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Intervention to Repair a Tritiated JET Neutral Beam Injector

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1. INTRODUCTION

At the end of May 1997, tritium neutral beams were run for the first time in the JET Octant 8 Neutral Injector Box (NIB8). On 4 June 1997 there were indications of a water leak in the NIB8. The leak was associated with operation of the Fast Shutter [1] system positioned between the Injector and the Rotary Valve. The presence of water was detected at a very early stage by routine operating procedures using the NIB Mass Spectrometer and Penning gauge instrumentation. Operations on NIB8 were suspended whilst the pressure was still below 5.10^{-7}mb with the Cryopumps cold [2]. The pressure was still two orders of magnitude below the interlock trip level from the Fast Beam Interlock system which would have automatically inhibited pulsing. Some $3cm^3$ of water was estimated to have leaked into the NIB.

In order to effect a manned intervention with minimal impact on the JET operational programme several critical issues had to be addressed in parallel:-

- Rate of tritium removal from NIB8 using the Exhaust Detritiation System (EDS).
- Health Physics procedures to be agreed and the appropriate controls established.
- NIB access requirements and the removal of the Octant 8 Central Support Column (CSC).
- The design and procurement of an access facility together with the appropriate services.

2. HEALTH PHYSICS ISSUES

The foremost method of controlling tritium exposure at JET has been the use of metal sealed UHV technology to provide high integrity containment for all gas handling processes. However, there exists greater potential for worker exposure to tritium during breaches of containment or repair work. In this particular case the only feasible method of repair involved manual intervention into an area with high levels of tritium. This required a controlled approach in order to limit worker doses and minimise aerial discharges of tritium.

At this time a total of 11.4g of tritium had been supplied to the Octant 8 Neutral Injectors and it was estimated that up to 0.3g (100TBq) of tritium might be held up in the ion dumps, neutralisers and beam scrapers, having been driven in by incident T^0 or T^+ beams [3]. For the purposes of controlling tritium uptake during the intervention, a dose restraint figure was established at 2mSv/person. This was set to be compatible with the previous experience of the average dose accrued by JET workers undertaking specialist tasks in radiation areas. On this basis, the maximum tolerable exposure would be 1 DAC (HTO) for the 80 hours estimated to complete the repairs.

Given the potential for large tritium uptakes, there was a clear need to extract as much of the tritium as possible and then ventilate the NIB. However, direct pumping and discharge to stack would not be possible, since a target of 40 GBq/day aerial discharge had been agreed with the regulators. Discharge would therefore be required via the EDS where a detritiation factor of $> 10^3$ be achieved [4].

With the dose constraint on exposure of 1 DAC averaged over 80 hours and the limit on discharge to the atmosphere, the only workable option was to use personal protection in the form of air fed pressurised suits. Protection factors for these suits in excess of 1000 have been reported. Assuming a protection factor of 100 over an 8 hour shift implied a mean concentration of 100 DAC would be an acceptable upper limit at which entry to the NIB could be made.

3. NIB ACCESS CABIN

The preliminary radiological assessment suggested that access to the NIB would require the use of pressurised suits. This requirement naturally led to the need for an access cabin to be positioned on the NIB after removal of the CSC. Careful consideration was given to the safety issues regarding entry and exit to the NIB from the access cabin and a full safety assessment carried out. Design of the cabin was based on the experience gained in suited operations with beryllium on JET in-vessel operations. The cabin was assembled from modular fibre-glass panels with a metal floor and sub-frame secured to the NIB. Interior surfaces of the cabin were spray coated with a thin peelable coating (0.1mm) of PVA formulated solution (Gramos 6121) in order to assist with subsequent decontamination. The cabin served as a change area/ access control point for suited work. Audio and visual communications allowed controlled supervision at all times. Entry and exit from the lower levels of the NIB for suited personnel was arranged using a custom built man access hoist which could be set up at different locations (Fig 1).

Fig 1 Suited personnel preparing the hoist in the NIB access cabin

A mock-up of the NIB was built to prove that the access proposals were satisfactory. An additional requirement of the safety assessment was that all personnel were trained on the use of the hoist and the emergency procedures prior to being allowed access to the NIB. This included Rescue Service personnel. The complete system was delivered to JET twelve days after completion of the design layouts.

4. DECONTAMINATION PROCEDURES

Following a one week period of clean up operations in order to remove tritium from the walls, the Torus was brought down to room temperature and filled with dry nitrogen in order to immobilise the remaining tritium and maintain its conditioning. In parallel NIB8 was subjected to moist air soaks and pump downs via the EDS to remove tritium from the internal surfaces. In 18 soak/pump cycles, taking five days to complete, the NIB tritium in air concentration dropped from 33 GBq m^3 to 3 GBq m^{-3}. At this concentration level it was thought possible to remove the tritiated CSC from NIB8. This was necessary in order to gain access to the likely source of the water leak in the Fast Shutter system. The CSC (Fig 2), which carries most of the beamline components, was highly tritiated and required placement in an enclosure (NIB4) where the atmosphere could be intermittently pumped via the EDS. With the major source of tritium evolution removed from NIB8 the tritium concentration levels quickly dropped below 80 MBq m^{-3} (100 DAC) airborne and 7000 Bq cm^{-2} surface inside the NIB. At this level the air fed pressurised suits provided a reduction in personnel dose levels which were one order of magnitude below the JET routine exposure limit of 1 DAC. However, later welding operations were thought likely to raise concentrations further. One of the first tasks following inspection of the repair area was to install high capacity air heaters in order to dry the coolant pipe systems. The background NIB temperature was raised to 50°C and the leaking components to ~ 150°C for some 36 hours. This had the immediate effect of further increasing gross airborne levels until the system cooled to ambient. Measurements showed that NIB airborne levels had fallen to a few DAC with the EDS throughput at 250 m^3h^{-1}.

