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**ITER SAFETY TASK NID-5A. SUBTASK 1-1:  
SOURCE TERMS & ENERGIES - INITIAL TRITIUM SOURCE  
TERMS. FINAL REPORT.**

**VOL. I of III**

**CFFTP G-9508  
February, 1995**

C. Fong<sup>1</sup>, K.M. Kalyanam<sup>1</sup>, M.R. Tanaka<sup>1</sup>, S. Sood<sup>1</sup>, A. Natalizio<sup>2</sup>, M. Delisle<sup>3</sup>  
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## 1.0 SUMMARY

A user friendly tritium enclosure model (TEM) was developed as an interface to the ITER approved TMAP4 code. Correlations for the interaction of tritium with epoxy painted surfaces were derived from experiments performed at TSTA, and were loaded into TEM in order to account for the effects of surface interactions.

A number of ITER relevant accident scenarios were studied to determine the effectiveness of cleanup systems in mitigating tritium releases and to study the effect of surface adsorption/desorption on effluent releases.

Accident scenarios were selected on the basis of greatest possible consequence. Thus various Loss of Coolant Accidents (LOCA's), breach in the Vacuum Vessel and accidents in systems with high tritium inventories were analyzed. As an exception to this general rule, accidents in the water distillation systems were studied, as the oxide form of tritium in water distillation is much more radiotoxic than elemental tritium.

The specific events analyzed were, ex-vessel LOCA, in-vessel LOCA, LOVA, torus exhaust line failure, fuelling machine process boundary failure, fuel processing system process boundary failure, water detritiation process boundary failure, and isotope separation system process boundary failure.

The mobile inventories were taken from results of ITER Task NID 3b. After defining the scenarios and using the mobile inventories, TEM was used to estimate initial environmental source terms.

For each scenario there are 4 TEM combinations that must be run:

- 1) No surface interactions without a cleanup system,
- 2) Surface interactions with a cleanup system,
- 3) No surface interactions with a cleanup system,
- 4) Surface interactions without a cleanup system.

The objective of this report was to use TEM to determine environmental source terms for the above accident scenarios and to determine the effects of cleanup systems in mitigating the source terms and assess the impact of surface interactions on the source terms.

In the cases with an efficient cleanup system, the source terms represent a lower bound. In the same cases analyzed without an efficient cleanup system the source terms represent an upper bound. Together the cases frame a likely environmental source term range.

In completing this study it has been demonstrated that TEM is useful for analyzing tritium accidents and determining environmental source terms from these accidents. Also it has been

confirmed that efficient tritium cleanup systems are essential in mitigating the effects of acute events. It was shown that adsorption of tritium on painted surfaces can attenuate the initial environmental source terms, however, this probably has an adverse impact on occupational exposure.

As environmental source terms are design specific, further analysis must be performed when ITER design parameters are changed as a result of detailed design of various systems.

## 2.0 INTRODUCTION

This is the final report for NID Task 5a - Subtask 1-1, Source Terms and Energies - Initial Tritium Source Terms.

The overall objective of the Early Safety and Environmental Characterization Study (ESECS) is to assess the environmental impact of tritium using appropriate assumptions on a hypothetical site for ITER, having the "reference" site characteristics as proposed by the JCT.

The objective of this Work under the above Subtask 1-1, NID-5a, is to determine environmental source terms (i.e., process source term x containment release fraction) for the fuel cycle and cooling systems.

The Work is based on inventories and process source terms (i.e., inventory x mobilization fraction), provided by others (under Task NID 3b). The results of this Work form the basis for the determination, by others, of the off-site dose (i.e., environmental source term x dose/release ratio).

For the determination of the environmental source terms, the TMAP4 code has been utilized [ref 1]. This code is approved by ITER for safety assessment.

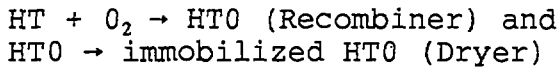
The Scope of Work includes the following items:

- Item 1: Incorporation of available surface characteristics (adsorption and desorption) for a typical enclosure surface into the TEM (TMAP4) Code.
- Item 2: Analysis of tritium release scenarios as described in Section 4.0 of this report.
- Item 3: Determination of environmental source terms (i.e., process source term x containment release fraction) for ITER Fuel Cycle and Cooling System, using the updated TEM code where appropriate.

### 3.0 BACKGROUND

#### 3.1 TEM Code

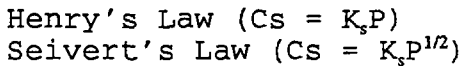
The TEM model consists of 7 functional enclosures and one boundary enclosure. There are 10 links between the functional and boundary enclosures. Four enclosures act as recombiner/dryer systems where:



The model allows for a variable efficiency for recombiner and dryers.

T<sub>2</sub>, HT, HTO, O<sub>2</sub> and H<sub>2</sub>O are modelled as distinct species. Enclosures can incorporate up to 4 diffusion/thermal segments each. Each segment can be assigned an independent area and thickness. The segment is modelled by 10 nodes equally spaced over the thickness plus two nodes acting as 'surfaces' for left and right sides. The right hand side of each segment is defined as a 'noflow' boundary. The left side is open to the enclosure and boundary conditions may be defined as:

#### Recombination/Dissociation Rates



Solubility rates and diffusivities may be defined independently for each species but only one boundary condition may be assumed for each surface. Mobile concentrations at each node may be defined in terms of number of molecules per cubic meter. There may either be no interaction between species or in three of the ten enclosures, the following reactions can be modelled:



Where the reaction rate is given by:

$$k = 2 \times 10^{-29} \cdot C_{\text{T}_2} \times (\text{inventory of tritium species})$$

$$k = 1 \times 10^{-29} \cdot C_{\text{HT}} \times (\text{inventory of tritium species})$$

TEM output can be automatically written to an Excel spreadsheet file. This facilitates data processing and the production of graphs.

### 3.1.1 Code Validation

To validate the windows interface to TMAP (TEM or tritium enclosure model), the case described in Appendix 3 of the TMAP users guide was used as it had already been validated against TSTA data.

For the TMAP sample case, a release of 10 Ci of  $T_2$  into a  $0.96 \text{ m}^3$  room with a painted surface of epoxy approximately 0.16 mm thick and with surface area  $5.6 \text{ m}^2$  was modelled. The flow into and out of the room was set at  $1.5 \times 10^{-4} \text{ m/s}$ .

The reaction  $H_2O + T_2 \rightarrow HT + HTO$  and  $H_2O + HT \rightarrow HTO + H_2$  was modelled as in the TMAP example.

Two cases for surface thickness of 1.6 and .16 mm thickness were considered at 1 and 10 hours each. The inventories of species  $T_2$ , HT, HTO,  $H_2O$  and  $O_2$  were compared for both the TMAP input deck case and the TEM model. The inventories matched exactly.

### 3.2 Pre-Screening Study

Prior to performing analysis using the TEM Code, a pre-screening study, shown in Appendix 1, was performed. The objective of the study was to generate environmental release fractions following an acute tritium release into a tokamak or tritium building room.

The tritium environmental releases following an acute release into a room will depend on several factors, including:

- a) the chemical and physical form of the tritium (ie., whether it is in the elemental or oxide form, and, if in the oxide form, whether it is in the vapour or liquid state),
- b) the size of the room,
- c) the room ventilation system including air detritiation, and
- d) other liquids or gases accompanying the tritium.

Attenuation mechanisms such as surface plateout (sorption) is not significant for tritium in the elemental form, but may be significant for tritium in the oxide form. Conversion of HT to HTO is not significant for short time scales.

Five typical release scenarios were assessed:

- a) a release of 200 g of tritium gas, which is representative of fuel cycle events - a dry release,

- b) a release of 1,000 g of tritium gas accompanied with wet steam, which is representative of in-vessel LOCA's - a wet release,
- c) a release of 50 g of tritium in the form of HTO vapour, which is representative of ex-vessel LOCA's,
- d) a release of 0.5 g of tritium in the form of HTO vapour, which is representative of ex-vessel leaks, and
- e) a release of 5 g of tritium in the form of HTO liquid, which is representative of water detritiation system events.

Scenario a) does not generate a room overpressure, whereas b) does, hence, release fractions will be available for pressurized and non-pressurized room conditions. Similarly scenario c) will have a room overpressure, but scenario d) will not; and there is no overpressure for scenario e). These scenarios are discussed further under the following headings in Appendix 1:

- Acute Tritium Gas Release with No Room Overpressure,
- Acute Tritium Gas Release with Room Overpressure,
- Acute Tritium Vapour Release with No Room Overpressure.
- Acute Tritium Vapour Release with Room Overpressure,
- Acute Tritiated Water Release.

