Progress on the Inactive Commissioning and Upgrade of the JET Cryogenic Distillation System

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The JET Active Gas Handling System (AGHS) is now fully installed and most subsystems have been or are being commissioned. In particular, the Cryogenic Distillation System (CD), dedicated to the separation of hydrogen isotopes has been successfully tested with H/D mixtures.

Eight commissioning runs totalling 4237 h of operation were carried out from February 1991 to December 1993. Minor deficiencies revealed during the tests have been corrected and since then the plant has operated very reliably. Protium of very high purity (>99.9996%) and fairly pure deuterium (>99.998%) were produced on a continuous mode.

The CD system fully meets its specifications for H/D separation. Commissioning with tritium will then take place mid 1995 to demonstrate that the CD system is capable of detritiating protium down to a very low level of HT (less than 5ppb).

1. INTRODUCTION AND STATUS OF THE AGHS

The tritium phase of the JET Joint European Torus is presently planned to be conducted in 1996. In preparation for this phase, JET has built a fusion fuel processing facility[1, 2]: the Active Gas Handling System (AGHS). This system is designed to collect exhaust gases from the torus and its associated systems, remove impurities (mainly tritiated water and tritiated methane) and separate the hydrogen isotopes into pure species which will be recycled to the torus. The AGHS is capable of processing a daily throughput of 5 moles of tritium mixed with 15 moles of deuterium and 150 moles of protium. Fig 1 presents the overall AGHS flow diagram.

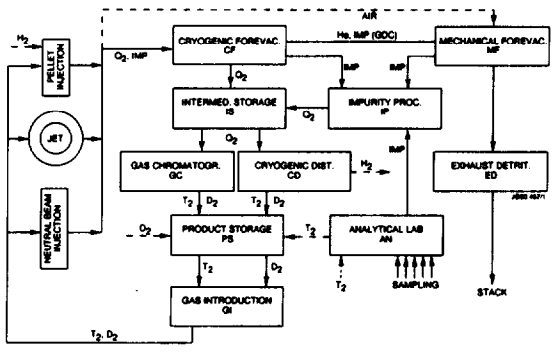

Fig 1: Overall AGHS flow diagram

All the subsystems except the Gas Introduction System have been commissioned successfully with hydrogen, deuterium and other test gases[3].

The commissioning of the interconnecting lines between subsystems and the operation of several subsystems as a whole (ie: CD, IS, PS, AN) is now well under way.

Tests of the safety related devices and commissioning of the hardwired safety interlocks are currently in progress.

Tritium commissioning of the AGHS is due to start by the end of 1994.

2. AIM AND DUTIES OF THE CRYOGENIC DISTILLATION SYSTEM AT JET

The Cryogenic distillation system (CDS) is designed to process in parallel:

- a high protium/low tritium stream coming from the Multi Pellet Injector
- a DT mixture recovered from the torus and its auxiliaries

The tritium concentration in the feed gases is expected to range from 1 to 27 atom percent.

The products specifications require the deuterium and tritium streams to be enriched to 99%. The protium product must contain less than 5ppb of tritium to be released to atmosphere with a negligible impact on the environment (10Ci/y).

3. PROCESS DESCRIPTION

The CDS (Fig 2) comprises three interconnected packed columns working at cryogenic temperature (18 to 26K) and two room temperature equilibrators. The columns are housed in an 11m high stainless steel vessel working as a secondary containment kept under vacuum (p<10-6mbar) by sputter and getter pumps. This vessel is thermally insulated and actively cooled by a circulation of 18K helium through copper coils surrounding the thermal shields. Fig 3 shows a view of the process components when the process cold box and the shielding are removed.

The columns are filled with a stainless steel packing which promotes the isotopic separation due to the difference in volatilities of the six isotopic species of hydrogen: H2, HD, HT, D2, DT, T2. The overall efficiency of the cascade is around 260 theoritical plates. The equilibrators are filled with a special catalyst to convert the mixed species into elemental protium, deuterium and tritium.

The driving force needed to circulate the gas throughout the cascade is given by four static transfer pumps.

The cascade is operated in recycle mode as long as the tritium concentration monitored by the on-line tritium ionisation chambers is out of specification, otherwise the production mode operates: pure protium, deuterium and tritium are drawn off from the top of column 1 and 3 and the bottom of column 3, respectively.

The refrigeration power needed to cool down the thermal shields, the column walls and the condensers is supplied by a Sulzer TCF20 helium refrigerator capable of delivering 528W at 16.9K. The temperature is controlled with an accuracy of 0.05K.

