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Use of the JET Active Gas Handling Plant Exhaust Detritiation System during and after DTE1

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ABSTRACT

The Exhaust Detritiation System (EDS) of the JET Active Gas Handling Plant has operated continuously for the last three years. The system has been used during the active commissioning phase, during the DTE1 deuterium-tritium experiment and subsequently during the Remote Tile Exchange (RTE) operation. The Exhaust Detritiation System is one of the key safety systems which permits the operation of the JET machine with tritium. This paper describes the experience gained of operating the Exhaust Detrititaition System throughout the tritium operations at JET. The design [1] and the construction and commissioning [2] of the Exhaust Detritiation System have been discussed previously.

1. INTRODUCTION

1.1 Plant Description

The Exhaust Detritiation System consists of two sections an initial recombiner section and a drier rack. The recombiner section has an inlet filter followed by a chiller running at 4-6°C to remove some of the ambient humidity. The incoming gas then enters a two stage heat exchanger where the temperature is initially raised to 150°C and passes through a recombiner. At this temperature the hydrogen isotopes are catalysed into water. The second stage of the heat exchanger raises the temperature of the gas to 500°C. At this temperature, in a second recombiner, tritiated compounds such as methane will be oxidised to form water. After passing back through the heat exchanger the gas passes through another cooler to remove some of the water vapour.

The second section consists of three identical driers.. Each drier has a molecular sieve bed, a cooler, a blower and a heater. In adsorption mode the gas carrying the tritiated water vapour passes through the molecular sieve, where the water is adsorbed by the 5Å molecular sieve. The detritiated gas then passes out of the drier into a common outlet manifold. Depending on the mode of operation the dry gas may then be re-circulated back through the recombiner and drier or it may be discharged to a monitored stack.

1.2 Sources of Gas to the Exhaust Detritiation System

The Exhaust Detritiation system is designed to perform a number of roles and receive gases from a number of sources as follows.

1. EDS provides the depression for the secondary containment boxes of the AGHS
2. EDS provides local ventilation for the purpose of carrying out breaches of tritiated systems within the AGHS, and also for handling off-gassing components.
3. By manipulating the building ventilation it is possible to use the flow rate of EDS to provide detritiation of the room air in the event of a leak in one of the small rooms within the AGH building.

4. EDS is designed to provide emergency air flow and detritiation of that air in the event of a breach of the torus or the neutral beam boxes (NIB)
5. EDS can provide ventilation of the NIBs or the vessel during planned interventions.
6. EDS can detritiate the low level contaminated gases arising from the tritium processing operation of the AGHS.

1.3 Operation

As stated in the previous section the EDS can be operated in two modes. Normally there is little load on the EDS and it is run in re-circulation mode with most, if not all, of the gas re-circulating round the recombiner/drier circuit. If a large air flow is required then EDS can be run in once-through mode where the air goes through in a single pass.

The EDS is controlled by a Siemens plc with primary safety parameters also controlled by a hard wired interlock system which are routinely tested in accordance with the safety case.

The driers are used sequentially e.g. initially drier 1 will be placed in absorption mode until the dew point in the outlet manifold rises to -60°C. The operator will then switch drier two into adsorption mode before switching drier one into regeneration mode thus maintaining an open path through the system at all times. Regeneration is carried out concurrently in a closed loop. Air driven round the circuit by a blower is heated to 305°C. This hot air drives the water off the molecular sieve and onto a condenser. The resultant tritiated water condensate is then collected in a 100 litre tank. Each molecular sieve has a saturation capacity of water of 100 litre and will yield approximately 50 litres when regenerated after maintaining a dew point of -60°C or better. Once a drier has cooled it is switched to standby mode, where air is circulated around the cold, closed drier loop.

2. OPERATION OF EDS DURING DTE1

During the main phase of the DTE1 experiment, all the gases emanating from the torus were processed through the AGHS. Discharges to the EDS were mainly from the Impurities Processing System, which separated out gases such as helium from the torus exhaust and also some gases arising from the processing and analysis of the exhaust gas within the AGHS. During the DT experiment EDS collected 50.8TBq of tritium in 3100 litres water.

3. OPERATION OF THE EDS DURING THE REPAIR OF A LEAK IN THE NEUTRAL BEAM BOX.

A water leak in one of the neutral beam boxes (NIB) occurred after the start of DTE1. Initially NIB 4 and NIB 8 were vented with nitrogen and pumped to EDS using the pumps in the Mechanical Forevacuum System. The NIBs were then alternately vented with air and pumped to EDS. This operation continued for several days . Eventually NIB 8 was vented to atmosphere with EDS providing a slight depression and a constant through flow of air at 450m^3/h. Up to this time only two of the driers were in regular use in order to preserve the third in an uncontaminated state. However at this flow rate EDS was working at full capacity and therefore all three driers were brought into consecutive service. The period between switching driers was approximately 15h, therefore leaving 30h for regeneration and cool down. It was found that the regeneration quality suffered due to this quick turn round of the driers. Typically the driers would achieve an outlet dew point of -40°C. This dew point would improve as the drier continued in service and the humidity peak at the drier outlet gradually diminished. Driers 1 and 3 were the duty driers during the initial nitrogen venting of the NIB, during this period 21TBq of tritium was captured by the EDS. It became clear that Drier 3 had seen the bulk of this activity, as when it was switched into adsorption with an initial outlet dew point of -40°C, a rise in activity was seen at the outlet of EDS and in the stack corresponding to a release rate of 4 GBq/h. In order to reduce the load on EDS it was decided to allow the outlet humidity of the driers to rise to -30°C before switching driers and also to reduce the volume flow rate through EDS to 300m^3/h. This flow rate was a compromise between reducing the load on EDS and maintaining sufficiently low tritium concentrations in the NIB.