### 3.2.1 Environmental Release Fractions

The environmental release fractions for an acute release of tritiated water are:

- a) 2.8% per day for the ventilation pathway,
- b) 0.0036% per day for the leakage pathway, and
- c) 0.00036% for the detritiation pathway.

The tritium environmental release fractions, for the first day of releases, are given in the following table.

Release Scenario	Ventilation Pathway	% Released in 1 Day	
		Leakage Pathway	Detritiation Pathway
Acute Tritium Gas Release with no Room overpressure	100	1	.01
Acute Tritium Gas Release with Room Overpressure	100	10	.01
Acute Tritium Vapour Release with no Room Overpressure	100	1	0.1
Acute Tritium Vapour Release with Room Overpressure	100	5	0.1
Acute Tritiated Water Release	2.8	0.0036	0.00036

The above results are based on the following assumptions:

- a) room leakage is 1%/day for unpressurized conditions and 10%/day for pressurized conditions,
- b) room ventilation (and detritiation) flow rate is 8 volumes/day,
- c) detritiation system efficiency is 99.9%.

The following observations can be made from the above table:

- a) The normal building ventilation system ensures that environmental releases will be "elevated releases", but does not provide any attenuation. Of course, the purge flow from this system could be sent to the exhaust gas detritiation system, where significant (factor of 1000) reductions in environmental releases would occur.
- b) Room isolation appears to provide at least a factor of 10 reduction, relative to unrestricted purging via the ventilation system, for pressurized rooms and a factor of 100 for unpressurized rooms. Hence, room isolation is a key mitigating system for tritium releases of all types.

- c) Room air detritiation provides at least a factor of 1000 reduction, relative to unrestricted purging via the ventilation system.

Clearly, these observations apply to the specific conditions and assumptions made in the calculations, therefore, care is required in applying these results to conditions that are significantly different.

Based on the above pre-screening study, the above scenarios were re-analyzed to determine tritium releases more rigorously using the TEM Code. The effect of including surface adsorption, desorption was also assessed.

#### **4.0           EVENTS ANALYZED**

Events that would result in the release of tritium are as follows:

- a) Cooling System Pipe Break (ex-vessel LOCA);
- b) First Wall, or Diverter Tube Rupture (in-vessel LOCA);
- c) Vacuum Vessel Boundary Breach (LOVA);
- d) Torus Exhaust Line Failure;
- e) Fuelling Machine Process Boundary Failure;
- f) Fuel Processing System Process Boundary Failure;
- g) Water Detritiation System Process Boundary Failure;
- h) Isotope Separation System Process Boundary Failure;

This list covers releases in most areas of the facility, therefore, it provides a good starting point for estimating the initial environmental source terms.

#### **5.0           DESIGN ASSUMPTIONS**

##### **5.1           Ventilation and Detritiation**

###### **5.1.1        General**

It is assumed that the design intent is to prevent the uncontrolled leakage of radioactivity from the building. Therefore, non-active areas inside the building will be maintained at a slight negative pressure with respect to atmosphere. Likewise, active areas will be maintained at a slight negative pressure with respect to non-active areas. The concept is illustrated in Figure 1. (Appendix 1)



### **5.1.2 Non-Active Areas**

As shown in Figure 1, non-active areas are assumed to be served by the building ventilation system. This is the normal heating and air conditioning system, with a large recirculating flow and a small purge flow to make up for building in-leakage. Normally the purge flow is exhausted to the stack, however, if the radioactive contamination reaches the non-active areas, then the purge flow will be directed to the exhaust flow detritiation system.

### **5.1.3 Active Areas**

As shown in Figure 1, active areas are assumed to be served by the active area detritiation system. It is further assumed that the system has a recirculating flow of 5000 m<sup>3</sup>/h as per the latest ITER-JCT Naka design [ref 5]. A small purge flow is required to maintain the active areas under negative pressure relative to non-active areas. This purge flow is directed to the exhaust flow detritiation system.

Normally, the system is on stand-by, but will operate intermittently, on pressure reduction mode, to maintain the pressure within the specified range.

After a tritium release, the system will operate in a clean-up mode and will remain operational until the tritium concentration in the room or compartment has reached the required value.

### **5.1.4 Cryostat Detritiation System**

Figure 1 shows a schematic of the proposed Cryostat Detritiation System. The recirculating flow is also assumed to be 5,000 m<sup>3</sup>/h. This system is only used in the clean-up mode, only when the pressure in the cryostat is near atmospheric.

### **5.1.5 Exhaust Flow Detritiation System**

As shown in Figure 1, this system is assumed to receive a purge air flow from the building ventilation system (under accident conditions only), the cryostat detritiation system (under accident conditions only) and the active area detritiation system under normal conditions. However, this system will also receive a purge flow from the glove box clean-up system, the cryostat vacuum pumps, the isotope separation cold box vacuum pumps (under accident

conditions), and others. As there are a large number of users of this system, it is assumed that it will be a continuously operating system. The overall design capacity of this system is assumed to be 500 m<sup>3</sup>/h.

#### **5.1.6 Recombiner Efficiency**

Each detritiation system described above will have a hydrogen recombiner to ensure that elemental tritium will be converted to the oxide form so it can be captured by the molecular sieve dryers. The recombiner efficiency is assumed to be 99.95%, based on efficiencies that are achievable with available catalytic recombiners. This efficiency has been assumed to remain constant over the very large concentration range during detritiation. In reality, it is expected that the efficiency will decrease at very low concentrations of tritium (ppb levels). However, the effect on tritium releases is expected to be insignificant.

#### **5.1.7 Dryer Efficiency**

Each detritiation system described above will be equipped with molecular sieve dryers to capture tritiated water vapours. The dryer efficiency is assumed to be 99.95%.

### **5.2 Tritium Confinement**

All process components in direct contact with tritium are assumed to have a secondary confinement boundary (the first being the process boundary itself). The secondary boundary may be a glove box, a cold box, a second conduit (pipe) or vessel, or a sealed room (caisson).

### **5.3 Water Detritiation system**

The water detritiation system is assumed to comprise a water distillation unit and a vapour phase catalytic exchange unit [ref 4]. All process components of the water distillation unit, which handles high concentration liquids and vapours, are assumed to be contained in a caisson. All process components of the vapour phase catalytic exchange unit, which handles gases, are assumed to be contained in glove boxes.

#### **5.4 Isotope Separation System**

It is assumed that the cryogenic distillation columns will be contained inside a cold box, which is held under a hard vacuum [ref 4]. This vacuum is required for operation of the ISS. All other components of the system will be contained in glove boxes.

#### **5.5 Cooling System Inventory**

It is assumed that the total coolant inventory is 700 m<sup>3</sup> (500 for shielding blanket and 200 for diverter). Assuming that there are 4 shielding blanket cooling loops (rather than 12, as is the current thinking), then the maximum discharge from a single loop will be 125 m<sup>3</sup>. Hence, the amount of tritium that can be released from a single loop failure is 125,000 Ci (125,000 kg \* 1 Ci/kg = 125,000 Ci). Similarly, if there are 4 diverter cooling loops, then the maximum discharge from a single loop will be 50 m<sup>3</sup> or 500,000 Ci (50,000 kg \* 10 Ci/kg = 500,000 Ci). It is assumed that the amount of tritium discharged will be at most 500,000 Ci, as HT0.

#### **5.6 Room Volumes**

When tritium is released into a room/area/zone of unknown size (because the design has not progressed that far) it is arbitrarily assumed that the room volume is 1,000 m<sup>3</sup>. When design information becomes available, then the appropriate volume will be inserted into the analysis. Whether the volume is 1,000 or 10,000 m<sup>3</sup> should not significantly affect the environmental source terms.

### **6.0 ANALYSIS ASSUMPTIONS**

#### **6.1 Ex-Vessel LOCA**

An ex-vessel LOCA can occur in the cryostat or in the cooling system equipment rooms.

##### **6.1.1 Ex-Vessel LOCA Inside Cryostat**

A cooling system pipe break inside the cryostat is not expected to cause the pressure in the cryostat to exceed the design pressure, due to the high vacuum and cold masses contained within it. However, it may not be possible to exclude the possibility that a coolant pipe break could cause damage to one or more cryostat penetrations, in which case a leakage path would be established to the active areas of the building. For this

reason, it is assumed that cryostat penetrations will terminate in rooms served by the active area detritiation system. Furthermore, for leakage to occur, the pressure inside the cryostat must increase to atmospheric pressure. When this happens, the atmosphere inside the cryostat can be cleaned up using the cryostat detritiation system. Therefore, there is redundancy even if there is an impairment of the cryostat boundary. Hence, a release of tritium inside the cryostat can be:

- a) contained within the cryostat, if the pressure does not immediately or quickly rise above atmospheric pressure (most likely outcome),
- b) mitigated by the cryostat detritiation system once the pressure has reached atmospheric, or
- c) mitigated by the active area detritiation system, if there is leakage from the cryostat to an active area (failure of penetration) and the cryostat detritiation system is unavailable.

