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ABSTRACT

The waste management activities at JET include not only the collection, processing and dispatch of radioactive and beryllium contaminated waste, but also for the operation of several supporting facilities (the beryllium controlled areas); the provision of respiratory protection; (including pressurised suit operations) and the procedural support for maintenance of active handling operations.

The consequences of carrying out the Deuterium-Tritium experiment (DTE1) were reviewed throughout 1996 and 1997 in order that appropriate preparations could be implemented. Several procedural, regulatory, technical and managerial functions were identified for modification and the planning and subsequent execution of these functions is described here. In general the regulatory and procedural aspects were accurately anticipated, eg radioactive waste authorisations, the operation of the radioactive drainage system and improvements in managerial control were successfully implemented. However in the case of materials storage the increased tritium off gassing rates were higher than expected. This required the engineering controls and storage facilities to be enhanced before the DTE1 tile modules could be transferred from the Torus Hall. The predicted consequences of DTE1 and the preparations made are detailed here with discussion of further actions which proved necessary in practice.

1. INTRODUCTION

The waste management functions at JET are split broadly into three areas, professional support for waste management and radiological management issues; radioactive waste collection, receipt, sampling and disposal; and support facilities for the operation of areas handling radioactive materials and their storage.

The prospect of increasing the site tritium inventory from 0.2 grams in late 1995, to 3 grams in 1996 and to 20 grams for the DTE1 period [1] in 1997, with a throughput to the torus and neutral beam of around 100 grams lead to a review of many systems to ensure that this quantity of material could be handled with the appropriate detail of supporting procedures and operator skills to ensure the safety of operators and in an environmentally acceptable manner.

The anticipated increase in neutron yield would also give rise to increased activation levels and it was necessary to review the storage, handling, waste management and operation of facilities available during and after the proposed DTE1. This included the Remote Tile Exchange (RTE) which was planned to take place only a few weeks after the end of DTE1. The short delay between DTE1 and RTE left no opportunity to address RTE issues after the end of the DTE1 campaign, therefore the planning had to address the requirements of both DTE1 and RTE.

The following sections describe the preparations which were made in advance of DTE1 and the RTE, report on the results in terms of waste management, and discuss the modifications made as a result of experience and lessons learned for future D-T operation.

2. PREPARATIONS

Following the review of appropriate procedures and systems the following preparations were made in anticipation of DTE1 and the subsequent RTE.

2.1 Regulatory Aspects - Compliance with the Radioactive Substances Act

The Radioactive Substances Act 1993 (RSA93), puts an obligation on the user of radioactive materials to register the radioactive materials to be used obtain authorisations to accumulate or dispose of waste materials. JET had previously obtained registration for up to 90g of tritium and waste authorisation that would enable JET to handle of the quantities of tritium anticipated for deuterium-tritium plasma operation. There were however several issues relating to accumulation and disposal or radioactive waste arisings which fell outside the existing authorisations. These are itemised below.

2.1.1 Activated Freon (organic liquids)

It was recognised that JET had been using this organic coolant in the Toroidal Field (TF) and Divertor coils for several years and that the increased neutron yield would increase the specific activity. If the coolant were declared waste, following a major leak for example, this would increase the radioactive waste inventory. JET had previously operated in a way which did not require radioactive waste to be accumulated. All waste generated was entered immediately into a processing stream which would achieve its disposal or transfer off site as soon as it had been processed for dispatch. However in the case of Freon 113 (trichlorotrifluoroethane) the specific activity predicted immediately after DTE1 was of the order 55 G Bq (see table 1). The majority of this activation, however, was made up of short lived radionuclides. Since the material is inherently volatile, and disposal routes are limited by total radioactive content of the waste, Best Practical Environmental Option (BPEO) and Best Practicable Means (BPM) were both satisfied by allowing the radionuclides to decay within sealed containers minimising both environmental discharges and reducing waste disposal costs to as low as is reasonable achievable.

It was necessary therefore to apply for a authorisation under RSA93 for the accumulation of organic liquids for a period which would allow sufficient decay to dispose of a potential volume of 120 m^3 at the post decay activity level. The resulting liquid could then be readily disposed of to commercial incinerators with low radioactive content.

It was therefore decided to apply for an authorisation which provided sufficient scope to handle all of the activated freon if it were to be declared as waste after a campaign of 10^{23} neutrons. An authorisation to accumulate up to 30TBq for up to three years was approved with a disposal authorisation of up to 2GBq per calendar year.

2.1.2 Solid Accumulation

It was recognised that DTE1 would produce solid radioactive materials including inconel and graphite which might, in the future, require facilities for tritium recovery or detritiation to be

Table 1: Assessment of organic liquid activation with respect to the radioactive substances act authorisation application

NUCLIDE	10^{23} NEUTRONS (ref [4] and [5]) Bq g^{-1}	$2X10^{20}$ NEUTRONS Bq g^{-1}
Be^{10}	$1.5x10^{4}$	$3x10^{-7}$
C^{14}	$3.3x10^{-4}$	$6.6x10^{-7}$
F^{18}	$4.3x10^{4}$	$8.6x10^{1}$
P^{32}	$6.4x10^{4}$	$1.2x10^{2}$
P^{33}	$3.4x10^{2}$	$6.8x10^{-1}$
S^{35}	$1.1x10^{5}$	$2.2x10^{2}$
$C\ell^{36}$	6.4	$1.2x10^{-2}$
$C\ell^{38}$	$1x10^{4}$	$2x10^{1}$
Totals	$2.3x10^{5}$	$4.6x10^{2}$
120 Tonne Equivalent	NA	55 GBq
Activation after 5 years decay	Total Activity (MBq)	1.5
	Specific Activity (Bq g^{-1})	1.3×10^{-2}
Tritium Content	Total (predicted)	16 MBq
	Specific Activity (Bq g^{-1})	200 Bq ℓ^{-1}
Accumulation Application		30 TBq
Annual Disposal Requirement		1GBq Tritium
		1GBq Activation Products

built. It would be likely that the materials could, if necessary, be disposed of immediately. However it might prove more cost effective if the materials were to be processed prior to disposal to recover tritium and materials destined for intermediate level waste disposal were to be treated and disposed of as low level radioactive waste. In the event that it proved necessary to store such materials temporarily pending treatment, it would be necessary to arrange an authorisation to accumulate a fixed volume of solid waste. An authorisation to accumulate specific pre-processing volumes of solid radioactive waste for a period of up to 5 years was applied for and received [2].

