radiation dose limits. The estimated total collective dose of 5000 µSv given in the planning stage, was recorded as 3500 µSv at close of project. The highest individual recorded dose was 500 µSv. In summary by our Health Physicist, it was stated "The success of the decommissioning operation owes much to the planning and skill in execution of the Radiation safety Protocol, by all members of the team".

7.0 SUMMARY

In a high energy accelerator like ISIS it is possible to run the machine within levels of beam loss required for a hands on maintenance regime. Doing so requires good beam monitoring systems providing both warnings and immediate trips when the beam becomes unstable or off orbit.

Control Room staff must be trained and knowledgeable in machine operational requirements, diligent in observation, and empowered to take action to minimize beam loss when required to do so.

When faced with a major mechanical change to high energy accelerator machines in radioactive areas, it takes many hours of planning involving several different departments working together. Preparation is key to conducting such an exercise within the limits of Radiation Regulations. Team players have to be experienced, knowledgeable, motivated and committed to team planning and implementation.

Figure 3 View of the new straight 1