Failure of both the cryostat detritiation system and the active area detritiation system is not considered credible.

For case a) there will be no significant environmental release, hence, no further analysis is required. Releases during the cryostat clean-up period will be bounded by case b).

For case b) it is assumed that the exhaust flow from the cryostat will be an upper bound of 1% of the cryostat volume per day (ie., 200 m<sup>3</sup>/day). This exhaust flow has to be made up by leakage into the cryostat, hence, it is considered to be a pessimistic upper bound, given that the cryostat boundary remains intact. As the cryostat detritiation system is assumed to not be designed for high vacuum operation, it can only be started once the cryostat pressure reaches close to atmospheric. The model for this case is shown in Figure 2a.

For case c) it is assumed that the exhaust flow from the cryostat will be an upper bound of 10% of the cryostat volume per day (a hypothetical upper bound). The exhaust flow is assumed to be ten times greater than in case b) given that the cryostat boundary is assumed to be breached and inleakage from the penetration termination room would dominate (the room is not designed for high vacuum operation as is the cryostat). As noted above, either the cryostat detritiation system or the active area detritiation system could be used. For the purposes of this analysis, it does not matter which is used. The need for the cryostat detritiation

system would be evident soon after the LOCA. Equally, a high tritium, and/or a high pressure, alarm in an active area would signal the need for the active area detritiation system. The model for this case is shown in Figure 2b.

### **6.1.2 Ex-Vessel LOCA Inside the Cooling System Equipment Rooms**

Following a coolant pipe break inside the equipment rooms, the pressure will quickly rise and slow leakage from the room will result. In the long-term (hours after the break) the pressure will return to atmospheric due to condensation of the steam. For the purposes of this analysis, it is assumed that pressure equalization occurs at eight hours after the accident; and at this time the active area detritiation system will be used for clean-up of the room. Therefore, leakage to active areas of the building will occur only during the overpressure transient (assumed to be 8 hours).

Three leakage rates will be considered in the analysis (1, 10 and 100% of the cooling system equipment room volume per day). These leakage rates correspond to 10, 100, and 1,000 m<sup>3</sup>/day, on the assumption that the cooling system equipment room has a volume of 1,000 m<sup>3</sup>. To keep accident pressures to reasonable levels, it is more likely that the volume would be closer to 10,000 m<sup>3</sup>. The above leakage rates set the exhaust flowrates for the building ventilation system, which directs the purge flow to the exhaust flow detritiation system. To ensure that even the largest leakage rate can be accommodated, a purge flow of 50 m<sup>3</sup>/h is assumed for the building ventilation system.

After 8 hours, the active area detritiation system is started and a purge flow of 50 m<sup>3</sup>/h will maintain the cooling system equipment room under negative pressure, relative to its surroundings, hence, leakage from the room is reversed and inleakage will occur thereafter.

The model to be used in the analysis is shown in Figure 3.

## **6.2 In-Vessel LOCA**

There are two LOCAs to consider: a small LOCA and a large LOCA.

### **6.2.1 Small In-Vessel LOCA**

The small in-vessel LOCA is the more severe, if it is assumed that the discharge of steam into the vacuum vessel is just at the right flow to optimise the steam/metal reaction with the first

wall or divertor. The steam/metal reaction will produce heat and hydrogen. The heat will cause tritium imbedded into the first wall to be released into the vacuum vessel. The scouring action of the steam jet will also cause tritium laden dust on the surface of the first wall to become airborne. The pressure inside the vacuum vessel will rise above atmospheric pressure, but will remain below the design pressure of the vacuum vessel. The pressure will eventually peak and the overpressure will diminish as heat is removed from the unbroken loops and the shield cooling system.

The amount of leakage from the vacuum vessel to the cryostat will depend on the magnitude and duration of the overpressure. But, as long as the leakage is into the cryostat there will be no significant environmental release and will not be considered further in the analysis.

However, due to the fast temperature and pressure excursion, it may not be possible to exclude the failure of a vacuum vessel window, which could cause tritium and tokamak dust to be transported directly to the outside of the vacuum vessel and cryostat, into the penetration termination room. If the breach is into the cryostat, as above, there will be no significant environmental release, hence, it will not be considered further.

The amount of leakage from the penetration termination room into the non-active areas of the building will depend on the magnitude and duration of the overpressure. It is assumed that the overpressure will last for eight hours. During this period, the building ventilation system exhaust will be directed to the exhaust flow detritiation system.

Three leakage rates will be considered in the analysis (1, 10 and 100% of the penetration termination room volume per day). These leakage rates correspond to 10, 100, and 1,000 m<sup>3</sup>/day, on the assumption that the room has a volume of 1,000 m<sup>3</sup>. The last represents a hypothetical upper bound. These leakage rates set the exhaust flowrates for the building ventilation system, which directs the purge flow to the exhaust flow detritiation system. To ensure that even the largest leakage rate can be accommodated, a purge flow of 50 m<sup>3</sup>/h is assumed for the building ventilation system.

After 8 hours, the active area detritiation system will be started with a purge flow of 50 m<sup>3</sup>/h, which will be sufficient to maintain the penetration termination room under negative pressure. The model to be used is shown in Figure 4.

It is assumed that up to 1 kg of tritium could become airborne in the vacuum vessel following the in-vessel LOCA. The transport of tritium and tokamak dust from the vacuum vessel to the

penetration termination room will be via a long cold tube, which has the potential to remove significant quantities of both. Initially, it will be assumed that the tritium will all be in the elemental form, and there will be no attenuation mechanisms. In addition to the tritium, it is assumed that 1 kg of hydrogen would be produced from the steam/metal reaction. Hence, in a 4,000 m<sup>3</sup> volume (3,000 + 1,000) there will be 1 kg of hydrogen and 1 kg of tritium. This corresponds to concentration of 0.4%, well below the detonation threshold of 18%. In cases where 10 kg hydrogen is produced and 1 kg tritium is mobilized, the concentration will be approximately 2.9%. Hence, the possibility of a large volume (gross) hydrogen/tritium detonation can be excluded.

### **6.2.2 Large In-Vessel LOCA**

It can be hypothesized that the largest in-vessel LOCA could discharge the entire inventory of the first wall and shielding blanket cooling system into the vacuum vessel. This is not a credible event, but clearly represents an upper bound to the thermal energy release into the vacuum vessel. Such an event would very quickly fill the vacuum vessel with a water/steam mixture and would quickly quench the first wall and divertors. Because such a large discharge of steam would cause the first wall to cool, the steam/metal reaction discussed above would not likely occur. However, the peak pressure generated by this event would be considerably higher and would occur even faster. Hence, there may be an even stronger possibility of vacuum vessel failure.

As in the case of the small in-vessel LOCA, it is assumed that up to 1 kg of tritium could become airborne. Because the amount of energy discharged into the vacuum vessel is greater than in the case of the small LOCA, the leakage rate for this event would be expected to be higher. However, as a range of leakage rates up to 100% of room volume per day was already considered, the same range will be analyzed for this event. The model to be used is shown in Figure 5.

### **6.3 Vacuum Vessel Boundary Breach (LOVA)**

There are two possible breaches: a breach which produces a direct connection between the vacuum vessel and the cryostat; and a breach which produces a direct connection between the vacuum vessel and the outside of the cryostat.

### 6.3.1 Vacuum Vessel Breach Into Cryostat

A breach of the vacuum vessel boundary into the cryostat is not a safety significant event, unless it is a common cause failure, which also breaches the cryostat boundary. Such a possibility is not considered credible.

### 6.3.2 Vacuum Vessel Breach Outside Cryostat

A breach of the vacuum vessel boundary via one of the diagnostic tubes has the potential to connect the vacuum vessel with the room where the cryostat penetration terminates. Such an event would cause a rapid depressurization of the room and the ingress of air into the vacuum vessel, unless the room contains an inert gas.

After the pressure inside the room and the vacuum vessel equalize (in-leakage from the room plus thermal expansion of the air/gas mixture), tritium can be slowly transported from the vacuum vessel to the room. However, by this time the active area detritiation system can be turned on, to maintain the room under negative pressure relative to its surroundings. An exhaust flow of 10 m<sup>3</sup>/day (1% of room volume per day) will be used for the active area detritiation system. The model to be used is shown in Figure 6.