2.2 Storage of Activated Components

The Remote Tile Exchange plan [3] assumed that divertor modules would be removed from the torus be 9 weeks, 11 weeks and 13 weeks from the end of the DTE1 campaign. It was essential to co-ordinate the movement and storage of tile module ISO containers in such a way as to minimise delay to the RTE shutdown caused by shielding beam movement or personnel access. A series of activation assessments were carried out based on the model used for the shielding assessment [4] and dose rate calculations were made to assess the effect of storing modules in arrays of 6 x 8 x 2, or 5 x 5 x 2 and evaluating the effect of differing shielding thicknesses for the storage ISO containers. Table 2 shows a typical dose rate assessment for an array of base modules in a 5 x 5 x 2 array in a shielded or unshielded container.

Table 2: Estimated Dose Rates in mSv hr^{-1} from a 5x5x2 Array of Base Tile Modules

Unshielded container					**Shielded container**				
Decay time from DTE1					**Decay time from DTE1**				
Long side of ISO					**Long side of ISO**				
Distance m	**1 Wk**	**9 Wks**	**11 Wks**	**13 Wks**	**Distance m**	**1 Wk**	**9 Wks**	**11 Wks**	**13 Wks**
1	186	108	94	82	1	93	54	47	41
2	67	39	34	30	2	34	20	17	15
5	14	8	7	6	5	7	4	4	3
10	4	2	2	2	10	2	1	1	1
Short side of ISO					**Short side of ISO**				
Distance m	**1 Wk**	**9 Wks**	**11 Wks**	**13 Wks**	**Distance m**	**1 Wk**	**9 Wks**	**11 Wks**	**13 Wks**
1	166	96	84	73	1	83	48	42	37
2	58	36	29	26	2	29	19	15	13
5	12	7	6	5	5	6	4	3	3
10	4	2	2	2	10	2	1	1	1

From these assessments it was decided to provide shielding of 2 cm steel cladding on the storage ISO containers, which would produce dose rates typically below 100 μSv hr^{-1} at a distance of 2 meters from the containers. This would facilitate storage within the Torus Hall if necessary (with the addition of local shielding at the unshielded end of the container).

A further radiological assessment was made to compare the size of storage compound necessary to provide an external dose contour below 2.5 μSv hr^{-1}. Either a large fenced compound approximately 30m wide or a shielded compound using 40 cm concrete would be necessary to achieve an external dose rate of 2.5 μSv hr^{-1}. (Note that 2.5μSv hr^{-1} is the upper limit for an area at JET to have *uncontrolled* access.

A shielded concrete storage compound was constructed adjacent to the Active Gas Handling Facility. The facility incorporated a concrete roof, and high efficiency particulate filtration (HEPA) on the ISO container exhaust lines.

Tritium off-gassing rates had been estimated by comparison with off gassing and retention information gained during the Preliminary Tritium Experiments (PTE) in 1991 [6] and were in the range of 0.4 to 2 GBq per day, from all 3 containers. In order to provide a low ventilation rate to avoid the build up of tritium within the containers, provision was made to ventilate them at a rate of 2 air changes per day, or approximately 200 m^3 per day through the monitored extract system of the Active Gas Handling Building.

2.3 Radioactive Drainage Preparations

2.3.1 General Description

The JET Radioactive Drain serves several facilities on the JET site that produce potentially radioactive aqueous wastes. The potential sources are: the Beryllium Handling Facility that carries out wet decontamination operations; the J25 Active Gas Handling Building, that recycles tritium; the plant that conditions the air in the Torus Hall and basement; the Health Physics Laboratories that analyse the samples generated through active monitoring; the cooling circuits in the JET machine; and the suit cleaning facility that provides the cleaned protective clothing for manual operations in hazardous areas in and around the JET machine.

The JET Radioactive Drain has developed and grown throughout the life of JET to service these facilities as they came into being. The water from the various sources is collected in local holdings tanks, transferred in a double contained pipe-work to the discharge monitoring tanks. The contents of the $10m^3$ holding tanks are sampled to determine that they meet the relevant radioactive and chemical limit and are discharged into the Culham site trade waste tanks which can contain up to $500m^3$ of water. These tanks are discharged when full via a pipeline into the River Thames.

2.3.2 Procedural Control

In order to ensure that all disposals of radioactive contaminated aqueous wastes were within the applicable consents and authorisations, the arrangements to be followed were laid down in a two waste management procedures and a set of Local Rules and Operating Instructions [7].

The Local Rules describe the management arrangements to be followed for all aspects of the radioactive drainage facility and the Operating Instructions lay down the detailed tasks to be followed in order to comply with the rules. Modifications and maintenance on the radioactive drain must be strictly controlled in order to maintain the immediate and long term integrity of the system and ensure that all necessary changes are recorded and incorporated into the descriptions, operations and safety assessments.

In addition to handling the routine arisings, the radioactive drain was prepared for arisings which were beyond the normal operational constraints of the radioactive drain. These contingent arisings had been allowed for at the early design. All sources that would be generally outside the scope of the radioactive drain were routed elsewhere and for example could be drummed for reprocessing. However it was recognised that some sources that would generally be of an acceptably low level could, through accident or mishap, yield unacceptable arisings.

