Radiological Protection at JET and the Tritiated Dust Hazard

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1. INTRODUCTION

This poster gives a brief overview of the radiation protection issues at JET and includes a discussion of the hazards presented by the tritiated dusts collected and studied so far. The implications for the International Thermonuclear Experimental Reactor (ITER) project are discussed. ITER is the next step machine after JET on the road to fusion power.

JET is the world's largest tokamak and the only fusion reactor capable of working with tritium (^3H).

The project is best known for producing 16MW of fusion power in the Deuterium Tritium (D-T) Experiment (DTE1) in November 1997. It is also the only fusion tokamak supported by facilities capable of safely handling ^3H and beryllium (Be) contaminated components. A site dose limit of 5mSv/yr per person is worked to.

2. OPERATIONAL RADIATION HAZARDS

During Deuterium-Deuterium (D-D) machine operations and particularly after high performance neutral beam (additional heating) experiments the dose-rates on the structure of the machine can approach 1mSv/hr. During D-T operations several Sv's/pulse of neutron and gamma radiation can be produced.

These conventional hazards are controlled by a 3m thick biological shield, regular dose-rate surveys, limited access (barriers with the issue of digital dosimeters), reference to installed radiation protection instrumentation and the use of additional administrative controls at times and places of elevated risk.

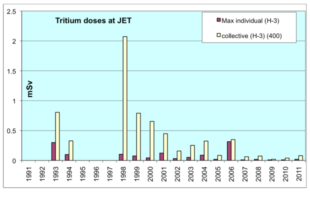

Fig 1a. Annual maximum individual and collective **tritium** doses.

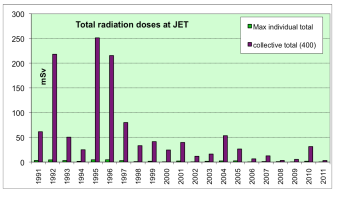

Fig 1b. Annual maximum individual and collective **total** doses.

The peaks are associated with shutdown work and the occasional need to undertake manned vessel entries. This data illustrates that the ^3H doses are insignificant.

3. SHUTDOWN RADIATION HAZARDS

During shutdowns and interventions additional precautions are required to protect staff from the hazards associated with HT/HTO and tritiated dusts encountered during breaches of the machine containment. A few TBq's/g of ^3H in dust was measured after DTE1. The residual ^3H inventory (several grams in total) led to an in-vessel ^3H-in-air concentration of 63MBq/m^3 at the start of the subsequent shutdown in 1999.

Engineered precautions are used wherever possible with extensive use of remote handling techniques for in vessel work and ventilated gloveboxes, isolators and tents for ex-vessel breaches of containment. Tents and isolators up to several 100m^3 have been made on-site in an plastics workshop dedicated to their production.

Fig 2. A large tent containing a contaminated component

Fig 3. Small isolater in use on the torus

The main activity leading to elevated doses at JET is vessel manned entries for work that cannot be undertaken remotely. The in vessel dose-rate must be <300µSv/hr. This is achieved by controlling the neutron yield and allowing decay of ^{57}Co, the main short lived activation product in the machine Inconel steel structure. Pressurised suits are used to protect operatives from the Be hazard as well as the tritiated dust hazard. Comparison of the ^3H personnel doses with the in-vessel ^3H concentration has confirmed that the JET suit has a ^3H protection factor of ≈1000.

4. TRITIUM DETECTION TECHNIQUES

All operational areas at JET are monitored by ion chambers which like the installed gamma monitors have local audible and visible alarms and are connected to the JET control room to provide remote monitoring. Health Physics atmosphere monitoring of breaches of containment is carried out with portable (Overhoff) ion chambers.

'Bubblers' are used for long term area surveillance, assessing the HTO off-gas from contaminated components and assemblies and environmental impact assessment purposes.

Tritium surface contamination levels are surveyed by smearing with paper filters and are counted directly in a liquid scintillation vial; this technique has been validated by oxidation of duplicate smears.

5. THE TRITIATED DUST HAZARD

Up until the installation of the ITER like wall in 2010-11 the majority of the plasma facing wall in JET was graphite with some carbon fibre composite (CFC) and solid Be components. All these surfaces had a few microns of Be evaporated onto them through the operation of four Be evaporators. Beryllium, being of low atomic number and an oxygen getter, helps reduce impurities in the plasma. Plasma operations creates a 50-80µm thick layer of loosely attached flakes on plasma facing components. Once a critical thickness is exceeded this spalls off to form dust & flakes (Ref 1 & 3). Particle size, chemical composition, dissolution properties (in simulation lung serum), specific surface area of particles and tritium specific activity have been determined. There are differences in detail between these parameters dependent upon the origin of the dust and its composition. It is estimated that JET produces ≈1kg of dust for each operational campaign which typically last for many months and include hundreds of pulses.