It is assumed that up to 1 kg of tritium could become airborne inside the vacuum vessel. As for the in-vessel LOCA, it is assumed that the tritium will all be in the elemental form, and there will be no attenuation mechanisms. In the interim, mechanisms for tritium attenuation will be studied, and if they are considered to be significant, then they will be incorporated in the analysis.

## 6.4 Torus Exhaust Line Failure

There are two places where a breach of the process boundary can occur: in the suction line or the discharge line of the mechanical pump.

### 6.4.1 Breach in Suction Line

A breach in the suction line would cause an ingress of air (or inert gas) into the vacuum vessel. Phenomenologically, the event sequence would be similar to a vacuum vessel breach outside of the cryostat (Section 6.3.2). For this event, the penetration termination room (Section 6.3.2) would be the mechanical vacuum pump room.



#### **6.4.2 Breach in Discharge Line**

A breach in the discharge line would cause tritium and deuterium to be released inside the pump room, pipe interspace, or glove box, where the break occurs. Assume the break occurs in the pump room, as shown in Figure 7. The analysis would not differ materially if the release was in the pipe interspace, or in the glove box.

Assume that the event occurs at the start of a 1,000 s burn and that the fuel management system has sufficient holdup to support the burn, that is 140 g ( $500 \text{ g/h} * 1,000 \text{ s} / 3,600 \text{ s/h}$ ). Hence, if the pumps continue to pump, the most that could be discharged is the free inventory of 140 g. For conservatism, the maximum tritium release into the room is assumed to be 150 g. An equivalent amount of deuterium would also be discharged. The pressure rise from the discharge of this quantity of tritium and deuterium is small ( $<1 \text{ kPa}$ ), therefore, there won't be any significant leakage from the room.

Under normal conditions, following this event, the pump would be isolated and the release would be quickly terminated. Therefore, the above represents a bounding analysis.

Upon receipt of a high tritium alarm in the room, the active area detritiation system would be started and the pressure inside the room will be returned and maintained below that of the surrounding rooms. Two exhaust flowrates will be considered: 1% and 10% of the room volume per day (ie., 10 and 100  $\text{m}^3/\text{h}$ , respectively). The latter is a pessimistic upperbound. The model to be used is shown in Figure 7.

#### **6.5 Pellet Injector/Gas Puffer Process Boundary Failure**

Fuelling will consist of pellet injectors and gas puffers, which will be located in the fuelling rooms around the torus. Hence, failure of the process boundary would cause a release of tritium inside the fuelling room. Phenomenologically, this event will be similar to that described in Section 6.4.2. The mechanical vacuum pump room in Section 6.4.2 becomes the fuelling room. Clearly, there will be several fuelling machines, hence, failure of one would not necessarily cause the shutdown of the reactor. Equally, the failed fuelling machine can be easily isolated thus terminating the tritium release. To a first approximation, however, the environmental source terms for this event will be the same as those for the event in Section 6.4.2.

It is assumed that the pellet injector propellant gas is helium. If it is hydrogen, then the possibility of a hydrogen detonation has to be assessed, unless the pellet injector room is filled with an inert gas.

#### **6.6 Fuel Processing System Process Boundary Failure**

The fuel processing system equipment will be located inside glove boxes rather than inside a room. The event is a breach of the process boundary inside the glove box.

Phenomenologically, this event will be similar to that described in Section 6.4.2. The environmental source terms will be bounded by those of Section 6.4.2. This assumes that the pellet injector propellant gas is helium. If it is hydrogen, then the possibility of a hydrogen detonation has to be assessed.

#### **6.7 Water Detritiation System Process Boundary Failure**

Only the water distillation unit of the water detritiation system is considered here, as it has the largest tritium inventory. The tritium inventory in the vapour phase catalytic exchange unit is small, even if the tritium concentration is higher. Therefore, the environmental source terms for the vapour phase catalytic exchange unit are bounded by those of the water distillation unit.

There are two places where a breach of the water distillation process boundary can be significant (other than the column itself): in the pump suction line of the reboiler circuit, or in the vapour line of the reboiler circuit.

##### **6.7.1 Breach in Pump Suction Line**

A breach in the pump suction line will cause a spill of hot water in the water distillation room. The water in the column is between 50 and 70°C, therefore, there will not be any significant flashing of water to steam. Hence, the airborne tritium concentration will not be high. The TRITSPILL [ref 2] code will be used to determine airborne concentrations for this event. The spilled water will be collected in drain tanks for future processing.

Following the water spill, a high tritium alarm will cause the active area detritiation system to be started, hence, the water distillation room will be maintained under negative pressure,

relative to its surroundings. The exhaust flowrate is assumed to be 50 m<sup>3</sup>/h. The model to be used for this event is shown in Figure 8.

#### **6.7.2 Breach in Vapour Line**

A breach in the reboiler vapour line will cause tritiated steam to be discharged into the room.

If the reboiler pump continues to operate, which is unlikely, as it would trip on high column pressure, then it is possible to discharge the complete column inventory into the room. Assuming a column inventory of 6,000 kg and an average tritium concentration of 10 Ci/kg, then, the total amount of tritium that could become airborne is 60,000 Ci. Most of this tritium (HTO) will condense on the walls of the room. However, as there is no significant overpressure associated with this event, leakage will be negligible. As discussed in Section 6.7.1, above, and as shown in Figure 8, the active area detritiation system would be turned on to maintain the room under negative pressure.

#### **6.8 Isotope Separation System Process Boundary Failure**

The tritium inventory is held mostly in the cryogenic distillation columns, therefore, a process boundary failure inside the cold box will give rise to the largest possible release of tritium from the system. The inventory of the ISS is still being determined, but could be in the range of 130 g T<sub>2</sub> to 180 g T<sub>2</sub>.

The cold box is kept under vacuum, hence there is no leakage from it. However, as the pressure and tritium level inside the cold box increase, the vacuum pumps will turn on. As shown in Figure 9, the discharge from the vacuum pumps is sent to the exhaust flow detritiation system. If there is a significant amount of tritium in the pump flow, the flow can be directed to a buffer tank for later tritium recovery. The discharge rate of the vacuum pumps is assumed to be 10 l/s and the volume of the cold box is assumed to be 30 m<sup>3</sup>.

All piping and equipment outside the cold box is doubly contained with either conduits or glove boxes. The containment volume will have a cleanup system.

The isotope separation room is also served by the active area detritiation system, but it is not required for this event. Therefore, no analysis is required.

## 7.0 METHODOLOGY

### 7.1 Codes

In this past year, CFFTP has developed a user interface for the TMAP4 code, which is the official ITER code to be used for tritium source term work. Included in the interface is a tritium enclosure model (TEM), which can simulate accidental, or chronic, tritium releases in a room that is directly connected to an air detritiation system, or connected to another room. This model is therefore ideal for the analysis work presented in this report. CFFTP is planning additional development work on TEM. The next upgrade will contain data from experiments conducted at CRL on various architectural/structural surfaces. This will allow the interaction between airborne tritium and surfaces (the sorption/desorption process) to be modelled in TEM. However, this version of TEM will not be available for this task. It is expected that it will be available for source term analysis in 1995 and beyond.

The TRITSPIL code [ref 2] predicts the tritium release rates into the room air following a spill of tritiated water. The model rigorously considers mechanisms such as evaporation and condensation from wetted surfaces, as well as isotopic exchange of hydrogen species between the pool surface and room air.

### 7.2 Analysis

#### 7.2.1 TEM Assumptions for HTO Surface Interactions

##### a) Empty Cubical Geometry

The enclosures with epoxy painted surfaces were assumed to be cubical. This is a simplified and standardized model. While it is known that the mature design will be much more complex in nature with diverse geometries, it is not known what the final mix will be. This would probably be a topic of study in itself.

##### b) Painted Surface Interactions

Surface interactions were modelled if the surfaces were painted.