For example a fracture of a freon cooling circuit could release liquid freon into the Torus Hall and basement which would need to be immediately diverted. Secondly a release of tritium from the Torus into the Torus Hall due to broken diagnostic window could lead to higher tritium levels in the condensate that would need then to be collected separately. Modifications were made with extra hold-up tanks which enabled the activity of freon content to be assessed before mixing with the normal drainage streams.

2.3.3 Test and Commissioning

In order to demonstrate that the routine and emergency operations were working satisfactorily, a complete set of tests of the operation of the radioactive drain was completed prior to the start of the DTE1. The safety aspects were mandatory but the remaining aspects of the operation of the radioactive drain was considered desirable and included in the comprehensive function testing of the radioactive drainage system which confirmed readiness for operation prior to the start of DTE1 and to the re-start of operations after the completion of the RTE shutdown. The requirements of all applicable systems as identified by the overall safety case were included in their commissioning programme.

2.3.4 System Constraints

The operation of the radioactive drain is strictly controlled on a daily basis. There are several constraints imposed on the operators via the series of Local Rules, Procedures and Operating Instructions.

A management limit of 100 MBq m^{-3} has been introduced for the water being released to the river Thames. This is to ensure that even with no dilution this maximum dose outside the JET boundary from water discharge cannot exceed the legal limit of 1mSv.

A total of 25 GBq has also been defined in the safety assessment as the maximum tritium activity to be retained in the storage tanks at the Tank Farm. Remaining below this figure ensures that sufficient dilution is readily available to meet the 100 M Bq m^{-3} management limit even in the event of catastrophic failure of all retention tanks. A further constraint of 10 GBq per $10m^3$ JET discharge tank has also been introduced to provide an additional margin. From practical considerations and working within sensible operational margins the normal monthly discharge is approximately 25 GBq or 5% of the aqueous monthly authorisation.

2.4 Waste Management Procedures

Waste Management at JET is carried out subject to Waste Management Procedures. These procedures are generally written to a standard format in order to list the activities to be carried out. The control documents, record documents and those responsible for carrying out the activity are defined.

New procedures, and modifications to existing procedures, are endorsed at a JET Co-ordination meeting which representatives of all divisions at JET attend in order to ensure across site acceptance of the method of waste management. The responsibilities for carrying out the waste generation tasks in all the procedures are defined. Each division and operational facility at JET has an Area Waste Officer who is trained in the carrying out of his nominated tasks and activities by Waste Management Section.

Waste minimisation is an important issue and new procedures involving the quarantine of waste from tritium controlled areas were developed to ensure that housekeeping waste from these areas was only consigned as radioactive waste if there was detectable surface or airborne contamination.

2.5 CDU Commissioning and Suit Procedures

The RTE shutdown in February-June 1998, followed the DTE1 experiment and revolved around the use of remote handling equipment to remove the MK IIA divertor and replace it with the Gas Box divertor. Manned access into the JET vacuum vessel was not practicable as the dose rate was > 3mSv hr^{-1}.

However as the enclosures which house this remote handling equipment were attached to the vacuum vessel and therefore exposed to the atmosphere of the vessel, access into these enclosures required the use of pressurised suits to mitigate the potential presence of airborne and surface beryllium and tritium contamination.

To provide controlled access into the remote handling enclosures, purpose built ‘Controller Dresser Units’ (CDUs) were procured and commissioned. These units provide the means to dress operators into pressurised suits, monitor and ensure the safety of the operator and the environment within which he is working, decontaminate by showering the suited operator upon exit and safely undress and dispose of all potentially contaminated wastes generated. An isometric drawing of one of the CDUs is shown in Figure 1.

During RTE JET utilised two forms of pressurised suits

a) Full Pressurised Suit: which is a one piece re-usable suit fully enclosing the entire body. It has an internal air distribution manifold system and built-in audio system which allows two way communications between the CDU controller, other suited operators and personnel stationed in the Remote Handling Control Room. (Figure 2)

b) Pressurised Half Suit: which is a two piece single use suit consisting of a blouson and trousers. The blouson is air fed and communications available by the use of a separate headset. (Figure 3)

The majority of entries were carried out utilising the Full Suit, the Half Suit was used for a limited number of specific tasks for which its good visibility and more dextrous gloves were vital.

