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Management of Operational Active Wastes on JET

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ABSTRACT.

During Tokamak operationson JET, activation of the first wall components will occur. Subsequent intervention and maintenance work on the machine will result in the generation of same active wastes.

Activity levels of first wall components and in the vacuum vessel are low during D-D operations and all maintenance and associated waste handling tasks can be carried out using hands ontechniques. Activation resulting from the production of 14MeV neutrons during tritium pulses in the D-T phase will necessitate the use of remote handling equipment for maintenance and waste handling.

In addition to the constraints imposed by activation products and tritium, waste management will be affected by the presence of beryllium to be used as a first wall material from 1989.

Studies have been carried out to estimate the volumes and characteristics of the wastes generated in both the D-D and D-T phases. The disposal options for the differing waste streams have also been investigated.

The conceptual design of facilities for active handling and waste management tasks, required for the support of torus maintenance and intervention work, has been completed and the detail design is scheduled for ccmpletion in April 1989. These facilities, which include areas for decontamination of tools and equipment, equipment maintenance and storage, will be operational before the start of the DT phase.

A quality assurance plan has been developed for the identification and safe disposal of the active wastes.

2. INTRODUCTION

JET plasma operations will be carried out with hydrogen and deuterium until the end of 1991, after which tritium will be progressively introduced to the torus. Commissioning of the active gas handling plant with tritium will commence prior to this in 1991. During the tritium phase, maintenance and waste handling operations will be affected, not only by the presence of tritium, but also by beryllium particulate and activation products. The main systems involved will be the torus, the active gas handling system (AGHS), the gas introduction system - including a multi-pellet injector - the main vacuum circuit and the neutral beam injection system.

All JET maintenance and waste handling tasks can be conducted using hands-on methods until the start of the D-T phase. Subsequently, extensive remote handling will be necessary.

3. OPERATIONS AND MAINTENANCE PROGRAMME

Planning work at JET, involving active waste handling, has to take account of the separate constraints imposed by tritium, activation products and beryllium.

The programme for the JET operations phase is summarised in the time-table shown in Figure 1. Tasks which will produce potentially active wastes during the D-D phase, are mainly restricted to the vacuum vessel. These involve modification to the vessel internal components to meet the physics objectives of the operational programme.

In the final shutdown before the introduction of tritium, the machine will be modified with the objective of reducing routine maintenance to a minimum during the D-T phase. Several diagnostic systems will be removed from the machine at this time. Provision must be made, however, for component waste arisings from unscheduled maintenance. This material will be both activated and tritium contaminated. The JET responsibility for active waste management covers the wastes generated during the operational period of the Machine. Decommissioning of JET and management of the decommissioning wastes, is the responsibility of the Host Organisation (UKAEA).

4. SOURCES OF ACTIVITY IN WASTES GENERATED AT JET

4.1 D-D Operations

Activation of the Inconel 600 vacuum vessel during operations with hydrogen plasma is due to isotopes being generated by photo-nuclear (γ,n) reactions and by the interactions of neutrons produced in such reactions. Following an initial dominance by Ni 57, the in-vessel dose rate is mainly due to Co 56, Co 57, Co 58 and Ni 56 [1]. For D-D operations the main neutron source is the D-D fusion reaction. The principal activities induced in the vessel walls and the resulting dose rates within the torus at shutdown have been calculated [1]. From a neutron source of 10^{20} n (2.45 MeV) in one year, in-vessel dose rates > 300 μSvh^{-1} would be expected one week after shutdown. JET policy is to restrict the dose burden to radiation workers to 5 $mSva^{-1}$, and for this reason the neutron flux during D-D operations will be limited to < 3×10^{19} n, resulting in an in-vessel dose rate < 100 μSvh^{-1}.

4.2 D-T Operations

The JET tritium systems will have a maximum inventory of 90 g of tritium with a maximum daily throughput of $\sim$ 30 g of tritium.

