Operational Health Physics Experience during the JET D-T Experiment

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1. INTRODUCTION

The JET deuterium-tritium experiments in 1997 (DTE1) utilised 20 grams of tritium, produced more than $2.3x10^{20}$ D-T neutrons, and generated peak fusion powers of 16MW. Significant health physics input was required to measure and quantify the radiological consequences of high yield neutron and gamma production, and of processing large tritium quantities. This paper summarises the results of radiological protection monitoring carried out during the campaign. Figures are presented of neutron and gamma doses and tritium levels in occupied areas during the D-T operations. Results are given of aerial discharges of tritium and the levels found in the local environment.

There has also been potential for measurable tritium exposure in torus operational areas during maintenance and repair activities. Operational health physics knowledge has been gained during work on tritium contaminated systems, and descriptions are given of the initial radiological protection experience of work in areas with high levels of surface and airborne tritium. Initial experience at JET shows that tritium exposure controls have been very effective, giving very low operator doses. JET results also show that the environmental impact of processing 0.1kg of tritium is not significant.

2. TRITIUM OPERATIONS

D-T operations commenced in May 1997 with the supply of tritium to the torus by gas introduction and neutral beam injection. The active gas handling plant (AGHS) provided the means for storage, supply of tritium, and its recovery and recycling from the torus machine exhaust. There was a break in D-T operations in June-August to repair a water leak in a neutral beam injector box . Operations then resumed, and by the end of DTE1 in Nov 97, more than 200 D-T fuelled pulses had been generated and about 99 grams of tritium had been processed by the AGHS [1].

3. RADIATION & TRITIUM MONITORING

Radiation protection monitoring for DTE1 was aimed at confirming that: (i) dose rates outside the shielded, occupied areas remained low, (ii) residual activation levels of the torus were acceptable if torus hall access was required, (iii) tritium levels in operational areas were minimal, and that (iv) the effects of tritium discharges had a minimal environmental impact.

3.1 Dose Rates Outside Shielding.

Although the torus hall concrete shield was designed to allow operation with 14MeV neutron yields of up to $5x10^{23}$/year, the doses near to shield penetrations were of particular interest. The main shield walls are 2.8m thick and designed to transmit <1mSv/year. Large numbers of gamma and neutron dosimeters were installed outside the biological shield in addition to on-line measurement by 13 gamma and 6 neutron monitors. These showed that instantaneous dose-rates

were <5μSv/pulse and integrated doses were below 1mSv in all occupied areas during DTE1. Doses near penetrations particularly in the torus roof laboratory reached 14-25mSv (n), 1mSv (γ), but these were within secondary exclusion barriers. Gamma and neutron dose-rates at the site boundary remained generally indistinguishable from background levels.

3.2 Torus Activation.

Surveys of the torus after periods of pulsing showed increasing levels of neutron induced activation. Fig 1 shows the typical gamma radiation decay of torus machine activation after a pulse. The half life of the initial decay is ~5 mins, increasing to 1.5 hours. The residual dose-rates on the machine structure at the end of DTE1 following decay of short-lived nuclides are shown in Fig 2. The in-vessel dose rate deduced from these measurements was 7-8mSv/hr, in reasonable agreement with predicted figures.