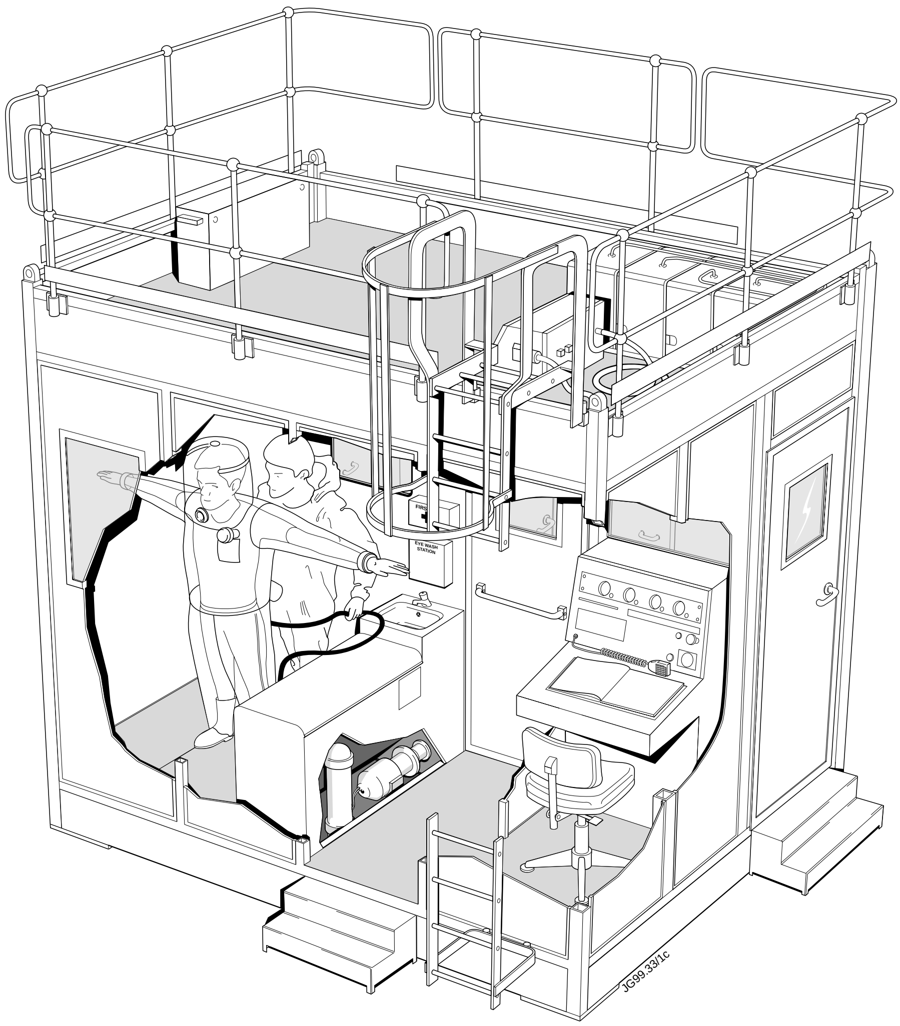

Fig.1: Isometric of a Controller Dresser Unit (CDU)

Fig.2: Full pressurised suit

Fig.3: Pressurised half suit

Prior to the RTE shutdown, used pressurised suits were double bagged and transferred back to the decontamination and maintenance facility. Suits could be stockpiled and processed in batches with minimal constraint on the turn-around time. However, due to the significant increase in tritium surface contamination levels and the capacity of tritium to permeate through PVC bags and the suit material it was necessary to fully revise the suit handling procedures. Suits and other forms of Respiratory Protective Equipment (RPE) were immediately removed, transferred and unpacked on arrival at the decontamination facility. The number of support staff and their shifts rosters for the CDU's and cleaning facility were revised to accommodate these changes.

2.6 Maintenance Facility

Prior to DTE1 it was expected that if a component failed which had high activation and/or tritium contamination with the added possibility of beryllium contamination, then some enclosure which could be ventilated would be required to work on such items. It was also expected that such components could be of various sizes and shapes, but that long items would most likely be activated/contaminated at one end only.

From these requirements a Ventilated Enclosure was specified (Figure 4). It was to be installed inside the existing Beryllium Handling Facility (BHF), the enclosure table top was approximately 2m long by 1m deep with removable panels on the front and ends. Separate gloveport panels and 20mm steel shielding panels were specified so that the enclosure could be operated in one of two modes.

Fig.4: Ventilated enclosure in fume cupboard mode

There are two modes of operation of the ventilated enclosure.

a) Glovebox mode: in which gloveport panels could be fitted and a small purge flow established in order to vent any tritium build-up inside the box. This mode was envisaged for items which had particulate and/or beryllium contamination hazards.

b) Fume cupboard mode: with access panels removed the ventilation can be switched to high flow mode giving $1m^3/s$ flow rate allowing openings totalling a maximum of $1m^2$ to ensure that the velocity was a minimum of 1m/s across any opening.

For each of these modes additional shielding in the form of flexible lead blankets and large mobile steel shielding plates were procured to provide local and general shielding. To accommodate long items one end has a bagging lip to allow tailored flexible isolators to be made to seal any protrusion from the enclosure.

It was considered that with such flexibility and with the enclosure sited inside an existing controlled area with all forms of RPE available that the Project would be in a position to repair most perceived mechanical failures during DTE1.

2.7 Spill Response

A number of potential radiological spill incidents were identified as part of the preparatory assessments prior to the start of the tritium phase.

a) Potential tritiated water spills, Torus Hall, or Basement, or J25, or during on-site movements.

b) Potential activated freon spill, Torus Hall or Basement.

c) Potential rupture of active drain system.

For all of the above incidents procedures existed for appropriate responses, however due to the increase in potential activity during DTE1 these procedures were re-assessed and responses ranging from simple remedial action by the Incident Response Officer (IRO) to an on-call team of RO's, Spill Co-ordinators and support staff with a full range of RPE including Self Contained Breathing Apparatus and Gas Tight Suits available.

This re-assessment identified that additional personnel were required to be trained and made available on-call in the event of an incident. A full incident exercise was carried out to demonstrate the effectiveness of the procedures and training.

3. RESULTS OF DTE1 AND RTE

The following paragraphs discuss the results of carrying out the DTE1 campaign and the subsequent RTE in terms of the effect on waste management.

3.1 Activated Tile Transfers

The first modules of each type removed from the vessel during the RTE by the remote handling equipment (inner, outer and base) were intercepted before being stored in the shielded ISO containers and the off-gassing rate measured. These measurements were used to estimate the total off-gassing rate for all the modules. These initial measurements indicated that the off gassing rates were significantly higher than the original estimates described in section 2.2. In the worst case estimates were as high as 750 GBq per day compared to 2 GBq per day.

This significant difference led to the re-evaluation of the storage option and transportation risks on-site. This re-assessment determined that these higher off-gassing rates could not be simply discharged to the environment in gaseous form and that the storage of these containers would require them to be inside a ventilated secondary containment. It was determined that the shielded concrete storage compound would have to be upgraded, a sealed base was laid and all the external joints in the walls and roof were sealed. The primary ventilation from the containers was routed to the AGHS Exhaust Detritiation System (EDS) [8] to remove the airborne tritium prior to the air being discharged to the environment. The sealed shielded compound was to be a secondary containment and was ventilated to the AGHS monitored discharge point.

This additional unanticipated work would not be complete before the first container needed to be removed from the TCTF, therefore interim storage was required.

