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Operation, Maintenance and Decontamination of the JET Torus Access Facilities

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INTRODUCTION

Since the introduction of 20 grams of tritium in the JET machine in 1997 the Torus Access Facilities have been used extensively for the removal of highly tritiated components from the torus during engineering shutdown periods. Such components are also neutron activated and beryllium contaminated.

Operations within these facilities are mostly of a hybrid nature encompassing both robotic and manual activities in air feed full-pressurised suits. Access to such facilities is through airlocks that provide containment or double lidded door systems that maintain the containment boundary.

Remote and manned access depend on achieving a delicate balance in the ventilation system such that a sufficient depression is held in-vessel whilst a number of access points are open. In addition both the breached Torus and the Torus Access Facilities require an increase in ventilation of one order of magnitude when compared to that provided by the Active Gas Handling Plant.

This is provided by the Controller/Dresser Unit (CDU) Ventilation system that discharges through a monitored stack. Low doses to operators and very small environmental discharges demonstrate that the ventilation systems achieve tritium containment

Airborne tritium levels of up to 150MBq/m^3 and surface levels exceeding 2MBq/cm^2 have been experienced during the Remote Tile Exchange and the Inboard Pellet Injector shutdowns. The use of sacrificial layers, vacuum cleaning, strippable and tie-down coatings within the Access Facilities are successfully used to control both tritium and beryllium contamination.

Strict work and posting procedures have lead to shorter clean up times and to a reduction in Respiratory Protective Equipment (RPE) or declassification of some areas. The practicalities of tritium absorption affecting the radiological status of equipment and the implications this holds for future tritium operations are described in addition to the design and experiences gained in the operation of such facilities.

1. GAINING ACCESS TO THE TORUS

The tritium hazard is present in-vessel as HT, HTO and tritiated dust from the plasma erosion process. Following operations and before any breach of vessel containment, a period of controlled venting and pumping of the Torus takes place involving dry nitrogen and then moist air.

This process reduces the free tritium evolution in the Torus via the Exhaust Detritiation System (EDS) in the Active Gas Handling System (AGHS). Such breaches will only occur when either local or remote ion chamber readings indicate levels less than 3 GBq/m^3.

Access to the inside of the Torus is through two of eight Main Horizontal Ports (MHPs) at Octants 1 and 5. There are three facilities that allow access to the Torus during shutdown campaigns. These are the TAC (Torus Access Cabin), the Tile Carrier Transfer Facility (TCTF) and the Boom Enclosure (See figure 1).

2. ACCESS FACILITIES

The TAC consists of a three-storey construction that supports prolonged manned access to the vessel through Octant 1 MHP. The integral features include its own breathing air plant to support pressurised suit operations and a showering facility when exiting. With a project philosophy of minimising operator dose and maximising remote handling techniques the future use of the TAC is unlikely.

The TCTF was purposely built for the Remote Tile Exchange (RTE) in 1998 for the remote removal and storage of activated, tritiated and beryllium contaminated components.[1] It is capable of supporting both remote operations and limited manned access to the Torus through Octant 1 MHP. (See Figure 2).

A short articulated Boom and end effector allows the remote transfer of all components into and out of the Torus. A posting facility provides a tritium-controlled interface that enables the transfer of all contaminated items into and out of the TCTF.

The Boom Enclosure houses the electrically actuated long articulated Boom (10m, 18 DOF) and force reflecting master-slave configuration manipulator (Mascot), This combination carries out all remote operations within the Torus, with access from Octant 5 MHP.

All three facilities have the ability to dock enclosures or modified freight containers onto them while attached and sealed to the Torus. These may be used to transfer particularly heavy and bulky components or may provide a unique support (i.e. storage or work shop facilities).

During such docking activities tritium and beryllium containment is maintained by the use of tailored flexible membranes or by a double lidded door system[2] (See Figure 3). The facility door mates with the container door and effects a seal around their periphery. When detaching, a clean break is achieved with both controlled areas maintaining their containment boundaries.

Such interchangeable containers can have a segregated storage area that is directly ventilated by EDS. This allows any off-gasing tritium to be removed and thus reduces airborne environmental discharges.

Access to both the TCTF and Boom Enclosure is supported by the Controller Dresser Units (CDUs) (See figure 4). These act as man access modules and provide change facilities, decontamination and controlled area and worker monitoring for up to four operators. An integral air lock shower is used to assist decontamination of operators' suits when exiting from any of the docked facilities.