The following data summarises the physical properties of the dusts studied so far:-

Size analysis:-

Multi-mode size distributions; peaks at approximately 0.5, 1, 5 & 20µm diameters. 10% of the total number of particles found at 0.5µ and 15% at 5µ. This means that a high proportion of dust particles are respirable.

Tritium dissolution:-

Of the CFC derived material; 3-5% of the ^3H dissolves in 1 min and 5-22% over the next 100 days. Of the graphite derived material; 1% of the ^3H dissolves in 1min and a further 1% in the next 100 days. Effective Dose Coefficients (EDCs) have been calculated and are summarised in Table 1.

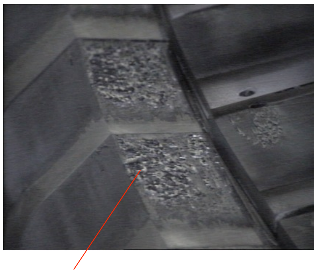

Fig 4. Loose flakes on a divertor tile

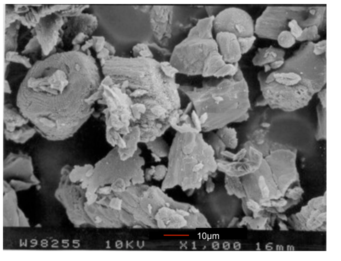

Fig 5. Micrograph of collected dust showing a wide variety of particle sizes

Elemental analysis:-

JET dusts consist of 87-93% C with 7-13% Be and traces of Fe, Ni, Cr and Al.

Tritium specific activities:-

1.2TBq/g (1998 – post DTE1); ≈16GBq/g now. At the 1998 levels inspiration of just 1µg of the dust would deliver 1ALI assuming the material behaved as HTO.

Species	Effective dose coeff (Sv/Bq)
HTO	1.8×10^{-11}
OBT	4.1×10^{-11}
'Coarse' particles (1999)	$2.6 – 2.8 \times 10^{-11}$
'Fine' particles (1999)	9.9×10^{-11}
SG1-1 m particles (scraped CFC tile; 1998)	$8.4 \times 10^{-11} – 2.0 \times 10^{-10}$
SG2-1 m particles (scraped graphite tile; 2004)	$2.6 \times 10^{-10} – 2.7 \times 10^{-10}$
SG1-5 m particles (scraped CFC tile; 1998)	$4.9 \times 10^{-11} – 1.1 \times 10^{-10}$
SG2-5 m particles (scraped graphite tile; 2004)	1.4×10^{-10}

Table 1. EDC's of tokamak dusts

Because the ^3H in the dust does not behave like HTO it (remains on the particles) has been estimated that doses of ≈3.7mSv would not be detected in urine bioassay samples. Doses to the lungs would dominate. However it is important to note that because the ^3H is intimately associated with Be in the dust an undetected ^3H dose is ***not*** being missed because the Be exposures at JET are in an overwhelming majority of cases less than the limit of detection (0.03µ/m^3). The health physics laboratory at JET holds a UKAS ISO17025 accreditation for the Be exposure sampling and analysis carried out on site.

6. DISCUSSIONS AND IMPLICATIONS FOR ITER

Further collection and study of dust samples from the new solid Be ITER like wall will be required to confirm the hazard assessment undertaken for ITER dusts. In vivo studies (Ref 4) of metal titrides (Ti, Hf & Zr) undertaken on behalf of ITER indicate similar EDC's to those given in Table 1. These are in line with the proposed EDC of 2.7×10^{-10} Sv/Bq that ITER has adopted. These figures indicate that, using the ICRP 66 lung model, tokamak dusts are 10-15 times more radiotoxic than HTO. ITER will ultimately operate with a 3kg ^3H site inventory and an operational limit of 100's of grams of ^3H in use at any one time. It is estimated that it's total dust production will amount to 100's of kg's so determining the hazard associated with this material is crucial.

7. CONCLUSIONS

The radiological hazards at JET are low compared to the other industrial (primarily electrical) hazards present on site. The ^3H doses are insignificant compared to the external doses. Further study of dusts generated by plasma interactions with the new ITER like wall will be required to confirm the EDC associated with the ITER dust.

ACKNOWLEDGEMENTS

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