##### c) HT Converted to HTO

From studying Chalk River sorption experiments [ref 3] it is known that HT will quickly penetrate the epoxy and just as quickly desorb. Also various published experimental results

show that in epoxy the permeability of HT is many orders of magnitude greater than HTO (estimate 16 orders of magnitude). In addition to the previous, all surfaces will have a boundary layer of water. The HT will isotopically exchange with the water and produce HTO. Thus to study a worst case environmental release converting HT to HTO is conservative.

d) Cryostat Painted

For this study it was assumed that the cryostat was painted.

e) TSTA Epoxy Data Used

Although CFFTP analyzed Chalk River data and developed diffusion and solubility constants, it was decided to standardize on the accepted TSTA epoxy data [ref 1]. The diffusion constant used was  $1 \times 10^{-14} \text{ m}^2/\text{s}$ , the solubility constant equalled  $6 \times 10^{24} \text{ molecules/m}^3 \text{ Pa}$  and the thickness was set at 0.16 mm.

f) Tritium has  $10^4$  Ci/g

For simplicity 1 gram of tritium was considered to be approximately  $10^4 \text{ Ci}$ .

g) Condenser

It is assumed that clean-up systems have a condenser to remove the bulk of water vapour, so the dryers are not overloaded.

h) 48 Hour Event Duration

As the cases for no surface interactions were run for 48 hours, for comparative purposes the surface interaction cases were also run for 48 hours.

### 7.2.2 HTO Surface Inventory Convergence Criteria

As TMAP4 is a highly sophisticated code it has many inputs. There are two convergence criteria that are important to accurately portray the hold up in the surface. Ten TEM 10 hour

runs using a high concentration of HTO (500 Ci/m<sup>3</sup>), various thicknesses of epoxy and various time increments were completed in order to establish:

- a) Time Increment-This is the time interval used by TMAP for the next calculation of the HTO mass balance in the enclosures and surfaces. If it is too small, the accuracy may be greater but the runs will take longer. If the time step is too large the next calculation of the mass balance will be inaccurate. These errors compound and by the end of run, the end result will not accurately reflect what was being modelled.

The time increments run were 1, 30 and 60 seconds. The 3 graphs in Appendix 2 show the results. It was concluded that for any set thickness of epoxy both short term and long term convergence were satisfied. To expedite TEM runs 60 seconds was chosen. It is possible that larger time increments could be used, however, for the purposes of this report 60 seconds was adequate.

- b) Epoxy Thickness-TSTA epoxy was set at 0.16 mm. However TMAP4 is set with 12 nodes and so this thickness may not allow TMAP4 to accurately calculate surface inventories.

In the graph in Appendix 2 with the 60 second time increment all the thicknesses used except 0.02 mm have convergent inventories at 10 hours. Early time data shows converging inventories as the thickness is set smaller, however early time phenomena is not a topic of this report. Any of the 10 hour convergent thicknesses is adequate for this report. Since 0.16 mm was demonstrated to be a valid thickness that thickness was selected.

This thickness is also realistic from a saturation point of view. Using the TSTA epoxy content and the formula to calculate time to 90% equilibrium:

$$t_{0.9} = 0.312 l^2/D$$

Where:

$$\begin{aligned} t_{0.9} &= \text{time to 90\% equilibrium value} \\ l &= \text{thickness} \\ D &= \text{diffusion constant} \end{aligned}$$

(All in dimensionally consistent units. [ref 6])

It is estimated that this time is 22 hours. In most of the cases HTO concentration is being reduced much before this time. Therefore HTO would start permeating out of the surface material.

## **8.0 RESULTS**

### **8.1 Scope of Work Items**

#### **8.1.1 Incorporated TSTA Surface Characteristics into TEM**

TSTA epoxy data was loaded into TEM[ref 1]. The diffusion constant used was  $1 \times 10^{-14} \text{m}^2/\text{s}$ , the solubility constant equalled  $6 \times 10^{24} \text{molecules/m}^3 \text{ Pa}$ .

The validity of TSTA epoxy thickness (0.16 mm) was checked and it was determined to be valid for the cases analysed in this report.

#### **8.1.2 Results of TEM Analysis**

The following is a summary of the results obtained with TEM. For details of the runs without surface interactions, refer to APPENDIX 4. For the HTO Surface interaction runs refer to APPENDIX 5. The table of contents at beginning of the appendices lists the specific cases. TEM input and output are listed in the appendices. Also graphs for enclosure(s) Ci levels and stack Ci levels are included. The stack graphs represent the environmental release. Where appropriate enclosure(s) wall inventory graphs were drawn.

For cases with HTO surface interactions where the first 8 hours operation is different than the last forty hours operation, graphs for only the last forty hours are included. Only the last forty hours shows the final environment release.

TEM uses a fixed recombiner and dryer efficiency as input. In reality the efficiencies may degrade at low flows and low concentrations, so the results from TEM have to be interpreted accordingly.

### 8.1.2.1 Ex-Vessel LOCA (Intact Case) Inside Cryostat

An acute release of 50 g tritium as HTO into the Cryostat, which is assumed to be impaired, is simulated under two conditions:

- a) the air detritiation system operating, and
- b) the air detritiation blowers working, but the dryer efficiency is assumed to be zero (ie., same as saying building ventilation system pushes the flow directly to the environment).

The environmental releases at the end of 48 hours are as follows:

- a) with air detritiation system operating =  $2.2 \times 10^{-8}$  g.
- b) with zero detritiation efficiency (ie., venting) = 1.0 g.

### Ex-vessel LOCA (Intact Case) Inside Cryostat with Surfaces Painted

With all the conditions the same as above and the surfaces painted with epoxy.

The environmental releases at the end of 48 hours are as follows:

- a) with air detritiation system operating =  $2.1 \times 10^{-8}$  g.
- b) with zero detritiation efficiency (ie., venting) =  $8.1 \times 10^{-1}$  g.

### 8.1.2.2 Ex-Vessel LOCA (Impaired Case) Inside Cryostat

An acute release of 50 g tritium as HTO into the Cryostat, which is assumed to be impaired, is simulated under two conditions:

- a) the air detritiation system operating, and
- b) the air detritiation blowers working, but the dryer efficiency is assumed to be zero (ie., same as saying building ventilation systems pushes the flow directly to the environment).

The environmental releases at the end of 48 hours are as follows:

- a) with air detritiation system operating =  $3.8 \times 10^{-8}$  g.
- b) with zero detritiation efficiency (ie., venting) = 4.0 g.



**Ex-vessel LOCA (Impaired Case) Inside Cryostat with Surfaces Painted**

With all the conditions the same as above and the surfaces painted with epoxy.

The environmental releases at the end of 48 hours are as follows:

- a) with air detritiation system operating =  $3.1 \times 10^{-9}$  g.
- b) with zero detritiation efficiency (ie., venting) =  $9.8 \times 10^{-1}$  g.

**8.1.2.3 Ex-Vessel LOCA Inside Cooling System Equipment Room**

An acute release of 50 g tritium as HTO into the Cooling System Equipment Room is simulated under two conditions:

- a) for the first 8 hours, the building ventilation system continues to operate, but the purge flow is directed to the exhaust air detritiation system, which is assumed to be operating, and after eight hours the active area detritiation system is used to clean up the accident room; and
- b) for 48 hours, the building ventilation system continues to operate with the purge flow going directly to the stack (i.e., no detritiation at all).

The environmental releases after 48 hours are as follows:

- a) with air detritiation system operating =  $3 \times 10^{-3}$  g
- b) with zero detritiation efficiency (ie., venting) =  $3.5 \times 10^{+1}$  g.

**Ex-vessel LOCA Inside Cooling System Equipment Room with Surfaces Painted**

With all the conditions the same as above and the surfaces painted with epoxy.

The environmental releases after 48 hours are as follows:

- a) with air detritiation system operating =  $2.6 \times 10^{-5}$  g
- b) with zero detritiation efficiency (ie., venting) =  $2.3 \times 10^{+1}$  g.

#### 8.1.2.4 Small In-Vessel LOCA

An acute release of 1 kg of tritium into vacuum vessel is simulated assuming breach of an optical window, which permits venting of the vacuum vessel into the penetration termination room (outside of the cryostat). Two cases are performed:

- a) for the first 8 hours, the building ventilation system continues to operate, but the purge flow is directed to the exhaust air detritiation system, which is assumed to be operating, and after eight hours the active area detritiation system is used to clean up the accident room; and
- b) for 48 hours, the building ventilation system continues to operate with the purge flow going directly to the stack (i.e., no detritiation at all).

The environmental releases after 48 hours are as follows:

- a) with air detritiation system operating =  $1.7 \times 10^{-2}$  g.
- b) with zero detritiation efficiency (i.e., venting) =  $3.0 \times 10^{+2}$  g in 48 hours (17 grams in 8 hours).

#### Small In-Vessel LOCA with Surfaces Painted

With all the conditions the same as above and the surfaces painted with epoxy.

The environmental releases after 48 hours are as follows:

- a) with air detritiation system operating =  $3.6 \times 10^{-5}$  g.
- b) with zero detritiation efficiency (i.e., venting) =  $1.7 \times 10^{+2}$  g.