Respiratory Protective Equipment (RPE) for facility work normally consists of airline fed full-pressurised suits. Additional disposable over-suits are worn to minimise contamination. These are removed prior to exiting and disposed of as soft waste. The CDU also provides alarms for ventilation depression, oxygen and carbon dioxide levels and tritium concentrations within the Access Facilities.

3. VENTILATION SYSTEMS

The primary objective of the ventilation system is to limit the spread of contamination during shutdowns where access is required to the active areas. The CDU ventilation system[3] is served by a common power supply, fed from an automatic changeover contactor. Should the normal power supply fail, an alternative power supply is automatically engaged. The system comprises duplicate HEPA filters, duplicate variable speed centrifugal fans which have their outlets combined in a common elevated high velocity discharge stack and a fan control panel.

The duplicate HEPA filters are fitted with manual inlet and outlet dampers. The pressure drop across each filter can be measured with a manometer to indicate its condition. On-line filter changing is achievable by the selection and operation of duty and standby sets. The duplicate fans are fitted with manual inlet dampers and automatically driven ‘open’, spring ‘shut’ outlet dampers.

The common discharge stack is of ultra low leak construction and monitors the volume flow rate and concentrations of tritium in the discharge air. Under normal circumstances the daily management limit for the site stacks is 40GBq.

The system draws air into the vessel Access Facilities from the torus hall via attached CDU’s or interchangeable containers (See Figure 5). The design volume flow rate is 10 air changes per hour through the enclosures. All openings are sized for a minimum containment velocity of 1m/s. Each facility extract is located adjacent to the Torus entry port.

Depression sensors located within each enclosure regulate the volume of by-pass air, this enables typical depressions of 30Pa to be maintained within the enclosures. Additional breaches of the vessel adversely affect the depression levels and will cause the depression controllers to reduce the bypass volume and hence increase that being drawn out of the enclosures.

During shutdown periods, ventilation of the Torus Hall is generally configured for a once through mode of ventilation. This provides 3 volume air changes per hour for the 33,000m^3 Torus Hall. For initial breaches of the Torus or other containment issues the Torus Hall biological shield doors are partially closed such that the velocity across the opening is in the order of 4m/s.

Ventilation of the torus under shutdown conditions is provided by AGHS[4] (Active Gas Handling System) with nominally one air change per hour. In contract to the CDU ventilation, the Extract Detritiation system (EDS) in AGHS retrieves the tritium rather than discharging it to stack.

In the event of an emergency incident in-vessel, an operator may need to use his pressurise suit emergency breather when either receiving or administering first aid. This would necessitate these individuals breathing the tritium atmosphere through particulate filters.

Under such emergency circumstances a series of valves can be actuated causing the Torus to be ventilated by the CDU ventilation system (See Figure 6) that discharges directly to stack. Air is drawn from the TCTF, through the vessel and bypasses Octant 5 main horizontal port and Boom Enclosure and then discharged to stack. This corresponds to approximately 10 air changes per hour

4. OPERATIONAL EXPERIENCE

Extensive tritium monitoring is performed both in the vessel and attached access facilities. Tritium is measured using ‘Bubblers’ (HTO) and ion chambers (HT and HTO). ‘Bubblers’ pump air through a container of water that is then subsequently analysed for the quantity of tritium transferred to the water[5]. Airborne tritiated particulate is measured using filtered air samplers while surface tritium is measured by smears, which are analysed by water soak techniques. Urine sampling measures tritium uptake in workers but is a retrospective technique.

The various facilities have been exposed to highly activated and tritium and beryllium contaminated components over a number of previous shutdown campaigns. During the Remote Tile Exchange (RTE) in 1998 the in-vessel airborne tritium atmosphere varied from 100 – 150 MBq/m^3. Very high tritium levels associated with the dust and flakes lightly adhering to divertor carriers resulted in off gassing values as high as 0.6 GBq/hr and significant particulate on the facility surfaces. Smears as high as 2 MBq/cm^2 were measured in known hot spots during RTE but typically values during the previous three campaigns varied between 100 and 1000 Bq/cm^2.

The successful containment of the vessel Access Facilities and the Torus limited the Torus Hall tritium levels to 300 Bq/m^3 once conditions were stabilised with no other breaches of primary vacuum containment (i.e. diagnostic work etc.)