During plasma operations with tritium, the activation of the machine was initially calculated on the basis of 10^{24} neutrons emitted at 14 MeV during a total of 10,000 shots over 2 years [1]. At decay times between one month and one year, the vacuum vessel activation is due mainly to Co 58, but at longer decay times Co 60 is dominant. Surface dose rates of 1.7 Svh^{-1} have been calculated [1] at one month after shutdown for the outer vessel wall. Inner wall levels will be increased by a factor of 2. These levels clearly rule out man access for in-vessel maintenance.

Significant activation of other machine components will also occur during this phase of operations, and whilst the levels will be lower, they will have an impact on both the maintenance programme and waste handling.

Whilst activation estimates based on 10^{24} neutrons are used for shielding calculations and worst case maintenance scenarios, following revisions to the planned D-T operations period, the estimates of active waste arisings have been based on a total neutron production of 10^{23}. This will result in some reduction of the quoted dose rates.

5. OPERATIONS WITH BERYLLIUM

Protection tiles on the vessel inner wall, the belt limiter and R/F antennae have in the past been made from graphite. These will be replaced in 1989 with beryllium tiles. Four beryllium evaporators have been installed during the 1988/89 shutdown. Beryllium combines the characteristics of low Z with favourable thermal conductivity and fairly good resistance to thermal shock. A total of over 1300 tiles, representing $\sim$ 3 tonnes of beryllium metal are involved.

Following the installation of beryllium components in the vacuum vessel, subsequent intervention will be affected by the potential presence of beryllium dust.

The requirements for the safe handling of beryllium contaminated components will be superimposed on those for active and tritiated components.

6. WASTE ARISING AND COMPONENT HANDLING

Waste materials generated during D-D operations, which are contaminated with activation products or beryllium, can all be handled hands-on and disposed of via existing routes in the U.K. Typical components are listed in Table 1.

Active waste arisings during the D-T phase on JET can be grouped into the following categories:

i) Process wastes consisting of tritiated compounds from the active gas handling system (AGHS). The arisings of this category are presently under review.

ii) Component wastes consisting of contaminated/tritiated/activated solid components removed from the JET machine and its auxiliaries, generally of Inconel, stainless steel or other metals.

iii) Non-aqueous liquid wastes consisting mainly of oil from the turbomolecular vacuum pumps.

iv) Housekeeping wastes consisting of protective clothing, swabs, plastic covers etc, used in maintenance work and lightly contaminated.

v) Bulk tritiated water too large in quantity to process in the AGHS or discard on molecular sieve beds. For a proportion of this the tritium level may not allow discharge.

The waste arisings will result from maintenance work on the machine and active handling support operations, including remote handling equipment decontamination and maintenance. Whenever possible, a maintenance intervention will be preceded by a vessel bakeout at 350°C and glow discharge cleaning (GDC) in D_2. Under these conditions, the remote handling equipment deployed in the vessel is estimated to pick up a tritium surface contamination of 10 Bq/cm². Without such treatment of the torus, the equipment may absorb up to 2×10^6 Bq/cm².

Studies have been carried out at both JET and Harwell (United Kingdom Atomic Energy Authority) to identify the expected waste arisings in these categories, to characterise them and to investigate the options for treatment, storage, transport and disposal.

A study to establish the potential arisings of housekeeping and process wastes has also been completed. Table 2 summarises the waste volumes expected in the various categories. The figures represent first estimates and on-going modifications to the plant, in particular the cooling water systems, are expected to result in some volume reductions. Items falling into the category of component waste are similar to those listed in Table 1.

During D-T operations, however, the activation from 14 MeV neutrons will result in many ex-vessel and diagnostic components becoming active. The activity level of 12 GBq t^{-1} represents the threshold between ILW and LLW.

The waste list does not include structural components of the machine which will not be removed during the operational phase. These will be classified as decommissioning wastes. Typical in-vessel components requiring maintenance are illustrated in Figure 4. These include the belt limiter, protection tiles and A_1 antennae.