4. OPERATION OF THE EDS DURING THE REMOTE TILE EXCHANGE

Following the DTE1 experiment came the Remote Tile Exchange (RTE) where the torus was opened and the ventilation of the vessel was provided by EDS. At the beginning of the RTE there was up to 6g of tritium remaining in the machine. As for the NIB intervention the initial venting of the machine was with nitrogen and subsequently with air. The flow rate required of EDS was around 330m^3/h, this was sufficiently low as to allow adequate regeneration and cool down time between duty periods. In order to reduce humidity peaks on switching in a fresh drier, the standby speed of the blowers were raised. This accelerated the redistribution of water along the length of the bed following regeneration. Problems developed shortly after the initial pump down of the torus. During the regeneration of the driers tritium was released into the AGH building. The release was found to coincide with a pressure peak of 1.2-1.4 bar in the drier circuit undergoing regeneration. Non-return valves on the drier circuit designed to prevent over pressure were found to be of too high a rating. These non-return valves rated at 350mbar were replaced by similar valves rated at 70mbar. It was determined that the over pressure generated in the drier during regeneration was pressurising the active drain tank causing the release of tritium into the building. The very high active concentration of up to 1.3TBq/litre of the tritiated water generated by the first few regenerations of EDS continued to require careful attention to contamination control in the building. This diminished as the tritium in the water became more dilute. The highest tritium concentration measured in the AGH building during a regeneration was 13 DAC measured close to the drain tank and the highest daily discharge from the AGH building was 85GBq. After a period of six weeks the concentration of the tritium in the water had fallen to 204GBq/litre and at this level the first of the transfers of the tritiated water into drums occurred. Prior to this operation the highest active concentration transferred into drums had been 17.5GBq/l, consequently the operation was carefully rehearsed and was carried out in pressurised suits. 27 drums were filled without incident containing 602 TBq in 4483l water. In total during the remote tile exchange EDS collected 6921 litres water containing 1.97g (701TBq) tritium.

5. FACTORS AFFECTING THE PERFORMANCE OF THE EDS.

During the NIB intervention it became apparent that a valve in the drier 1 regeneration loop was not opening fully. The valve was of the Vatterfly type and the result of its failure was to initially reduce the regeneration efficiency by limiting the flow rate around the regeneration loop and finally to prevent regeneration at all by becoming jammed closed. The valve was replaced with a new one of the same type. Within the space of a month the same valve on the other two driers failed and needed to be replaced. When examined, the valves showed signs of corrosion with a rusty deposit covering their interiors. This corrosion lead the valves to stick and indeed in one case lead the actuating shaft to break. It should be noted that 4 of these valves have now been changed three during the NIB intervention and one after the start of the RTE when the EDS driers had been exposed to very high levels of tritium. In each case when the drier circuit was breached, little if any airborne tritium was seen (<<1DAC) and the valves themselves were found to be clean when smeared for tritium. The breaches were carried out using local ventilation only and no breathing protection. The driers were left in the standby mode i.e. circulating a fixed volume of gas around the regeneration loop whilst cold, for at least a few days before the breaches were carried out in order that any residual water from the previous regeneration was mopped up by the molecular sieve.

Another failure to affect the EDS was that of the bearings on the blower of drier 1. It was noted that the blower of drier 1 was exhibiting excessive noise and vibration. Upon investigation it was found that this was due to worn bearings. Again the breach turned out to be very clean in terms of airborne and surface tritium .

Due to the redundancy of the drier/blowers unit, none of the above failures affected the ability of the EDS to perform its detritiation/ventilation function.

A more conventional problem was the failure of a switching unit on the mains power supply to the EDS. The safety case requires that there is a main and back up power supply to the EDS and in the event of a loss of power to the system an autochangeover unit switches from the main supply to the back up. On one occasion during the clean up operation after DTE1 the main power supply failed as well as the back up. This caused the autochangeover unit to hunt between the two supplies and eventually to burn itself out. EDS had no power for 1hr and 40min. There were no radiological consequences due to this power failure. This was the only loss of availability of EDS in three years of operation.

6. CONCLUSION.

The Exhaust Detritiation System has worked well through the tritium campaign at JET. It has remained available throughout it and the initial tritium commissioning ready to provide emergency detritiation and it detritiated the impurities gas as part of the AGHS processing operation. EDS enabled the NIB intervention and the main Remote Tile Exchange to take place in the former by providing sufficient ventilation flow and detritiating that flow before discharge to atmosphere During the RTE the EDS managed to collect nearly 2g of tritium in the form of tritiated water. Maintenance of the EDS was relatively easy particularly the driers which were found to have negligible contamination and airborne tritium even after being exposed to significant quantities of tritium.

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