The exposed internal surfaces of the Access Facilities are coated in a sacrificial PVA strippable coating (See figure 7) that provides a continuous membrane.[6] This water-based solution is applied by air gun or brush and enables inaccessible and awkward areas protection from tritium contamination. Tie-down coatings are applied after particularly high contamination generating tasks to enable the loose contamination to be trapped. This sandwich layer is then removed and the facility re-sprayed.

The use of such techniques reduced the surface contamination during RTE from values as high as 2MBq/cm^2 too generally 30Bq/cm^2 or less. This allowed a reduction in the required respiratory protection equipment and significantly assisted working practices. Sacrificial ground sheets and regular vacuum cleaning are also used to minimise the spread of contamination. Such good house keeping techniques results in the production of up to 1.5m^3 of Intermediate Level soft and hard Waste (ILW) and 1m^3 of potentially contaminated water that is discharged to the active drain every week.

During the Inboard Pellet Launcher Shutdown in May 1999 in-vessel tritium levels were recorded from 35 to 80 MBq/m^3. In excess of the significant remote handling activities this shutdown consisted of a week of manned access to the Torus. The highest individual dose was 1800μSv from the activated vessel and 18μSv internal dose from tritium.

In comparison the 2001 Septum Replacement Plate shutdown experienced in-vessel tritium values of 10 to 36 MBq/m^3. The highest individual dose was 2100μSv from the activated vessel and 10μSv internal dose from tritium. This corresponded to 16 working hours over.

During this engineering shutdown a number of Gas Box divertor carriers were temporarily removed and dismantled in the TCTF. This involved a complete strip down to enable the fitting of diagnostics or the exchange of tiles. Although attempts were made to confine the spread of particulate, difficulties were experience with the pressurised suits becoming contaminated.

Even after the removal of the sacrificial over suits, showering on exit and suit cleaning (internally and externally) using brushes and cleaning agents (Neutrocon), surface contamination on the outside of the suits remained in the KBq/cm^2 range. Under normal operational circumstances the cleaning process normal reduces the contamination levels to under 1Bq/cm^2. This resulted in repeated cleaning operations and the use of the vast majority of pressurised suit stocks.[7]

A vast range of specialised tooling has been designed and manufactured in support of in-vessel shutdowns. This tooling once exposed to the torus environment is then registered as having a tritium history (Certificate of Radiological Monitoring CRM). Future rehearsals/trials or modifications can only be instigated in controlled areas unless the tritium content is assessed to be less than 0.4Bq/g. Large accumulations of such tooling can lead to significant tritium inventories. Under these circumstances formally approved methods of transport and storage are required (Package Movement Safety Cases PMSCs).

During the 2001 Shutdown this has lead to difficulties. With future shutdown work identified (January 2004) and the need for further specialised tooling, the logistics of tool storage and transport will need to be carefully planned.

A comprehensive monitoring programme demonstrates that the measures previously described have resulted in low discharges of less than 5% of the authorised limited.

In conclusion, unique experience has been gained at the JET Facilities during three major in-vessel shutdowns since the introduction of significant tritium quantities. Controlling, containing and operating within the previously described constraints are likely to be significant factors for the successful maintenance activities on future fusion devices.

REFERENCES

[1]. P.Edwards, 'Operating Experience of the Tile Carrier Transfer Facility During the JET Remote Tile Exchange', SOFT, Marseille, 1998.

[2]. A.D.Haigh, 'Developments in Contamination Control and Respiratory Protection at JET', SOFT, Marseille, 1998.