Maintenance during the D-T phase including handling of the waste components, some of which will have dose rates > 180 $mSvh^{-1}$, at 3 m, will be part of the JET remote handling programme. This has been described in several papers including one by A. Rolfe [2].

7. JET FACILITIES FOR WASTE HANDLING AND ACTIVE MAINTENANCE

Intervention work and waste handling during the D-D phase are carried out in the integrated facilities of the torus access cabin (TAC) [3] shown in Figure 2.

In addition to the torus hall and hot cell areas shown in Figure 3, extra facilities will be required for the support operations associated with the waste management. These areas will be constructed prior to the introduction of tritium.

The new active handling facility, to be built in the assembly hall, adjacent to the hot cell, will have dedicated areas for the following tasks:

- equipment decontamination
- warm workshops
- storage of RH equipment
- suit change area
- suit maintenance and cleaning area
- transit store for LLW
- interim shielded store for ILW and tritiated waste
- transfer airlock between hot cell and new area
- main change area.

The configuration of the control area will enable operations to be carried out consistent with the requirements of ALARA, whereby the dose burden to the personnel is kept to a minimum. Active or tritiated components removed from the machine will be transported to the hot cell using remote operations. There will be no routine decontamination of components, and after monitoring these will be stored in a shielded area within the hot cell. Heavily contaminated RH equipment will undergo an initial decontamination in the hot cell - using remote equipment - before transfer to the unshielded area for hands-on repair.

In addition to the new areas for active handling, a holding tank system for collection and sentencing of aqueous liquid waste will be constructed prior to the D-T phase.

Operational arisings of component wastes which fall into the ILW category, or contain levels of tritium > 2.22 GBq/m^3 will be stored at JET in the hot cell or the AGH plant. At the present time in the U.K. only LLW may be disposed of to an active waste repository - at Drigg. The conditions for acceptance of waste materials only make provision for low levels of tritium < 2.22 GBq/m^3, and any tritium must be retained within the package for a period of at least 10 years.

Following completion of the Harwell preliminary study on the transport, treatment and disposal of active wastes from JET, a number of areas have to be addressed with regard to the waste arisings. The reduction of tritium levels in component wastes will enable a greater proportion to be classified as LLW and meet the conditions for acceptance at Drigg. Although additional delay tank storage capacity will be provided for the D-T phase, a review of the cooling water systems has resulted in modifications which should significantly reduce the arisings of tritiated water.

A Q/A system for the management of LLW has been established at JET. Q/A of the waste streams will also be used to identify the location of the tritium inventory in the plant. The data produced will be used in the assessment of methods for equipment decontamination, with the objective of minimising secondary waste arisings. A test programme has been carried out at the TSTA facility in Los Alamos using JET RH equipment, to investigate the uptake of tritium to be expected during maintenance [4]. This work, together with other studies, will provide data on possible methods for decontamination of the RH equipment.

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REFERENCES

1. A.F. AVERY, "Dose Rates and Inventories of Active Isotopes at JET", Winfrith AEEW - R 1615, March 1987.

2. A.C. ROLFE, "Remote Maintenance of the JET Tokamak", JET-P(86)03, March 1986.

3. S.J. BOOTH, "Contact Maintenance on JET into the Active Phase", Transactions of ENC-4, Geneva, June 1986.

4. A. TESINI, R.A. JALBERT, Experimental Contamination and Decontamination Studies on JET Remote Handling Tools and Materials when Exposed to Tritium, JET-R(88)18.