#### 8.1.2.5 Water Detritiation System Breach in Liquid Line

For the first 8 hours  $T_2O$  is evaporating into the room. The TRITSPIL code was used to calculate this flux. After 8 hours it was assumed that the water was contained and the only of  $T_2O$  was that which remained in the enclosure and enclosure surface.

The environmental releases are as follows:

- a) with air detritiation system operating =  $3.8 \times 10^{-2}$  g.
- b) with zero air detritiation efficiency (i.e., venting) =  $1.4 \times 10^{-1}$  g.

### Water Detritiation System Breach in Liquid Line with Surfaces Painted

The environmental releases are as follows:

- a) with air detritiation system operating =  $3.8 \times 10^{-2}$  g.
- b) with zero air detritiation efficiency (ie., venting) =  $1.1 \times 10^{-1}$  g.

### 8.1.2.6 Water Detritiation System Breach in Vapour Line

The majority of the water will condense quickly on the walls:

$$\begin{aligned} Q &= h_s A \Delta T \\ &= 1.13 (\text{kW/m}^2 \text{ } ^\circ\text{C}) 599.8 \text{ m}^2 (70-30) \text{ } ^\circ\text{C} \text{ assumed } h_s \\ &= 2.7 \times 10^4 \text{ kW cooling} \end{aligned}$$

The latent heat of water at 70°C is  $2.3 \times 10^3$  kJ/kg or  $6.4 \times 10^{-1}$  kW hr/kg. So the rate of water condensing is  $4.2 \times 10^4$  kg/hr. We have 6,000 kg of vapour that would condense in 0.14 hrs.

After 8 hours it was assumed that the water was contained and the only HT0 was that which remained in the enclosure and enclosure surface.

The environmental releases are as follows:

- a) with air detritiation system operating =  $2.2 \times 10^{-1}$  g.
- b) with zero air detritiation efficiency (ie., venting) =  $8.2 \times 10^{-1}$  g.

### Water Detritiation System Breach in Vapour Line with Surfaces Painted

The environmental releases are as follows:

- a) with air detritiation system operating =  $2.2 \times 10^{-1}$  g.
- b) with zero air detritiation efficiency (ie., venting) =  $6.7 \times 10^{-1}$  g.

### 8.1.3 Release Fractions

In this section environmental release fractions are presented. These release fractions represent the fraction of the mobilized tritium inventory that will be released to the environment.

**8.1.3.1 Ex-Vessel LOCA Inside Cryostat**

a) Contained in Cryostat Release fraction = 0

b) Mitigated by CDS

	With No Surface Interaction	With Surface Interaction (Painted)
Cleanup Efficiency 99.95%	$4.4 \times 10^{-10}$	$4.2 \times 10^{-10}$
Cleanup Efficiency 0%	$2.0 \times 10^{-2}$	$1.6 \times 10^{-2}$

c) Mitigated by AADS

	With No Surface Interaction	With Surface Interaction (Painted)
Cleanup Efficiency 99.95%	$7.6 \times 10^{-10}$	$6.2 \times 10^{-11}$
Cleanup Efficiency 0%	$8.0 \times 10^{-2}$	$2.0 \times 10^{-2}$

**8.1.3.2 Ex-Vessel LOCA Inside the Cooling System Equipment Rooms**

	With No Surface Interaction	With Surface Interaction (Painted)
Cleanup Efficiency 99.95%	$6.0 \times 10^{-5}$	$5.2 \times 10^{-7}$
Cleanup Efficiency 0%	$6.9 \times 10^{-1}$	$4.6 \times 10^{-1}$

8.1.3.3 Small In-Vessel LOCA, Large In-Vessel LOCA, Vacuum Vessel Breach Outside Cryostat (LOVA), Breach in Suction Line

	With No Surface Interaction	With Surface Interaction (Painted)
Cleanup Efficiency 99.95%	$1.7 \times 10^{-5}$	$3.6 \times 10^{-8}$
Cleanup Efficiency 0%	$3.0 \times 10^{-1}$	$1.7 \times 10^{-1}$

8.1.3.4 Vacuum Vessel Breach Into Cryostat (LOVA), Torus Exhaust Line Failure 1) Breach in Discharge Line 2) Pellet Injector/Gas Puffer Process Boundary Failure, Fuel Processing System Process Boundary Failure and Isotope Separation System Process Boundary Failure

These cases are phenomenologically similar.  
The release fraction in all these cases = 0.

8.1.3.5 Water Detritiation System Process Boundary Failure

8.1.3.5.1 Breach in Pump Suction Line

	With No Surface Interaction	With Surface Interaction (Painted)
Cleanup Efficiency 99.95%	$6.3 \times 10^{-3}$	$6.3 \times 10^{-3}$
Cleanup Efficiency 0%	$2.3 \times 10^{-2}$	$1.8 \times 10^{-2}$

### 8.1.3.5.2 Breach in Vapour Line

	With No Surface Interaction	With Surface Interaction (Painted)
Cleanup Efficiency 99.95%	$3.7 \times 10^{-2}$	$3.7 \times 10^{-2}$
Cleanup Efficiency 0%	$1.4 \times 10^{-1}$	$1.1 \times 10^{-1}$

## 9.0 CONCLUSIONS

### 9.1 Utility of TEM

Having the validated TEM model has made it convenient to accurately perform quantitative analysis of ITER relevant accident scenarios. With the TEM model the analyst can focus on the analysis and thus be relieved of the time consuming input/output chores.

TEM uses a fixed recombiner and dryer efficiency as input. In reality the efficiency may degrade at low flows and low concentrations, so the results of TEM have to be interpreted accordingly.

Presently TSTA correlations for epoxy are loaded in TEM, future development work for TEM should include incorporation of more surface characteristics that would have ITER relevance.

### 9.2 Cleanup Systems

This report confirms that for accident scenarios assessed an efficient tritium cleanup system is required. The large differences between releases with and without a cleanup system conclusively prove this.

When ITER Cleanup System designs have been completed the scenarios outlined in this report should be re-assessed to reflect the actual design parameters.

### 9.3 Attenuation of Environmental Releases

As expected a high efficiency cleanup system significantly attenuates releases. For the two accident periods studied, these trends can be seen in the release fractions:

- 1) Having a cleanup system with high efficiency provides significant attenuation of release fractions.

- 2) Further attenuation of release fractions is caused by adsorption of tritium via enclosure surface interactions.
- 3) For the cases studied the environmental release varied with the number interlocked enclosures, the volumes, the cleanup scenario and the type of surface.

The results clearly show that the coating system can be a major passive contributor to the attenuation of T<sub>2</sub>O releases. While the coating system may reduce the environmental release, there is a potential for occupational exposure over a longer period as the tritium desorbs. TEM can be used to evaluate this.

#### 9.4 Future Analysis

The conclusions presented are valid for the epoxy coating used and process source scenarios. Future analysis must consider the following: 1) The form of tritium. Elemental or oxide, liquid or gas etc. 2) The room volume, geometry, coating system. 3) Ventilation system parameters. 4) Cleanup system parameters.

As the ITER design matures further safety analysis must be performed to comment quantitatively on a specific design.

#### 10.0 REFERENCES

1. Longhurst, G.R., et al, TMAP4 User's Manual, INEL EGG-FSP-10315, June 1992.
2. Busigin, A., et al, Estimation of the Tritium Release Rate From a Spill of Tritiated Water, Fusion Technology, Vol. 21, No. 2, Part 2, March 1992.
3. Miller, J.M., et al, Tritium Sorption on Protective Coating for Concrete, CFFTP G-9198 (AECL No. 10707), November 1992.
4. Sood, S.K., et al, ITER Task D55, Design of Water Detritiation Plant, CFFTP G-9502, January 1995.
5. Kveton, O., to Yoshida H., Correspondence, November 22, 1994.
6. CFFTP Basic Tritium Safe Handling Course Notes, CFFTP I-8850, January 1988.

APPENDIX 1

TRITIUM ENVIRONMENTAL RELEASE FRACTIONS



# APPENDIX 1

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## 1.0 INTRODUCTION

The tritium environmental releases following an acute release into a room will depend on several factors, including:

- a) the chemical and physical form of the tritium (ie., whether it is in the elemental or oxide form, and, if in the oxide form, whether its in the vapour or liquid state),
- b) the size of the room,
- c) the room ventilation system including air detritiation, and
- d) other liquids or gases accompanying the tritium.

Attenuation mechanisms such as surface plateout (sorption) is not significant for tritium in the elemental form, but may be significant for tritium in the oxide form. Conversion of HT to HTO is not significant for short time scales.