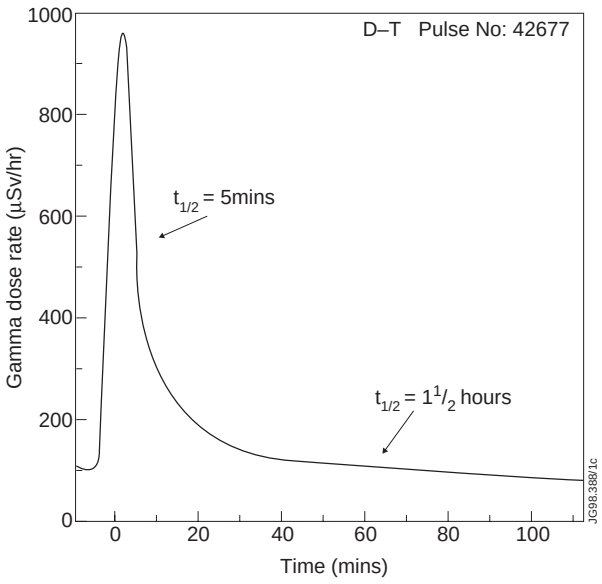

Fig 1. Radiation decay of JET after DT pulse

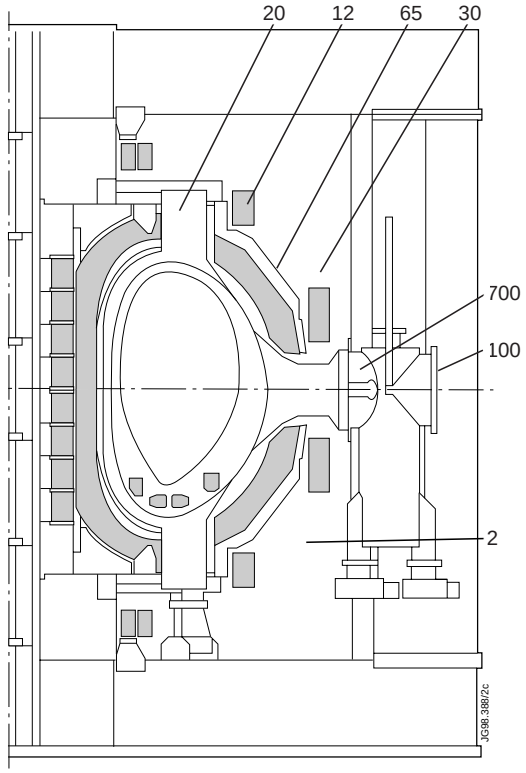

Fig 2. Residual torus dose-rates (μSv/hr)

3.3 Tritium Levels in Operational Areas.

Around 19 on-line ion-chambers, 3 HT/HTO samplers and a number of bubblers were used for routinely recording tritium in air levels in operational areas. During tritium operations no level above 0.8MBq/m^3 (1DAC, HTO) was detected in any occupied areas adjacent to the torus hall. Typical in-building levels were 10-500Bq/m^3, however increased levels up to 1kBq/m^3 HTO, 70kBq/m^3 HT were noticeable in some areas. These are believed to be due to the partial entrainment of stack discharged tritium in the building wake. More significant was the emergence of a steady rise in torus hall tritium levels about 3 weeks after the introduction of tritium into the

torus. During operations the torus hall ventilation of the N_2 enriched atmosphere was placed in partial depression/recirculation mode. Equilibrium concentrations reached 0.3MBq/m^3, and with a rate of one air change per day, discharges amounted to about 10GBq/day. This concentration was temperature related, and presented a potential source of exposure to torus hall entrants. The HTO fraction in the discharge was seen to start at 50% and later stabilise at 80% lending credence to permeation as the source rather than a hot leak. However, smears of the torus machine exterior revealed levels of merely 1Bq/cm^2, and only on the hotter surfaces.

3.4 Environmental Monitoring and Discharges.

Aerial discharges of tritium during 1997 occurred in four phases. These were Jan-April (pre-DTE1), May-June (start DTE1), July-August (interventions) and Sept-Dec (DTE1 completion and clean-up). The majority of the site aerial discharges of tritium related to two main sources, firstly the process exhaust from recycling of tritium in AGHS, and secondly, the ventilation discharge of torus permeated tritium. Discharges during interventions added a further amount. The site tritium aerial discharge during 1997 is shown in Fig 3. Discharges of HT in the first half of the year are largely attributable to AGHS commissioning. HT discharges later in the year correspond to torus hall stack discharges as well as AGHS operation. The higher discharges of HTO in the second and fourth quarters are a result of stack discharges from the torus hall. Discharges in the middle part of the year relate to ventilation discharges during maintenance work. For the 32 week period of DTE1 and the interventions, the total site discharge was 1.28TBq(HTO), 1.31TBq (HT) which is <1.5% of JET's annual authorisation. Approximately 55% of the HTO total was from the torus hall depression stack representing a sizeable source. Environmental monitoring was carried out on-site and in the local environment. The results of tritium in air, rainwater and river water are summarised below.

