OPERATIONAL CONSEQUENCES OF INDUCED ACTIVITY ON THE ISIS TARGET STATION

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1. INTRODUCTION.

ISIS has now been operating for several years at progressively increasing proton currents. This report examines the operational difficulties encountered as a consequence of the levels of induced activity in the components of several systems. In particular difficulties with maintenance of the water cooling systems, remote handling of the target, reflector and moderator assembly and discharge of radioactive gases to the environment will be discussed.

The hazard from induced activity is radiation dose to the staff working on the active systems. At ISIS the policy is to minimise both the radiation doses to individuals and the collective dose. The limit set for an individual is 5 mSv/y. The typical annual dose is less than 1 mSv. This has been achieved mainly as a result of the development of detailed working procedures.

The consequences of the experience at ISIS (160 kW of beam power) for the high intensity sources (beam powers up to 5 MW) discussed at this meeting are potentially serious and present a challenging design problem.

For reference figure 1 shows a schematic layout of the ISIS target station.

2. MAINTENANCE OF THE WATER COOLING SYSTEMS.

The plant which provides cooling for the target, moderators and reflector is both complex and compact. The pipework, pumps, filters and ion exchange columns, illustrated in Figure 2., are located in a shielded enclosure called the Services Area which has a volume of 1200 m^3. Regular maintenance is required to service pumps, renew ion exchange columns and replace components such as pumps and instrumentation sensors.

The dose rate around the pipework, even when empty, is typically 200 - 500 μSv/h. This is due to contamination of the inside of the pipes by Be^7 which is produced by spallation of Oxygen. All the active water circuits incorporate an ion exchange column which does trap a proportion of the Be^7. However. only a fraction of the total flow, typically 10%, passes through the columns with the result that the Be^7 is deposited on the pipe surfaces.

Meticulous planning of maintenance work is required to achieve acceptably low radiation doses to the staff involved. It is vital that the time spent in the areas where the dose rate is relatively high is minimised. This is particularly important for access into the more congested areas in the centre of the plant. Accurate documentation of the plant has proved crucial. A useful aid to this at ISIS is a comprehensive and detailed set of annotated photographs of the plant. This is illustrated in figures 3 and 4 which show a photograph of part of the pipework together with an overlay giving component and pipe numbers. Using these the individual can become very familiar with the task and the layout of the equipment before entry to the area. An extension of this facility using video film is being considered.

Early in 1992 all the rubber diaphragms in 150 control valves were examined and the damaged ones replaced. This involved 90 man days of work and the collective dose was 0.7 mSv.

The dose rate on the pipework will scale with the proton beam current for a water cooled system similar to the ISIS assembly. Even if a design can be developed where the proton beam does not pass through the water the likelihood is that the water will be in a substantial flux of high energy neutrons close to the target. In fact the activity of the reflector coolant at ISIS is only half that of the main target cooling circuit. For a 1 MW source dose rates around the empty pipework could well be as high as 1 - 4 mSv/h unless some method can be found to prevent the Be^7 from depositing on the pipes. The design of the high power cooling systems must take this into account so that the need for access is minimised. For a 5 MW source it may be necessary to consider limited remote handling.

3. REMOTE HANDLING.

Since start-up in 1986 there have been 12 target changes, three moderator replacements and other detailed work carried out in the remote handling cell. While these tasks are regarded as relatively routine some observations can be made which may be useful to those designing new sources.

Good engineering practice often requires a known torque to be applied when tightening bolts and nuts. This is particularly important when making sealed joints. Many devices are commercially available for this and several have been used in the remote handling work at ISIS. However, nearly all these require the friction between the threads to be definable and this generally means lubrication. The dose rate around the target assembly is high and the use of conventional lubricants is problematic. At ISIS the decision was taken to use no lubricants. Many of the nuts and bolts are now very stiff to turn. Visually there is little evidence for corrosion on the stainless steel and the reason for the stiffness is not clear. However, this effect has been progressive as the total proton dose on the target assembly has increased and it may well be necessary to replace some of the bolts and nuts. A consequence is that it is not possible to use conventional equipment to apply known torques which has had the result of much more difficulty than expected in achieving leak tight joints.

It can reasonably be expected that this effect will be much more severe for high power sources and this should be taken into account when designing the remote handling for the components.

The approach at ISIS in the design for remote maintenance of the target moderator and reflector assembly was to replace individual components. This requires water, cryogenic and vacuum joints to be made remotely. In general the flanged joints have, in practice, presented no great difficulty except the problem of applying the correct torque discussed above. However, the joints on flexible line have not been as reliable as had been expected. A bayonet connector illustrated in figure 4 is used. This works very well in laboratory conditions. Handling it remotely is also easy. However, occasional leaks have occurred and more development of this component is required. This illustrates the difficulty in design of remote handling equipment. Rigorous testing and development is essential and the design must be sufficiently flexible to allow changes in the installed equipment after operation as some problems will only appear on the real assembly.