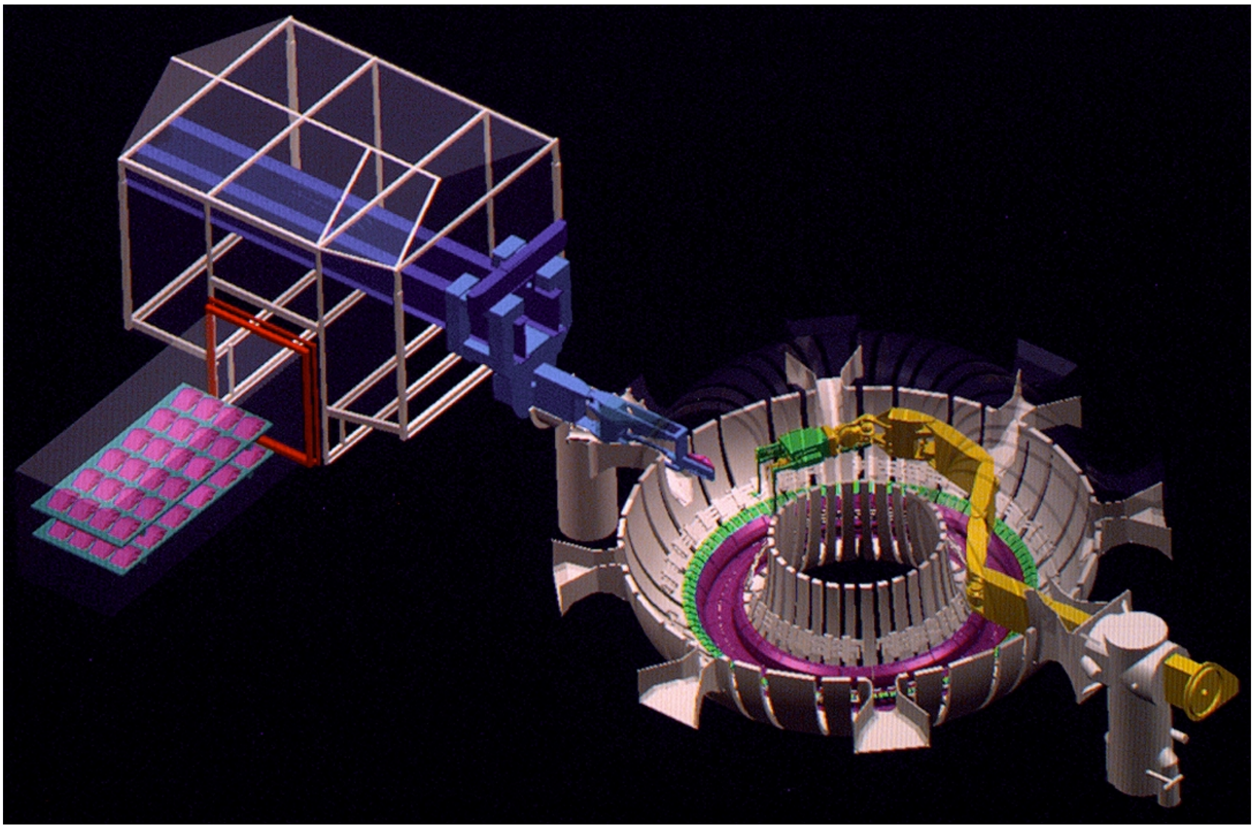
[3]. N.Davies, 'General Overview of the Active Ventilation Systems at JET', Internal document, August 2000.

[4]. P.D.Brennan, 'Long Term Operation of the JET Facilities' Active Gas Handling System', Tritium 2001, Tsukuba, Japan.

[5]. D.Campling, 'Tritium Bubbler Samples and Internal Radiation Doses at JET', Tritium 2001, Tsukuba, Japan.

[6]. P.Jordan, 'A Modular Solution to Temporary Containment Problems', AEA Technology, AEAT 0501, June 1996.

[7]. C.Callanghan, 'Review of Pressurised Suit Usage during the 2001 Septum Replacement Plate Shutdown', Internal document, November 2001.



CAD-Drawing

Figure 1: Schematic of remote access to the Torus

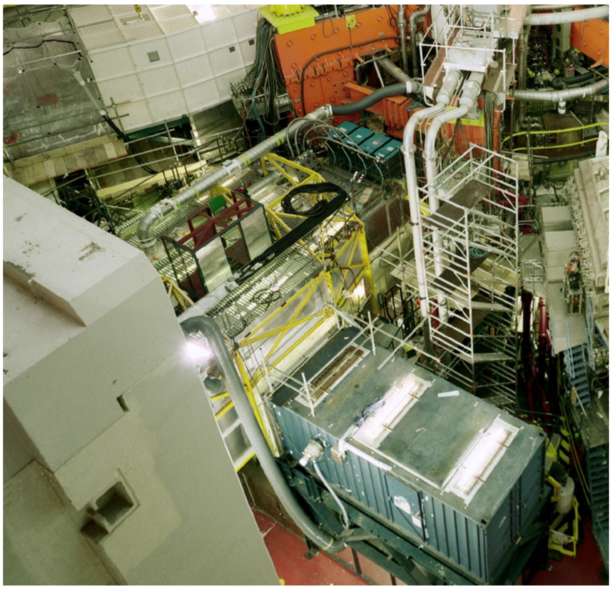


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Figure 2: Torus Access Facilities (TCTF) at Octant 1