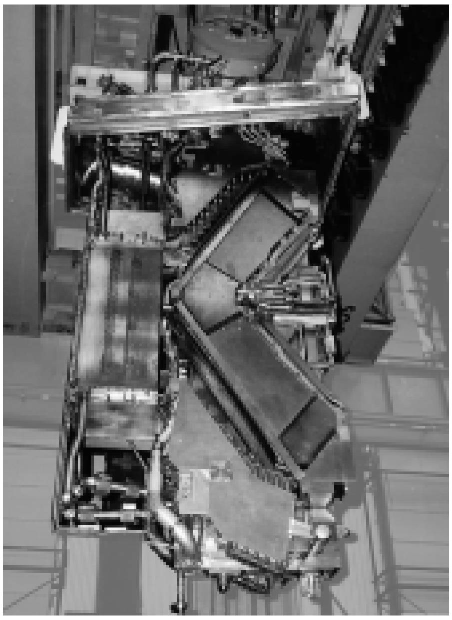

Fig 2 The CSC showing beamline components and integral NIB lid

5. WELDING REQUIREMENTS

The assembly and welding of pipework necessary to replace the failed flexible Fast Shutter water hoses presented new challenges with regard to both design and performance of the welding operations. The main constraints identified were those of the limited access, reduced options available concerning weld inspection, the requirement to carry out the work in full protective clothing and the necessity to complete all in-situ welds with minimal purge gas.

Welding operations were divided between two areas, the assembly and welding of the prefabricated pipework and the final positional welding within the NIB, The prefabricated pipework required twenty-two butt-welded joints using conventional manual TIG welding procedures followed by 100% radiographic examination. Final positional welding to the Fast Shutter/Box Scraper system required, due to access restrictions, the use of automatic Orbital TIG welding tools. In order to negate the requirement for radiography and limit the purge gas requirements a special weld joint was designed. The joint featured a specially designed insert ring (Fig 3)which enabled the orbital welding operations to be performed without the requirements for filler material and eliminated the need for a high quality gas purge. A further constraint was the inability to radiograph the in-situ welds as this would have resulted in tritium contamination of the X-ray source if exposed to the NIB atmosphere.

A spare Fast Shutter system and simulated Box Scraper pipework were set up in a full scale mock-up of the internal section of the NIB. The facility enabled the resolution of issues such as optimal joint position; training of fully suited welders; establishment of welding procedure specifications and production of detailed time schedules for each operation via full welding rehearsals.

Production Proof Samples (PPS's) were made in the NIB prior to each in-situ welding operation (and with the same equipment) and each PPS subjected to both visual inspection and examination via sectioned micrograph (Fig 4). Procedures were developed for orbital welding of pipe diameters 17, 26 and 60mm with appropriate inserts. On completion of all welding operations the Fast shutter/Box Scraper systems were subjected to a pressure test of 9 bar and a global helium leak test to < $1x10^{-9} mb\ell s^{-1}$.

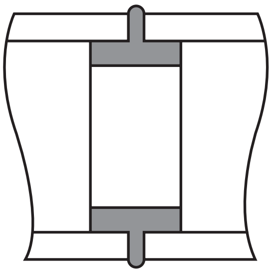

Fig 3 Detail of insert ring for orbital welding operations

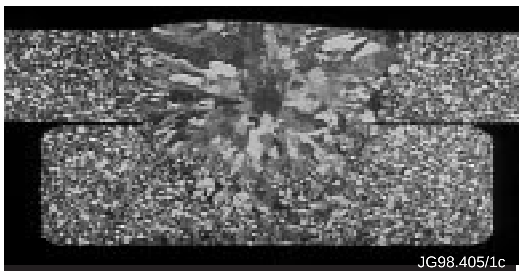

Fig 4 Macrograph section of completed orbital weld with insert ring

6. CONCLUSIONS

- Procedures for containment breaches involving pump/moist air vent cycles and general ventilation have been found to be effective.
- Using the EDS for general ventilation at $250m^3h^{-1}$ to ventilate NIB8 during the intervention proved successful in keeping tritium airborne concentration levels down to << 80MBq m^{-3} (<< 100 DAC).

- The isolation Rotary Valve at NIB8 provided invaluable in maintaining Torus conditioning with dry nitrogen.
- The total tritium discharged during the seven week intervention period was 300 GBq (HT) and 360 GBq (HTO), leading to negligible off-site impact. This level was only 30% of the JET authorisation over the period.
- Liquid evolution from the EDS dryers amounted to 29 TBq.
- The experience of tritiated intervention will be useful for planning future maintenance operations at JET.
- Sixty-eight days after the discovery of the leak, power recommissioning commenced on both injector systems.
- In total, 217 man hours of suited work was carried out. During the period (involving transfer of CSC's establishing access, leak detection, cutting, welding, leak detection and component replacement) a total of 65 persons were involved in the intervention. The highest individual dose was 70μSv, the collective dose was 500μSv [5].

7. REFERENCES

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