4. RADIOACTIVE GAS RELEASES.

Difficulties with Tritium releases to the atmosphere from the ISIS target station have caused serious disruption to the user programme in 1992 and 1993. Between 30 and 40 days of scheduled operation have been lost.

The regulatory constraints are becoming ever more stringent. RAL has a Certificate of Authorisation to release no more than 30 GBq per month of Tritium in any form. This limit is based on pollution considerations as even at the maximum level there is no conceivable safety hazard. This is a very low limit compared to that allowed at other laboratories but given the very much higher Tritium concentrations expected at the high power sources being planned they may well face similar operational difficulties to ISIS.

The dominant production mechanism for Tritium in the cooling circuits is spallation of Oxygen. The concentration in the target cooling water is currently 8 TBq m^{-3} giving a total inventory of 6 TBq. This represents a production rate of 0.15 Tritium nuclei per incident proton.

On line measurement of Tritium in an active air ventilation stream is very difficult and to date no commercial solution had been identified.. The low energy tail of the β spectrum (i.e. less than the end point energy of the Tritium β decay) from the other active radionuclides (O,N) gives, typically, 100 times the count rate of Tritium. At ISIS a fraction of the ventilation stream is passed through a water bubbler to absorb the Tritiated water vapour for later off line measurement. This then places extreme demands of leak detection in the water systems for giving prompt warning of a problem. For ISIS this requires a knowledge of the water inventory to better than 0.5% which is at the limit of the sensitivity of the instrumentation. Small leaks have resulted in releases of Tritium which are close to the monthly discharge limit. This has required the facility to be shut down for investigation and repair.

There are systems for collecting both Tritium gas and Tritiated water vapour. However, such equipment is very expensive on the scale required to deal with the active air ventilation systems at ISIS (flow rate about 7 m^3 s^{-1}).

It will be essential for future designs to anticipate the likely downward pressure on discharge limits.