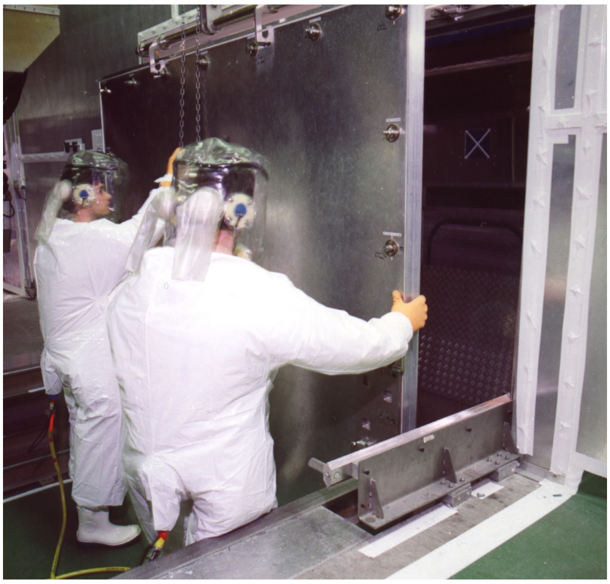

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Figure 3: Double lidded door assembly

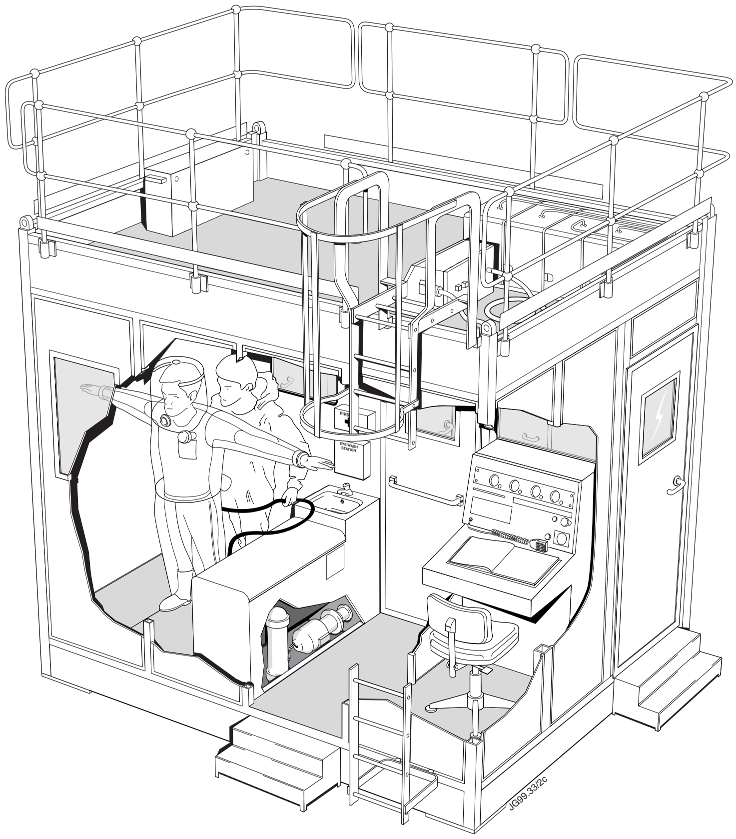

Figure 4: Controller/Dresser Units (CDUs)