SJB/mw/U/152-14.03.89

TABLE 1

ESTIMATED ARISINGS OF ACTIVE WASTES DURING JET D-D OPERATIONS (6-88 TO 6-91)

CATEGORY	ACTIVITY OR CONTAM.	WASTE TYPE	VOLUME(M^3) A (MEAN)	B (MAX)	C
1. Solid Waste					
1.1 Components(e.g. tiles,screens, protection plates,limiters etc.)	v. low activity + beryllium	LLW(*1)	20	30	30
1.2 Housekeeping(e.g. clothing,swabs, plastic wrapping etc.)	v. low activity + beryllium	LLW(*2)	85	128	77
2. Liquid Waste					
2.1 Washing water(ex-vessel)	suspect particulate activity + beryllium contam.	-	320		
2.2 Washing water(special tools, boom end-effectors)	higher levels of contam.	LLW(*2)	2		

NOTES:

*1: Specific activity between 100Bq/g and 12GBq/te

*2: Specific activity between 0.4Bq/g and 100Bq/g

A : Mean expected operational arisings of conditioned waste (compacted) at JET

B : Outright max. estimated operational arisings for transfer to Harwell

C : Resulting estimated waste volume for disposal to Drigg via Harwell

TABLE 2 (A)

ESTIMATED ARISING OF ACTIVE WASTES DURING D-T OPERATIONS

Category	Activity	Tritium Level	Volume
Components	$>$ 12 GBq/t $>$ 10 years	$>$ 3.7 GBq/m^3	0.8 m^3
Components	$>$ 12 GBq/t $<$ 1 month	$\sim$ 3.7 GBq/m^3	139 m^3
Housekeeping	$>$ 12 GBq/t $<$ 1 year	$<$ 3.7 GBq/m^3	7 m^3
Housekeeping	$<$ 12 GBq/t (LLW)	Trace levels	8 m^3
Non-aqueous Liquid	Minimal	$>$ 740 GBq/m^3	2 ℓ

TABLE 2 (B)

ESTIMATED ARISINGS OF AQUEOUS ACTIVE WASTES DURING D-T OPERATIONS

Category	Tritium Level	Volume
ROUTINE ARISINGS		
Air Conditioning System	50 MBq/ℓ	40 m^3/yr
Exhaust Detritiation System	75 MBq/ℓ	20 m^3/yr
Decontamination Waste	10 KBq/ℓ	55 m^3/yr
Decontamination Waste	Trace levels	50 m^3/yr
POSSIBLE SINGLE EVENT INCIDENT ARISINGS		
Air Conditioning System	$\leq$ 10 GBq/ℓ	2 m^3/event
Exhaust Detritiation System	$\leq$ 90 GBq/ℓ	1 m^3/event
Exhaust Detritiation System	$\leq$ 3.7 TBq/ℓ	5 m^3/event
Cooling Water Leaks		
PF Circuit	$\leq$ 37 MBq/ℓ	2 m^3/event
NIB	$\leq$ 0.67 TBq/ℓ	5 m^3/event
PINI	$\leq$ 75 MBq/ℓ	5 m^3/event
Vacuum Vessel Leak	$\leq$ 18 GBq/ℓ	5 m^3/event

NOTE: All cooling water may contain up to 200 Bq/ℓ of activation products. Decontamination waste may contain some residual beryllium, activated or tritiated particulate.