Five typical release scenarios are assessed:

- a) a release of 200 g of tritium gas, which is representative of fuel cycle events - a dry release,
- b) a release of 1,000 g of tritium gas accompanied with wet steam, which is representative of in-vessel LOCAs - a wet release,
- c) a release of 50 g of tritium in the form of HTO vapour, which is representative of ex-vessel LOCAs,
- d) a release of 0.5 g of tritium in the form of HTO vapour, which is representative of ex-vessel leaks, and
- e) a release of 5 g of tritium in the form of HTO liquid, which is representative of water detritiation system events.

Scenario a) does not generate a room overpressure, whereas b) does, hence, release fractions will be available for pressurized and non-pressurized room conditions. Similarly scenario c) will have a room overpressure, but scenario d) will not; and there is no overpressure for scenario e). These scenarios are discussed further under the following headings:

- Acute Tritium Gas Release with No Room Overpressure,
- Acute Tritium Gas Release with Room Overpressure,
- Acute Tritium Vapour Release with No Room Overpressure.
- Acute Tritium Vapour Release with Room Overpressure,
- Acute Tritiated Water Release.

The objective of this assessment is to generate environmental release fractions following an acute tritium release into a tokamak or tritium building room.

## **2.0 ACUTE TRITIUM GAS RELEASE WITH NO ROOM OVERPRESSURE**

There are many rooms in the tokamak building and the tritium building where an acute release of tritium gas can occur. The following is a representative case used to determine environmental release fractions.

### **2.1 Release Parameters**

Acute Release	=	200 g of T <sub>2</sub>
Room Volume	=	1,000 m <sup>3</sup>
Pressure Rise	=	negligible
Surface Adsorption	=	negligible

### **2.2 Release Pathways**

Three scenarios are considered:

- a) the building ventilation system is assumed to be on at the time of the acute release and no action is taken to isolate it, hence, tritium gas will be purged through the system without abatement,
- b) the building ventilation system is assumed to be isolated at the time of the acute release and no further action is taken, hence, tritium gas will be released through chronic room leakage, and
- c) the air detritiation system is assumed to be initiated immediately following a detection of tritium in the room, hence, tritium gas will be recombined into tritiated vapour and passed through molecular sieve dryers prior to release to the environment.

### **2.3 Environmental Releases**

For the building ventilation system pathway, assume the room air is changed at the rate of 8 volumes per day (a very high recirculation rate, which will cause environmental releases to be overestimated). This implies a flowrate of 8,000 m<sup>3</sup>/day, or 333 m<sup>3</sup>/h. The same flowrate is used also for the detritiation system pathway, which will have an air detritiation efficiency of 99.9%.

For the leakage pathway, assume a chronic leakage rate of 1% of room volume per day. As there is no pressure driven leakage, this represents a very conservative value - that is, it will cause the environmental releases to be overestimated.

### **2.3.1 Building Ventilation Pathway**

The tritium gas release rate is  $(200 \text{ g}/1,000 \text{ m}^3) * 333 \text{ m}^3/\text{h} = 66.6 \text{ g/h}$ . That is, in three hours all of the tritium will be released to the environment. The airborne tritium concentration decreases exponentially, hence the above release rate is the maximum rate corresponding to the initial airborne concentration.

### **2.3.2 Leakage Pathway**

The tritium gas release rate is  $200 \text{ g} * 0.01/\text{day} = 2 \text{ g/day}$  (0.083 g/h). As above, this represents the maximum release rate corresponding to the initial airborne tritium concentration.

### **2.3.3 Air Detritiation Pathway**

Within three hours all of the air inside the room will have been treated by the detritiation system, hence, 99.9% of the tritium will be captured and retained by the detritiation system and 0.1% (0.2 g) will be discharged to the environment via the stack.

## **2.4 Environmental Release Fractions**

The environmental release fractions for an acute release of tritium gas are:

- a) 100% for the ventilation pathway,
- b) 1% for the leakage pathway (at the end of one day),
- c) 0.1% for the detritiation pathway.

## **3.0 ACUTE TRITIUM GAS RELEASE WITH ROOM OVERPRESSURE**

There are many extensions of the vacuum vessel that have the potential, under accident conditions, to establish a direct connection between the vacuum vessel and rooms outside the cryostat boundary. In such instances, if the initiating event is an in-vessel LOCA, it is possible to transport large quantities of tritium and steam into the connecting room. The following is a representative case used to determine environmental release fractions.

### 3.1 Release Parameters

Acute Release into Vacuum Vessel = 1,000 g of T<sub>2</sub>

Steam Release into Vacuum Vessel = 1,000 Mg

Pressure rise inside  
Vacuum Vessel = 2-5 atm (limited by pressure  
suppression system)

Volume in Connecting Room  
= 1,000 m<sup>3</sup>

Surface Adsorption of Tritium Gas  
In Connecting Room = Negligible

### 3.2 Release Pathways

Three scenarios are considered:

- a) the building ventilation system is assumed to be on at the time of the acute release and no action is taken to isolate it, hence, tritium gas will be purged through the system without abatement,
- b) the building ventilation system is assumed to be isolated at the time of the acute release and no further action is taken, hence, tritium gas will be released through pressure-driven room leakage, and
- c) the air detritiation system is assumed to be initiated immediately following a detection of tritium, or overpressure, in the room, hence, tritium gas will be recombined into tritiated vapour and passed through molecular sieve dryers prior to release to the environment.

### 3.3 Environmental Releases

The assumptions made in Section 2.3, with respect to ventilation and detritiation system flowrate and efficiency, are also used in this section.

#### 3.3.1 Building Ventilation Pathway

The amount of steam and tritium gas driven through the connecting room will depend on the relative flow resistance between the suppression system pathway and the ventilation pathway. Given that the connection between the vacuum vessel and the room is likely to be through a 10-20 cm diameter tube, compared to many vacuum vessel pressure relief devices of larger diameter, it is conservative to assume that not more than 10% of the steam and

tritium will be transported through the ventilation pathway. Hence, 100 g of tritium gas and 100 Mg of steam would be vented via the building ventilation system directly to the environment.

### 3.3.2 Leakage Pathway

As the building ventilation system is isolated, the amount of steam and tritium transported to the connecting room will be significantly smaller than 10% (Section 3.3.1).

The number of moles of steam that can enter the room, if the room is pressurized to 5 atmospheres (the upper range of pressure is used for conservatism) is about

$$\begin{aligned} n &= (5-1) * 1,000 \text{ m}^3 / (0.0224 \text{ m}^3/\text{mole} * 423/273) \\ &= 120 \text{ kmoles (about 2.2 Mg)} \end{aligned}$$

Hence, the amount of steam transported to the connecting room would be about 2.2 Mg, which is 2.2% of the steam discharged into the vacuum vessel.

Assuming, at most, 2.5% (25 g) of the tritium gas enters the connecting room (97.5% enters the pressure suppression pool), and assuming also a leakage rate from the room of 10% room volume per day (conservative estimate for the assumed pressure), the amount of tritium gas that would be released to the environment is of the order of 2.5 g per day. Even if the leakage rate was 100% room volume per day, the maximum environmental release rate would be 25 g per day. However, due to steam condensation, the pressure inside the room would not remain at 5 atmospheres beyond the first few hours.

### 3.3.3 Air Detritiation Pathway

As in Section 3.3.1, it is assumed that, at most, 10% of the steam (and tritium) enters the room and the rest (90%+) enters the pressure suppression pool. Within three hours all of the air and steam inside the room will have been treated by the detritiation system, hence, 99.9% of the tritium will be captured and retained by the detritiation system and 0.1% (0.025 g) will be discharged to the environment via the stack.

## 3.4 Environmental Release Fractions

The environmental release fractions for an acute release of tritium gas and steam are:

- a) 100% for the ventilation pathway,
- b) 10% for the leakage pathway (at the end of one day),

c) 0.1% for the detritiation pathway.

#### 4.0 ACUTE TRITIUM VAPOUR RELEASE WITH NO ROOM OVERPRESSURE

Rooms containing cooling system, or cooling system auxiliary, equipment are representative of tokamak building areas where a small release of tritiated water vapour can occur without causing a significant rise in pressure.

##### 4.1 Release Parameters

Acute Release	= 0.5 g of tritium in the form of tritiated water vapour
	= 500 kg of steam (10 Ci/kg)
Room Volume	= 1,000 m <sup>3</sup>
Pressure Rise	= not significant
Surface adsorption of HTO	= significant for some scenarios.