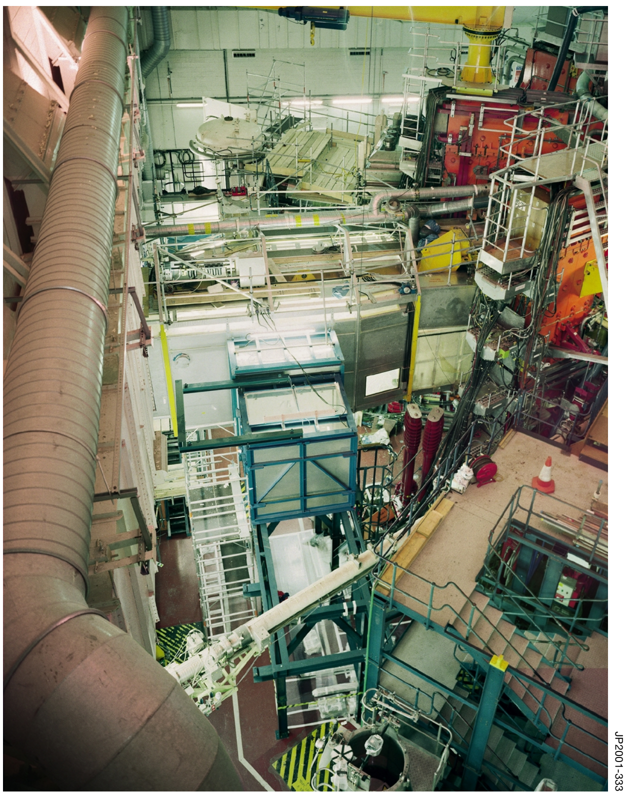

Figure 5: Ventilation system on Boom Enclosure

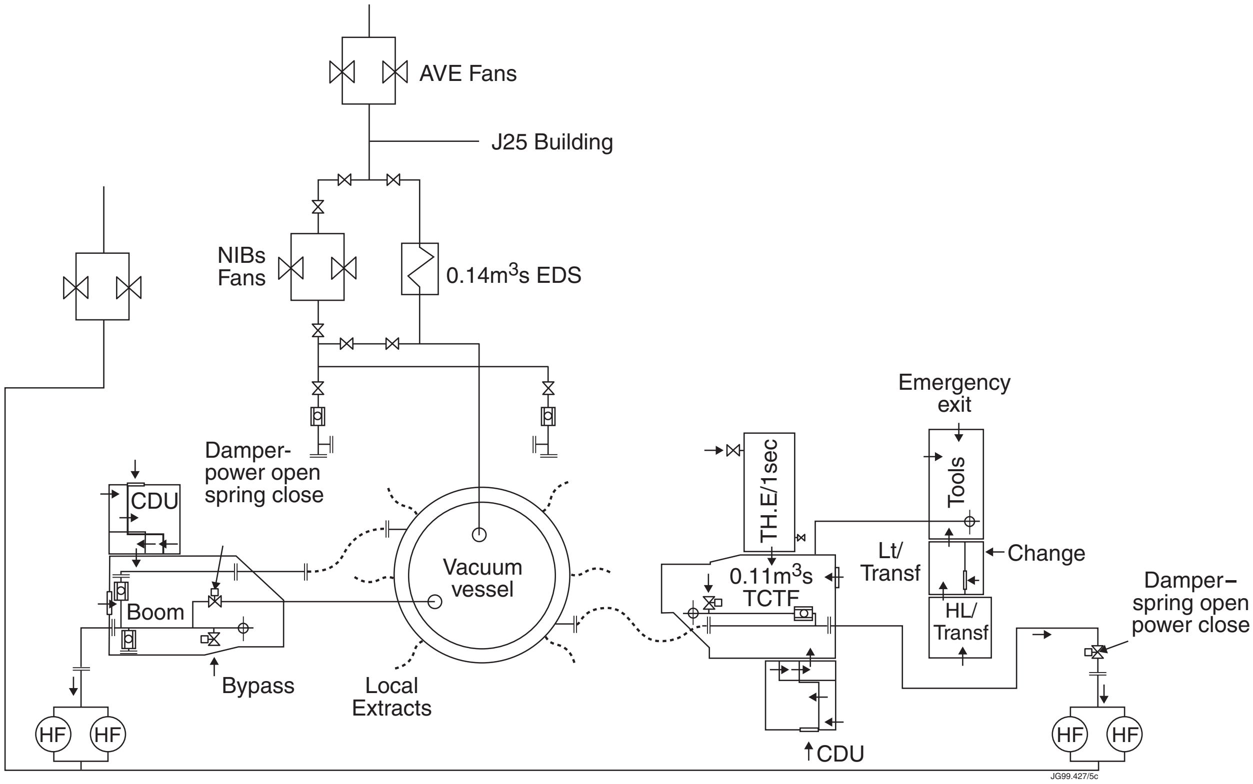

Figure 6: CDU ventilation system

Figure 7: Application of sacrificial strippable coating