FIG 1

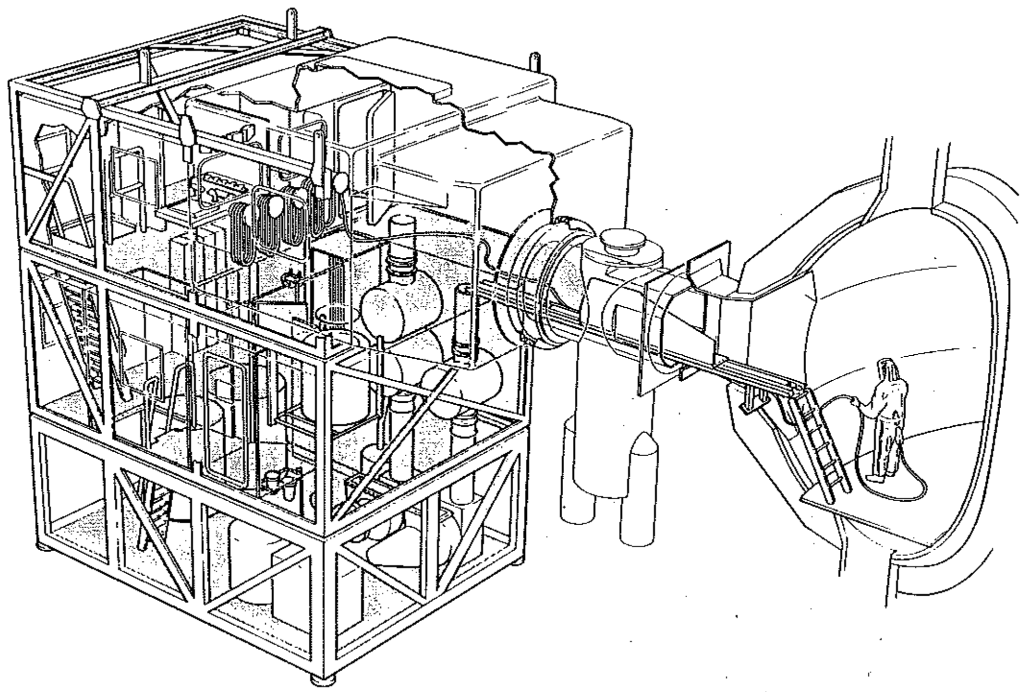
JET PROGRAMME (Revised January 1989)

1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
PHASE I		PHASE IIA		PHASE IIB		PHASE IIIA		PHASE IIIB	PHASE IV
Ohmic Heating Studies		Additional Heating Studies				Full Power Optimisation Studies			Tritium Phase

Ohmic Systems	5MA	Vessel restraints and improved volt-seconds for 7MA operation	Vessel reinforcements			
Separatrix		Additional P1 Coils	Separatrix dump plate supports		Cooled separatrix dump plates	
Limiters	Eight carbon mid-plane limiters	Carbon belt limiters	Beryllium belt limiters			
Pellets	Single pellet injector	ORNL multiple pellet injector ($1.5 km s^{-1}$)		Prototype high speed pellet injector ($>3 km s^{-1}$)	Multiple high speed pellet injector	
Pump limiters					Pumped Divertor	
NBI	First NBI line (80kV)	Second NBI line (2×80kV)	One line modified to 140kV D		Second line modified to 140kV D	One line modified to 160kV T
ICRH	Three A_0 antennae	Eight A_1 antennae		Be antennae Screens		
LHCD			Install Vacuum Chamber	Prototype system	Full system	
Disruption control					Saddle coils	
Tritium and Remote handling					Tritium plant and main RH modifications	Final modifications

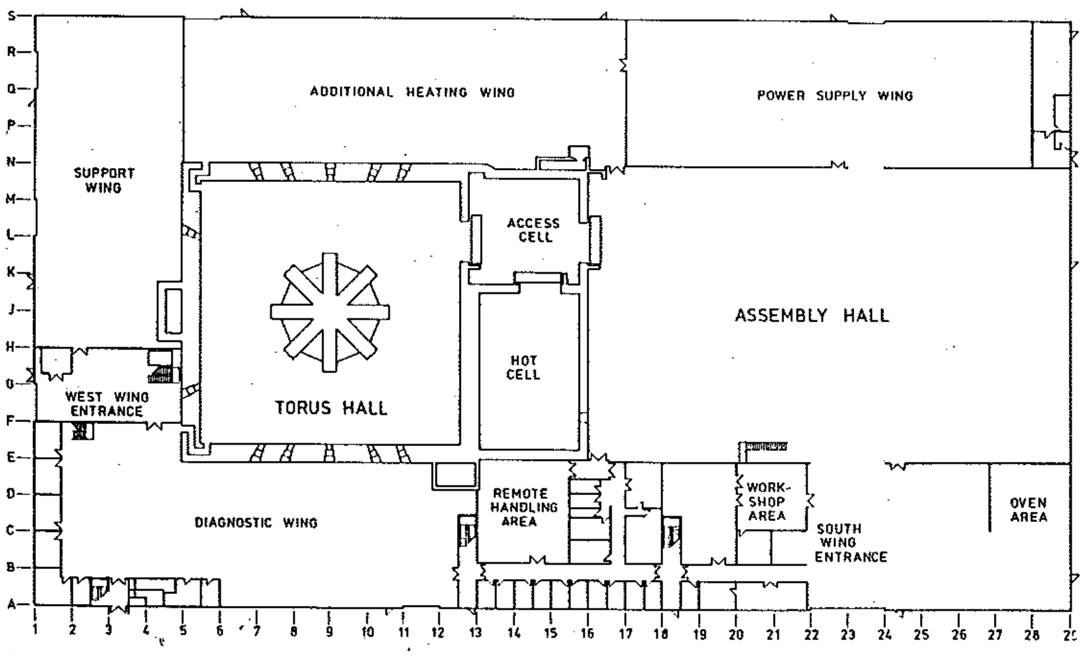
CR88.2 (rev.5/1/89)–Ro1540, H1.P CR86.2.2b