It was determined that the containers should be stored in the Torus Hall until the shielded compound upgrade was completed. The containers were stored along the north wall of the Torus Hall and two were double stacked to save floor space. The containers were connected to vacuum lines and ventilated to the AGHS EDS for exhausted detritiation in the same way as was planned for their final storage location. Mobile 25mm thick steel panels were used to form additional local shielding to limit the radiation field around the containers and exclusion zones were enforced to reduce the exposure to personnel working in the Torus Hall.

The highest risk operations involving the containers were deemed to be the lifting operations. Many hundreds of container lifting operations had previously been carried out on-site with no incidents, but the levels of tritium inside these containers meant that even tasks that would be normally considered routine were analysed for potential risk. This assessment lead to restrictions on other work whilst these lifting operations were being carried out and a full team of emergency personnel being on standby to deal with any incident that might occur.

All operations associated with these containers were carried out to plan with no unforeseen occurrences.

3.2 Condensate Arisings

The JET Torus is situated in the torus hall which is maintained at depression of 150 Pa relative to the outside world and at a constant temperature and humidity. The majority of the Torus Hall air is re-circulated and passed over large cooling coils which lower the humidity within the Torus Hall. The collected condensate contains tritiated water vapour which was present in the torus hall due to permeation from the torus through seal faces and hot materials forming the vessel walls. This condensate is collected by the JET radioactive drainage system.

During DTE1 torus operations the level of tritium in the Torus Hall air was typically 0.3MBq m^{-3}. The corresponding level of activity in the condensate was 5 to 10 MBq$\cdot\ell^{-1}$. The rate of collection of activity in the condensate depends on the outside environmental conditions. During periods of low outside specific humidity, for example during the winter the rate of collection of condensate is very low but during periods of higher specific humidity, for example warm muggy days in the summer the rate of collection of condensate and tritium activity is higher. On a humid day up to 5GBq could be collected from this source.

The activity in the Torus Hall condensate was monitored throughout DTE1 and RTE by determining the activity content of the discharge tanks each week. In the event that the condensate arisings were too high, the water could be diverted to a long term storage tank. If the condensate levels were low then a stable discharge activity was maintained by adding tritiated water from storage. Throughout the period from June 1997 to May 1998 the monthly tritiated aqueous discharges were maintained in the range 15 to 25 GBq per month. The only exception to this was in February and March 1998 when discharges from storage were ceased the start of the RTE shutdown. The Torus was cooled to room temperature and vented to atmosphere at this time and the activity of the Torus Hall condensate fell. Discharges from storage resumed in April 1998. Figure 5 shows the monthly aqueous tritium discharges from the JET site from June 1997 (the start of DTE1) to May 1998 (the end of RTE).

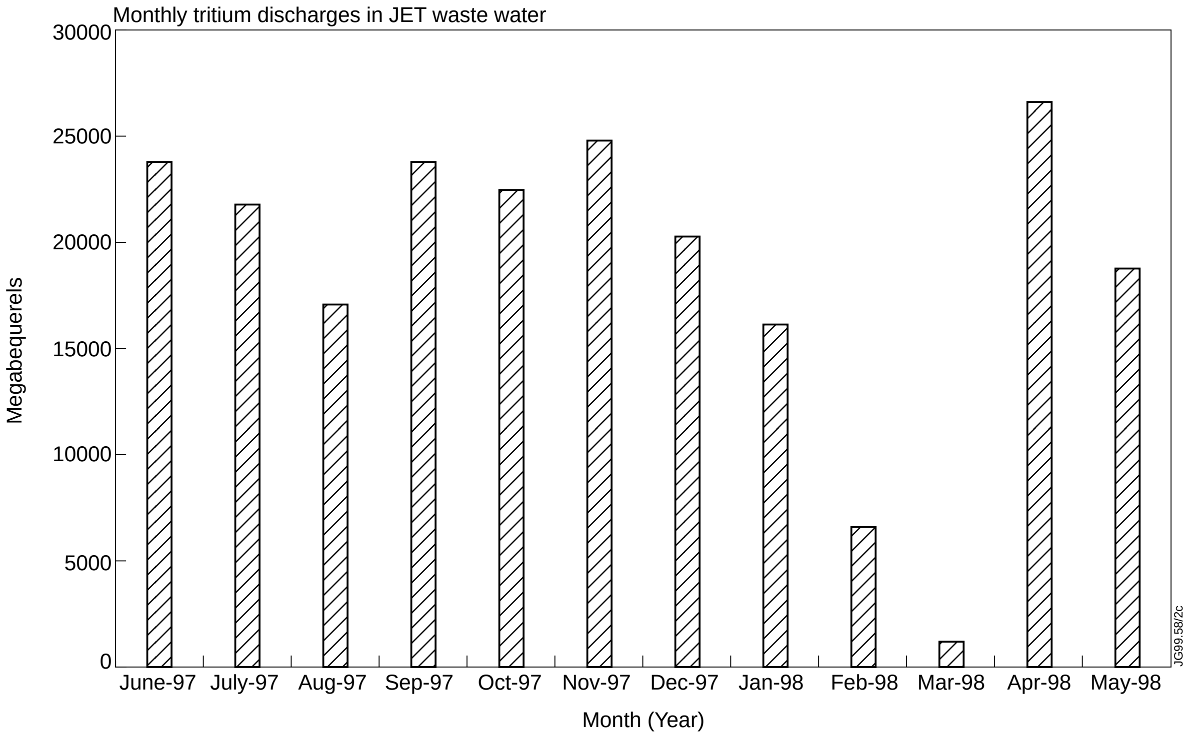

Fig.5: Monthly tritium discharges in JET waste water

3.3 EDS Water Arisings and Handling

In early February 1998 the JET Torus was first opened following the DTE1 in order to allow access for in-vessel work to be carried out. A depression was constantly maintained inside the JET torus so that an airflow direction was always from the Torus Hall into the vessel and associated areas. This extract air was carried through ducts to the Exhaust Detritiation System (EDS) in the J25 Active Gas Handling Building. The EDS system is essentially an extremely efficient dehumidification system that removes the >99.9 % of the water vapour and hence >99.9% of the off-gassed tritium from the airflow.