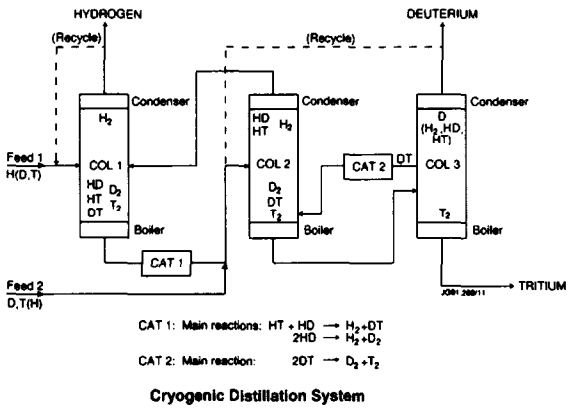

Fig 2: Flow diagram of the CD system

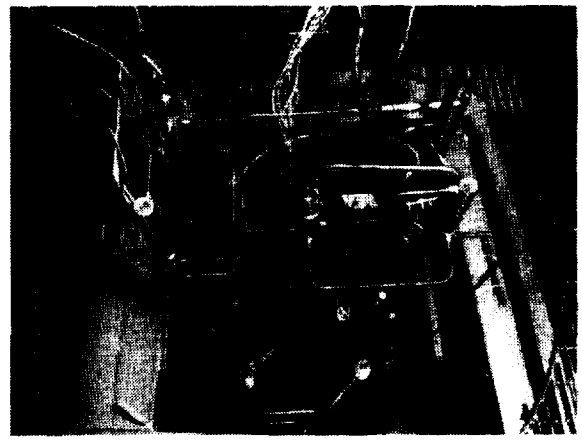

Fig 3: View of the process components with the secondary containment removed

4. SAFETY ASPECTS

A probabilistic and deterministic safety analysis has shown that probabilities of failures and their corresponding tritium emissions to the atmosphere were well below the safety guidelines. The plant has been designed to be safe and simple to operate.

The pressure in the columns is kept slightly above atmospheric pressure to avoid oxygen ingress. The primary process containment is built in compliance with high construction standards (ASME VIII) and was severely tested during the manufacturing, the erection and the commissioning. The overall leak rate in less than 1E-8mbar/l/s.

The process lines are double contained within stainless steel vessels capable of recovering up to 300% of the nominal gas load in case of emergency. Each vessel can withstand a pressure of 5bara.

Special care had also be taken during the design phase to minimise the tritium inventory into the system and finally, special components were developed to increase the reliability of the process to minimise the maintenance: ie static syphon pumps are used to drive the gas through the cascade instead of mechanical pumps which are prone to failure.

5. CONTROL OF THE COOLDOWN SEQUENCE

A dedicated automatic sequence controls the cooldown of the process. The coolant is first sent towards the columns' condensers, the column cooldown lines and the shielding of the cold box. When outlet helium temperature reaches 25K, the flow rates through the helium condensers are reduced

and the condenser controllers start to control around 10W the power delivered to the condensers. The reboilers heaters and their associated level controllers are switched on as soon as liquefaction takes place into the columns. Syphon pumps are switched on to establish internal recycling flows through the cascade. Pressure in the columns is also controlled around 1.2bara by adjusting the condensing power of columns 1 and 2. The cooldown lines are shut as soon as the hydrodynamic conditions in the system are stabilised to enable the column to work at near-adiabatic conditions. At this stage, the coolant is sent merely into the process condensers and the cold box shielding, the distillation cascade is in total reflux.

The cooldown sequence is achieved within 40 hours as indicated in the chart below (Fig 4). A cooling power of 200W is needed to run the process at its nominal design values (160W for the shielding, 40W for the gas liquefaction).

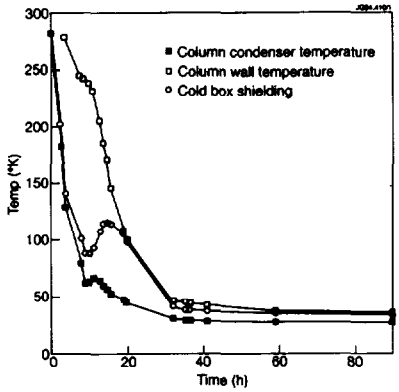

Fig 4: Cooldown curve

6. STUDY OF STEADY STATE AND DEUTERIUM TRANSPORT

Several 100-hour runs were carried out with protium and mixtures to study steady state conditions. The plant was running very steadily in all the operating configurations (Fig 5). Artificial disturbances created on flow rates and reboiler levels were settled down smoothly by the control loops. Nevertheless, we noticed a tendency to oscillations, probably due to the siphon pumps, when the columns are operated at high pressure drop (>8mbar).

The plant was operated in the recycle mode for 35 hours and gas samples were taken from the top of column 1 and the bottom of column 3. Protium purity removed at the top of column 1 was found to be better than 99.9985% whereas 99.977% deuterium was drawn off from the bottom of column 3 showing that deuterium transport occurred as expected through the distillation cascade.

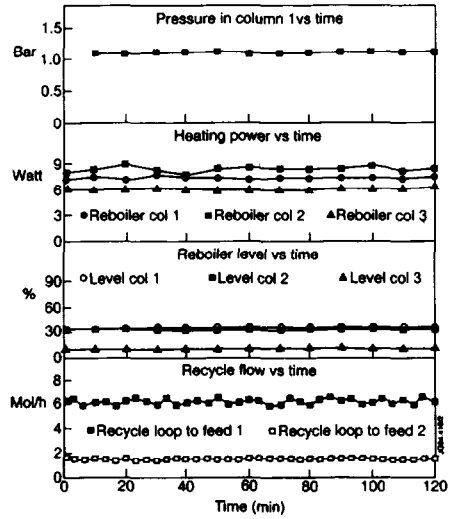

Fig 5: Steady state trends in normal operation

7. RESULTS OF ISOTOPE SEPARATION RUNS

Performance tests were carried out with a wide spectrum of hydrogen mixtures: [%H2,%D2]= [90,10], [80,20], [50,50], [25,75]. The distillation cascade was run on a continuous basis in the normal operation mode. Gas samples were taken at 8h interval from the product lines and analysed by high resolution mass spectrometry at CEA Bruyères Le Châtel, France.

Protium of very high purity (>99.9996 atom percent) and fairly pure deuterium (>99.998 atom percent) were produced in the system over long period of time (100h).

REFERENCES

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[3] J L Hemmerich et al, "Installation and Inactive Commissioning of the JET Active Gas Handling System", 15th SOFT (1993)