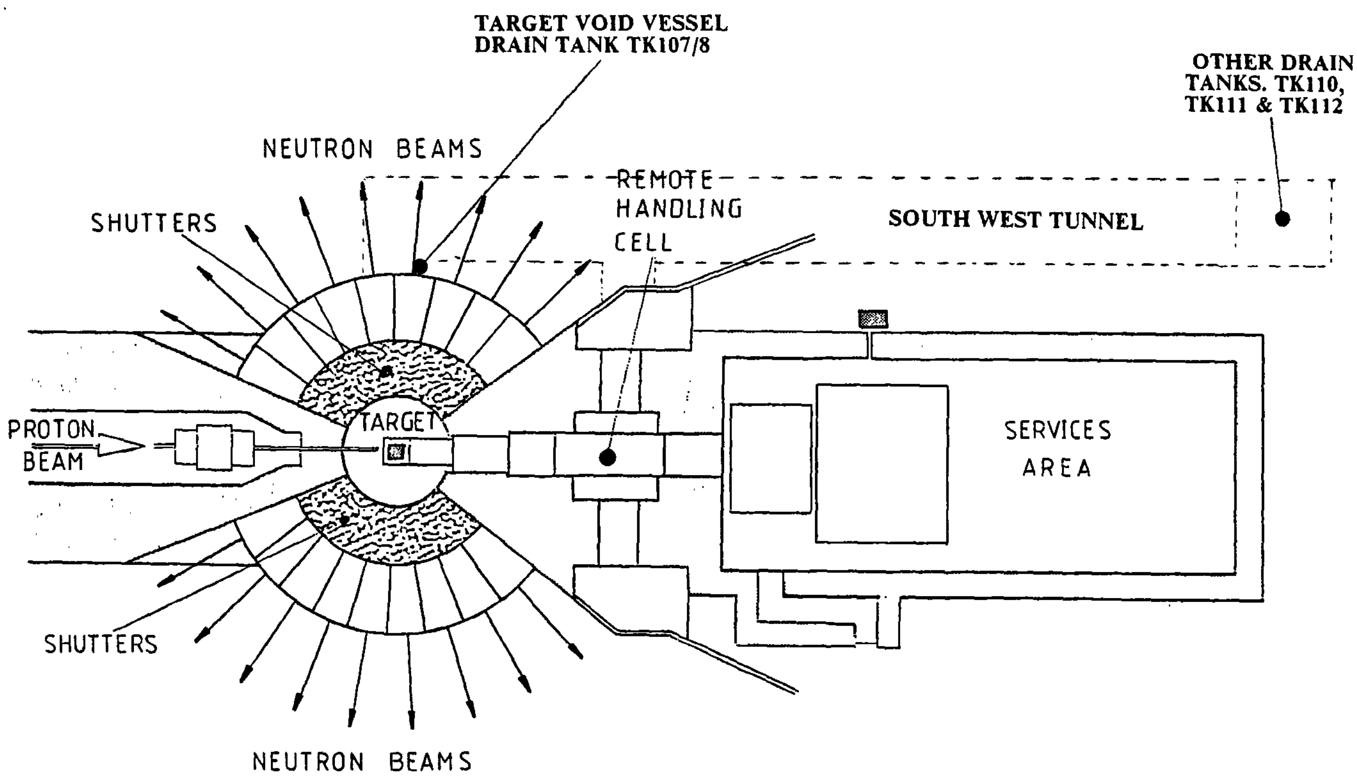

Figure 1. Schematic Layout of the ISIS Target Station

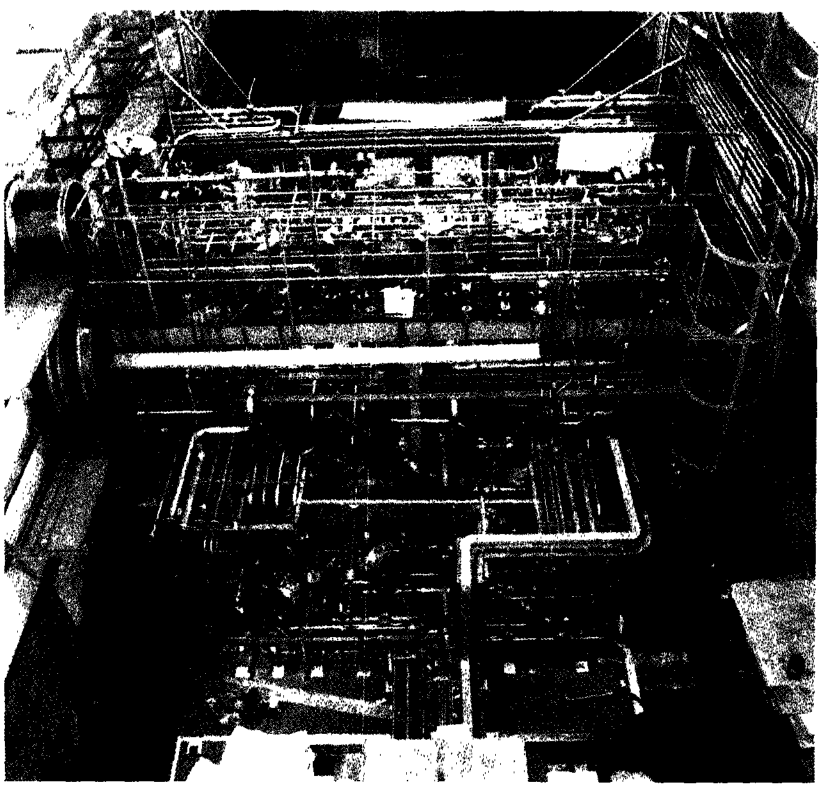

Figure 2. A View of the Water Cooling Plant

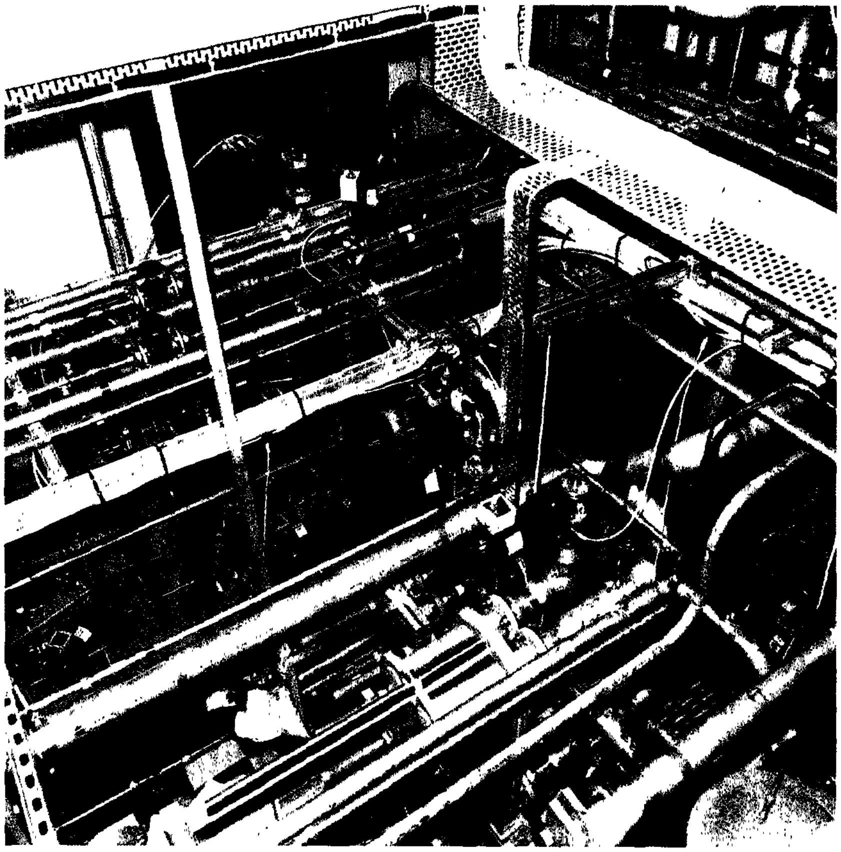