The average rate of tritiated water produced by the EDS system during the RTE shut down was 60 litres per day. Following the end of the shutdown and the restart of machine operations the ISO containers holding the tile modules that were removed at the start of the shutdown were stored in ventilated containers; their exhaust air was then dehumidified by the EDS. The water collected by the EDS drains from the EDS system into a 4m^3 tank below the floor of the Active Gas Handling Building. The rate of production of this EDS tritiated water is shown in Fig 6.

The tank of highly tritiated water had to be periodically emptied in order to allow continued operation of the EDS and hence the RTE shutdown. The water was pumped into drums. The drums used for this purpose are 200 litre 1.5 mm thick stainless steel drum with mild steel reinforcing rings. The drum design is certified to UN classification UN/1A1/X1.9/250/**/GB/ 1083, where ** is the date of manufacture.

The drums were collected and stored in a heated, secure safestore on the JET site. Presently 80 drums are filled containing over 2 grams of tritium in over 10 m^3 of water. The contract with Ontario Hydro Canada for the supply of tritium to JET used in the DTE1 experiment provides for the return of this tritiated water.

The rate of water arising can be seen (Figure 6) to slow down in late May 1998 when the Torus was closed to atmosphere and pumped down to vacuum. The actual tank volume can be seen to decrease in discrete steps coinciding with emptying of the tank into drums.

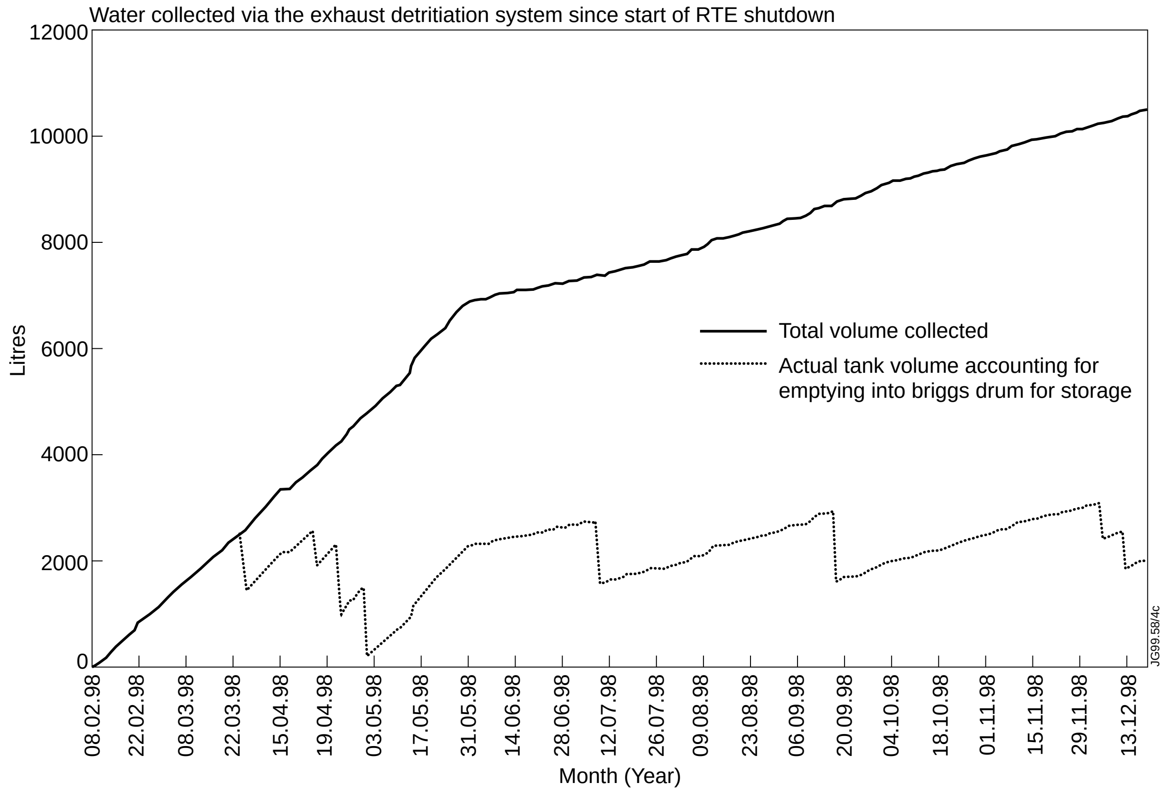

Fig.6: Water collected via the exhaust detritiation system since start of RTE shutdown

3.4 Airborne Tritium Discharges

Figure 7 shows the airborne tritium discharges from the site stacks (total) for both HTO and HT for the period covering DTE1 and the RTE. Prior to DTE1, ie prior to 28.5.97, the main contribution was from HT discharged from the Active Gas Handling Facility (J25). During DTE1, when the torus was hot, the proportion of HTO increased as tritium from permeation from the torus was discharged from the torus hall stacks. The increase in February 1998 is coincident with the start of the RTE shutdown when the torus was vented to air and the AGHS and CDU stack discharges of HTO increased.