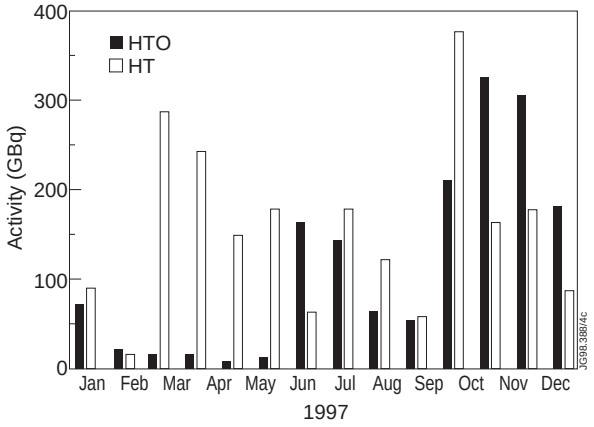

Fig 3. Atmospheric Discharges

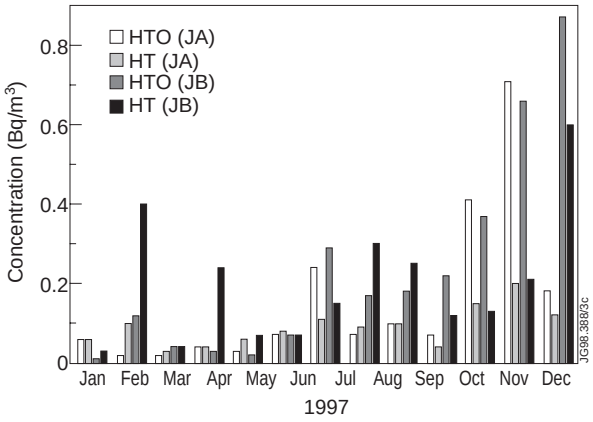

Fig 4. Site Tritium Levels (mBq/m^3)

3.4.1 Tritium in air.

Measurements were made using a series of diffusion samplers and four HT/HTO samplers located at various points on the site. Results show that tritium levels near the site boundary ranged

from 50-900 mBq/m^3 as a fortnightly average (Fig 4). For the fourth quarter when HTO discharges were more significant, tritium levels at the two positions to the north of the site (JA,JB) showed a trend which correlates with the predominant wind direction at that time. With site aerial discharges (HTO) of around 320GBq/month, environmental levels rise to ~1Bq/m^3 at most.

3.4.2 Rainwater.

Tritium levels in precipitation measured on-site showed levels of 5-35Bq/l, the trend again corresponding with the higher tritium discharges in the latter part of the year.

3.4.3 Riverwater.

Routine work in JET's active facilities and operation of the ventilation systems generates water with activity levels of 1-10MBq/litre. Most waste arisings are discharged to the local river, after dilution if necessary, within JET's compliance limit. During the year samples of river water downstream of JET's aqueous discharge point showed no levels significantly above existing levels in the water.

4. OPERATIONAL EXPERIENCE

Several small breaches of tritium containment were performed in the AGHS during maintenance tasks. Containment breach procedure involves repeat pump and purge cycles of the containment with dry N_2 and then moist air until process ion-chambers show a tritium content low enough to permit opening. Local ventilation is additionally used for reducing concentrations in the breathing zone of the worker. Containment isolators have also been used. Protective clothing typically comprises coveralls, gloves and overshoes; pvc aprons and boots for work with tritiated oils and water. Exposure concentrations in this period have been generally <1DAC (HTO) although levels >100DAC were observed during a primary containment breach to replace a seal on a vacuum pump. In this instance only dry N_2 purging was possible and local extract positioning was atypical. Contamination up to 26kBq/cm^2 was found on pump internal surfaces. More significant breaches occurred in the NIB repair outage. Manual intervention was necessary to effect repairs in the vacuum box, and use was made of airline supplied full-suits to provide protection [2]. Separate dose constraints were prescribed and operational exposure limits were defined to control doses. Air concentrations of 180DAC and surface levels of 56kBq/cm^2 were observed inside the box. However tritium doses during the 8 week outage were kept to less than 70μSv [3].

Doses to site personnel were very low during the year. The largest single tritium exposure resulted in a 160μSv dose, accrued during vacuum pumpout of a machine interspace. Of the 83 persons who recorded positive tritium doses for the year, 90% received a dose less than 40μSv,

and the integrated total was 0.0015man-Sv. Given the potential for significant radiation exposure in the torus hall following operations, access was stringently controlled, thereby limiting both internal and external doses.

5. CONCLUSION

The JET DTE1 operations carried a potential for significant tritium and external radiation exposure. Large dose-rates were evident and significant tritium inventories were handled. However operations were conducted without incident, personnel doses were kept to a very small fraction of the site limit, and the off-site environmental impact was insignificant.

Future D-T operations will have to address the control of tritium permeation from the vessel walls, and consider the need to enhance shielding near penetrations. JET experience also shows that work on tritium contaminated systems can be managed safely providing exposure constraints are carefully prescribed and control procedures are precisely followed.

6. ACKNOWLEDGEMENTS

L M Ashby, C Caldwell-Nicholls, and the JET Health Physics technician team

7. REFERENCES

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