Figure 3. Detail of one Area of the Water Cooling Plant

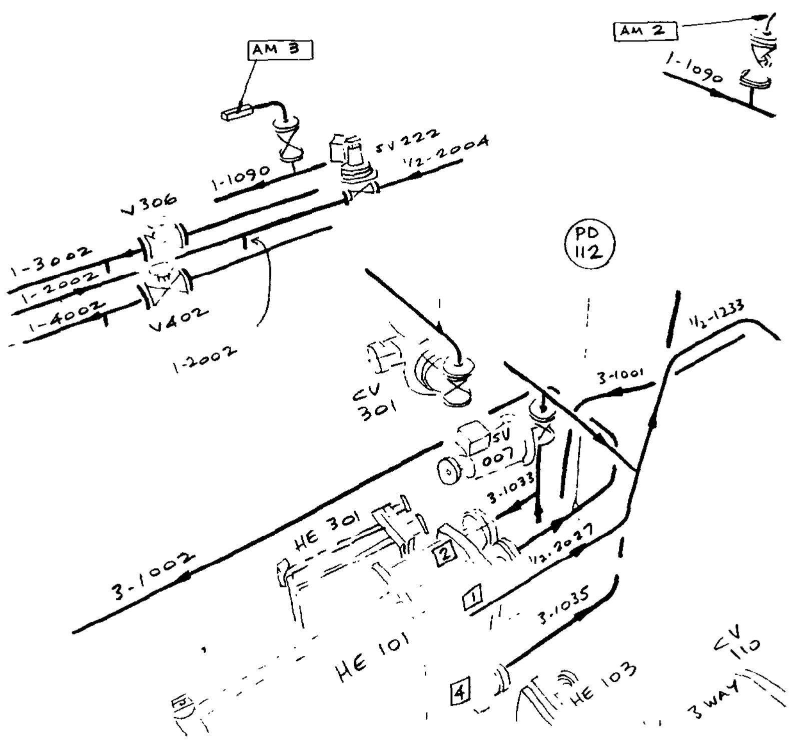

Figure 4. Overlay of Plant Photograph Defining Individual Components

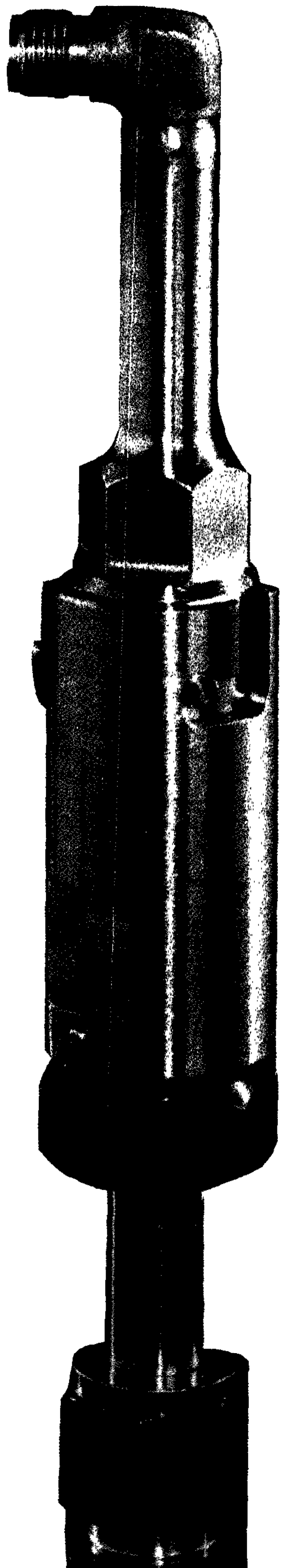

Figure 5. A Typical Bayonet Coupling for use in the Remote Handling Cell