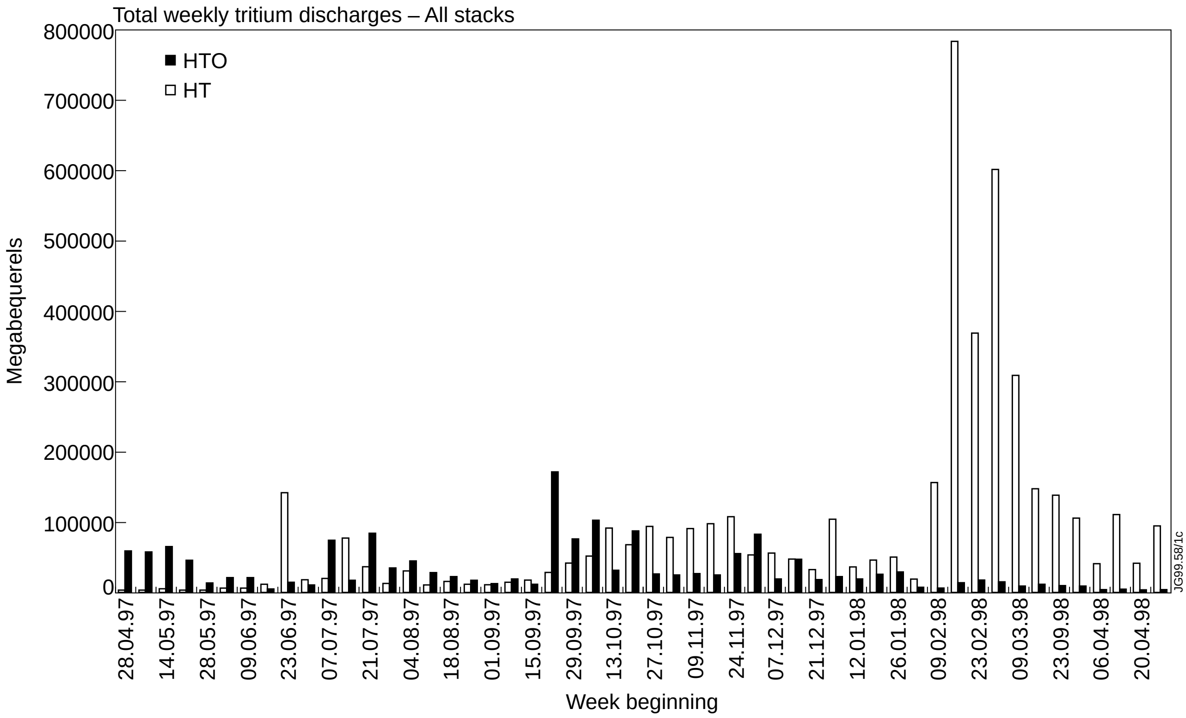

Fig.7: Total weekly tritium discharges - All stacks

3.5 Operation of CDUs, Suited Entries and Tie Down Layers

The RTE lasted for approximately 16 weeks during which the remote handling equipment was operated for two shifts per day six days per week. The seventh day each week being utilised for planned maintenance activities on a single shift.

This operating pattern meant that the CDUs were manned for 20 hours per day for six days and 10 hours on the seventh day each week giving a total of 134 hours per week, totalling over 2000 hours for the duration of the shutdown.

This level of continuous operation required a dedicated team of trained and motivated personnel to ensure that suited operations were carried out to the high standards of safety.

Detailed operational procedures for the correct commissioning, decontamination, maintenance and use of each type of RPE were written. These were tested in dedicated training facilities prior to the procedures being approved and the operators being trained in their use. In total some 611 suited entries were conducted during the RTE campaign with no reportable incidents or major failures. Out of the 611 entries only nine minor events were recorded by controllers which included two communications faults, two small punctures in suits and five holes in gloves.

3.6 Contamination Control

The elevated tritium levels associated with the torus and the high specific activity associated with particulate contamination (primarily graphite) meant that the standard of housekeeping and contamination control was very strictly enforced. Showering was compulsory for all suited operators exiting the TCTF and Boom Tent and sacrificial PVC sheeting was placed on many internal surfaces to allow cleaning and careful removal of contaminated surfaces.

Without regard for contamination control it is likely that heavily exposed surfaces would never be cleaned to free-release levels to allow uncontrolled access to the facility or indeed to allow re-usable items, such as respirators to be cleaned for re-issue.

The use of sacrificial layers was widespread, either:

– for Personal Protective Equipment, such as the use of overgloves changed at regular intervals, oversuits fitted over the pressurised suits and cut off prior to exiting at the end of the entry; or
– for the enclosure walls, this was achieved by spraying the internal walls and ceiling of the facility with a strippable paint and covering the floor with a heavy duty ground sheet over which thin plastic sheeting was lain and replaced a regular intervals to maintain the surface contamination levels within the limits set by Health Physics. If the walls or ceiling of the facility were to have unacceptably high levels of surface contamination then a second layer or ‘tie down layer’ could be sprayed over the existing layer trapping the contamination in a sandwich of paint and presenting a new clean surface.

3.7 Soft Waste Arisings and Assay

The rate of collection of soft waste over the period of DTE1 and RTE is shown in Fig 8. The units are expressed in terms of post compaction volume. Soft housekeeping waste such as gloves, coveralls and overshoes are typically size reduced by a factor of 6 in the JET waste handling facility using an in-drum compactor. The rate of production was low throughout DTE1 except for July 1997 when waste from the Neutral Injector Box intervention [9] was collected and increased in February 1998 as a result of the beginning of the Remote Tile Exchange operations.