FIG 2



JET TORUS ACCESS CABIN

FIG 3



Plan view of main JET building

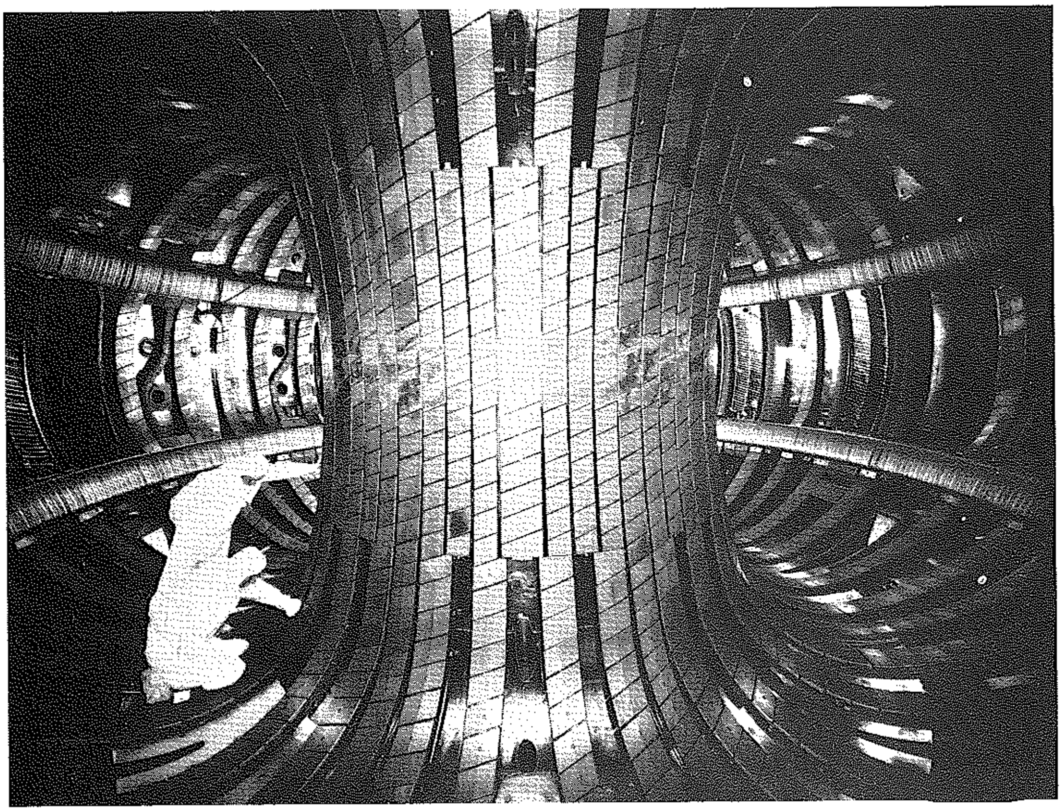


Fig 4 Vessel internals after 1987 shutdown

APPENDIX 1.

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