##### 4.2 Release Pathways

Three scenarios are considered:

- a) the building ventilation system is assumed to be on at the time of the acute release and no action is taken to isolate it, hence, tritium vapour will be purged through the system without abatement,
- b) the building ventilation system is assumed to be isolated at the time of the acute release and no further action is taken, hence, tritium vapour will be released through chronic room leakage, however, interaction of the tritium vapour with the room surfaces, will reduce the tritium airborne concentration, and
- c) the air detritiation system is assumed to be initiated immediately following a detection of tritium in the room, hence, tritium vapour will be passed through molecular sieve dryers prior to release to the environment.

##### 4.3 Environmental Releases

The assumptions made in Section 2.3, with respect to ventilation and detritiation system flowrate and efficiency, are also used in this section.



#### 4.3.1 Building Ventilation Pathway

The tritium vapour release rate is  $(0.5 \text{ g}/1,000 \text{ m}^3) * 333 \text{ m}^3/\text{h} = 0.166 \text{ g}/\text{h}$ . That is, in three hours all of the tritium will be released to the environment.

#### 4.3.2 Leakage Pathway

A chronic leakage rate of 1% room volume per day is assumed. For this leakage rate and room volume ( $1,000 \text{ m}^3$ ) the effect of surface sorption of HTO is of the same order as leakage, hence, it will not have a major impact on the amount of HTO leaked during the first day. Hence, during the first day, the tritium environmental release would be of the order of 0.005 g. However, if the room leakage rate is smaller, then surface sorption would be the dominating mechanism, and the HTO leakage rate would be significantly reduced.

#### 4.3.3 Air Detritiation Pathway

Within three hours all of the air and steam inside the room will have been treated by the detritiation system, hence, 99.9% of the tritium will be captured and retained by the detritiation system and 0.1% ( $0.0005 \text{ g}$ ) will be discharged to the environment via the stack.

#### 4.4 Environmental Release Fractions

The environmental release fractions for an acute release of tritium vapour and steam without room overpressure are:

- a) 100% for the ventilation pathway,
- b) 1% for the leakage pathway (at the end of one day),
- c) 0.1% for the detritiation pathway.

#### 5.0 ACUTE TRITIUM VAPOUR RELEASE WITH ROOM OVERPRESSURE

The cooling system equipment rooms are representative of areas where a release of tritiated water vapour can occur.

## 5.1 Release Parameters

Acute Release	= 50 g of tritium in the form of tritiated water vapour
	= 500 Mg of steam (1 Ci/kg)
Room Volume	= 1,000 m <sup>3</sup>
Pressure Rise Inside Room	= large

## 5.2 Release Pathways

Three scenarios are considered:

- a) the building ventilation system is assumed to be on at the time of the acute release and no action is taken to isolate it, hence, tritium vapour will be purged through the system without abatement,
- b) the building ventilation system is assumed to be isolated at the time of the acute release and no further action is taken, hence, tritium vapour will be released through pressure-driven room leakage, however, interaction of the tritium vapour with the room surfaces, will reduce the tritium airborne concentration, and
- c) the air detritiation system is assumed to be initiated immediately following a detection of tritium, or overpressure, in the room, hence, tritium vapour will be passed through molecular sieve dryers prior to release to the environment.

## 5.3 Environmental Releases

The assumptions made in Section 2.3, with respect to ventilation and detritiation system flowrate and efficiency, are also used in this section.

### 5.3.1 Building Ventilation Pathway

As the pressure rise in the room will be high even with a significant purge flow, most of the steam in the room will be purged before there is any significant amount of condensation. Hence, 50 g of tritium in the form of HTO will be released to the environment within minutes.

### 5.3.2 Leakage Pathway

Clearly, in this specific situation there is a significant mismatch of room volume and quantity of steam (a very severe or extreme situation). This results from the consistent assumption that the room volume is 1,000 m<sup>3</sup> in all the cases considered. However, what is important is that the room, even if it was larger, would experience a large overpressure, hence, the initial leakage rate would be large. Eventually, as steam condenses, the room overpressure is reduced and the leakage rate drops accordingly.

It is assumed that, after one hour 90% of the steam has condensed, and the leakage rate drops from 100% of room volume per day to 10% of room volume per day. Hence, during the first hour, the tritium environmental release would be about 2 g. Afterwards it becomes 0.5 g of tritium per day. Hence, during the first day, the tritium environmental release would be of the order of 2.5 g.

### 5.3.3 Air Detritiation Pathway

Within three hours all of the air and steam inside the room will have been treated by the detritiation system, hence, 99.9% of the tritium will be captured and retained by the detritiation system and 0.1% (0.05 g) will be discharged to the environment via the stack.

## 5.4 Environmental Release Fractions

The environmental release fractions for an acute release of tritium vapour and steam are:

- a) 100% for the ventilation pathway,
- b) 5% for the leakage pathway (at the end of one day),
- c) 0.1% for the detritiation pathway.

## 6.0 ACUTE TRITIATED WATER RELEASE

Spills of tritiated water can occur in many areas, but the water detritiation room can be considered typical.

## 6.1 Release Parameters

Acute Release = 5 g of tritium in the form of HTO  
= 5 Mg of water  
Room Volume = 1,000 m<sup>3</sup>

## 6.2 Release Pathways

Three scenarios are considered:

- a) the building ventilation system is assumed to be on at the time of the acute release and no action is taken to isolate it, hence, tritium vapour in the airspace above the water pool on the floor will be purged through the system without abatement,
- b) the building ventilation system is assumed to be isolated at the time of the acute release and no further action is taken, hence, tritium vapour will be released through chronic room leakage, and
- c) the air detritiation system is assumed to be initiated immediately following a detection of tritium in the room and the water is drained from the room, hence, the remaining tritium vapour will be passed through molecular sieve dryers prior to release to the environment.

## 6.3 Environmental Releases

The assumptions made in Section 2.3, with respect to ventilation and detritiation system flowrate and efficiency, are also used in this section.

### 6.3.1 Building Ventilation Pathway

Assuming a room relative humidity of 100% (after the spill) and 0% before the spill, the amount of tritiated water vapour in the air (at 20°C) would be at most 1,000 moles, or 18 kg. As the tritium concentration in the spilled water is assumed to be 10 Ci/kg (1 mg/kg) the amount of tritium in the air will be less than 18 mg. This amount is assumed to remain constant as evaporation will make up losses due to the room air purge. These assumptions were deliberately chosen to overestimate the amount of tritium in the air space.

The maximum tritium vapour release rate is (18 mg/1,000 m<sup>3</sup>) \* 333 m<sup>3</sup>/h = 6 mg/h (144 mg/day).

### 6.3.2 Leakage Pathway

The tritium vapour release rate is  $18 \text{ mg} * 0.01/\text{day} = 0.18 \text{ mg/day}$

### 6.3.3 Air Detritiation Pathway

After the water pool on the floor of the room is drained, the air inside the room will have been treated by the detritiation system within three hours. Hence, 99.9% of the tritium in the room air will be captured and retained by the detritiation system and 0.1% (18 micrograms) will be discharged to the environment via the stack.

### 6.4 Environmental Release Fractions

The environmental release fractions for an acute release of tritiated water are:

- a) 2.8% per day for the ventilation pathway,
- b) 0.0036% per day for the leakage pathway, and
- c) 0.00036% for the detritiation pathway.

## 7.0 SUMMARY

The tritium environmental release fractions, for the first day of releases, are given in the following table.

Release Scenario	Ventilation Pathway	% Released in 1 Day	
		Leakage Pathway	Detritiation Pathway
Acute Tritium Gas Release with no Room overpressure	100	1	.01
Acute Tritium Gas Release with Room Overpressure	100	10	.01
Acute Tritium Vapour Release with no Room Overpressure	100	1	0.1
Acute Tritium Vapour Release with Room Overpressure	100	5	0.1
Acute Tritiated Water Release	2.8	0.0036	0.00036

The above results are based on the following assumptions:

- a) room leakage is 1%/day for unpressurized conditions and 10%/day for pressurized conditions,
- b) room ventilation (and detritiation) flow rate is 8 volumes/day,
- c) detritiation system efficiency is 99.9%.

The following observations can be made from the above table:

- a) The normal building ventilation system ensures that environmental releases will be "elevated releases", but does not provide any attenuation. Of course, the purge flow from this system could be sent to the exhaust gas detritiation system, where significant (factor of 1000) reductions in environmental releases would occur.
- b) Room isolation appears to provide at least a factor of 10 reduction, relative to unrestricted purging via the ventilation system, for pressurized rooms and a factor of 100 for unpressurized rooms. Hence, room isolation is a key mitigating system for tritium releases of all types.

- c) Room air detritiation provides at least a factor of 1000 reduction, relative to unrestricted purging via the ventilation system.

Clearly, these observations apply to the specific conditions and assumptions made in the calculations, therefore, care is required in applying these results to conditions that are significantly different.