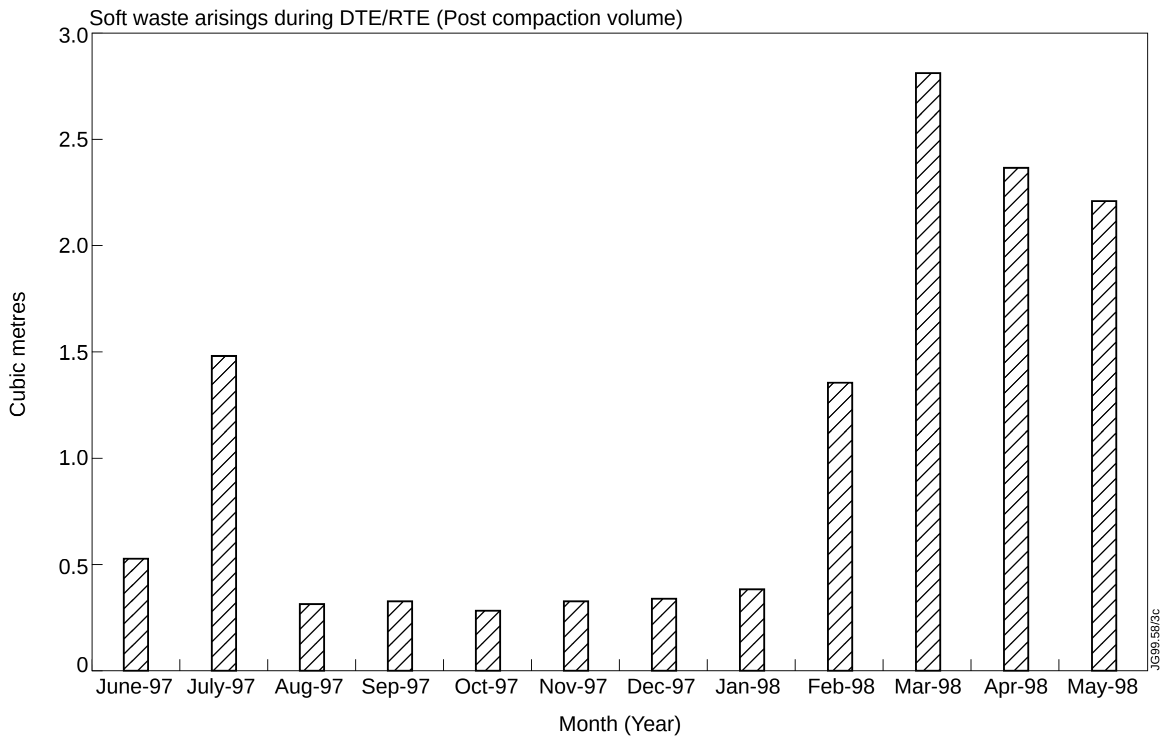

Fig.8: Soft waste arisings during DTE/RTE (Post compaction volume)

The outgassing of this tritium from waste items has caused working practices and operating instructions associated with the Waste Handling Facility to be reviewed. This waste is now being processed satisfactorily and new methods of tritium content assessment have been developed which include water soaking, sniffing and combustion.

4. DISCUSSION

Following the JET DTE1, 5 grams of tritium remained inside the Torus. [10]. 99% of this is expected to be trapped on the surfaces of tiles as co-deposited material on tile surfaces; loosely bound dust on the in vessel surfaces; or in flakes found at discrete locations with very high specific activity [11]. Assessments have been made which indicate that the specific activity of this surface layer will exceed the limits of the Drigg Low Level Radioactive Waste disposal site where JET's radioactive waste is normally disposed. A programme of detritiation trials is underway to determine the optimum conditions for reducing the surface tritium content of these tiles [12].

The preparations for DTE1 and RTE with regard to Waste Management Group issues enabled the experimental programme to proceed without any major delays. Some of the requirements imposed by the DTE1 experiment were anticipated as described above. Other issues, such as the higher than expected tritium retention and off-gassing rate, lead to a review of arrangements, but plans were put in place and carried out within a time scale that did not lead to any overall effect on experimental or shutdown planning. The increased levels of tritium off gassing measured when the first tile modules were removed from the vessel lead to a review of the immediate storage location and the integrity of the long term storage location. After a design review, and a revised safety assessment had been prepared, a program to modify the shielded storage area to accommodate the requirements of the ventilation plant and connection into the Active Gas Handling Facility exhaust detritiation system was implemented. These modifications were achieved over a very tight planning time scale but were completed before the end of the planned shutdown duration and all three ISO containers were moved to their final storage location before the TCTF was removed from the Torus Hall.

One of the main consequences of the DTE1 campaign with regard to waste issues is the accumulation of aqueous liquid with a tritium content of the order 25 GBq m^{-3} to 800 TBq·m^{3}. Water at a concentration below this range can be discharged in accordance with JET's radioactive drainage system constraints and are well within JET's discharge authorisations. In this concentration range, the tritium content is sufficiently high that recovery of the tritium becomes an option. JET has provisions within its tritium supply contract to allow the return of this category of water for tritium recovery since JET has no facilities to carry out this recovery at present. However, in the range 25 $GBqm^{-3}$ to 1 TBq·m^{-3} the ratio of tritium to protium and deuterium is sufficiently low that the recovery of the tritium is an onerous task. As regulatory pressure to reduce emissions to the environment grows, and authorisation to discharge into water courses becomes more difficult, it is likely that the lower end of this range will decrease to a very low level. Given recent political agreement that emissions to the marine environment may be reduced to zero, this will become a more pressing issue for any future large scale tritium plant. The development of a water recovery plant to address tritiated water in this concentration range would be an advantage as it would recover the tritium for subsequent re-use and ultimately reduce the levels of environmental discharges.

The DTE1 experiment has also provided an opportunity to develop new methods for assessing the tritium content of waste materials, not only with regard to tritium in its elemental or water form, but also when associated with graphite particulate. Novel methods for sniffing, soaking, leaching and sample combustion are being investigated in order to quantify the tritium content of post RTE waste. The methods developed will provide a useful basis for further practical waste handling and assay methods and will be reported on in future publications.

5. CONCLUSION

JET carried out a review of procedures and systems in place in anticipation of the DTE1 and RTE campaign. Areas where the preparations fully anticipated the challenge of the experimental programme were: the accumulation of waste materials, and subsequent disposals; the design, manufacture, commissioning and use if the Controller Dresser Units; the procedural aspects of pressurised suit operations; the development of appropriate contamination control procedures, particularly in the area of transport of radioactive materials; the waste management procedures supporting the various waste producers and the active handling facilities developed and commissioned.

The areas where useful experience has been gained and further areas of study have been developed include: the modification of the ISO container storage location to accommodate a larger than anticipated tritium off-gassing rate; the development of novel waste assay methods for tritium impregnated particulate; and the identification of further aqueous waste reprocessing capacity as a desirable longer term objective. In each of these cases remedies were either identified and successfully implemented or solutions are currently being developed.

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