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TITLE: TRANSPORTATION OF TRITIATED WASTE FROM FUSION FACILITIES

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***TRANSPORTATION OF TRITIATED WASTE FROM FUSION FACILITIES**

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ABSTRACT

This paper examines methods of handling tritiated waste from a fusion facility, concentrating on handling requirements specific to tritium. Gaseous effluent from a fusion reactor can currently be transported from a fusion facility in two forms - as a gas or solidified on uranium beds. Tritiated water can be transported if it is solidified by absorption onto molecular sieve beds or on clay or cement. Solid waste being shipped for disposal can be transported in low specific activity (LSA, less than 0.3 mCi/g [1.1×10^7 Bq/g]), type A (less than or equal to 1000 Ci [3.7×10^{13} Bq]) or type B (greater than 1000 Ci [3.7×10^{13} Bq]) standard containers. The method chosen for transport depends on the amount and level of activity of the tritiated material and whether or not it will be reprocessed at another facility.

INTRODUCTION

The production of tritiated waste from a fusion facility in the United States will soon become a reality. The Tokamak Fusion Test Reactor (TFTR) at Princeton Plasma Physics Laboratory (PPPL) is scheduled to begin using tritium as fuel, and therefore producing tritiated

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waste, in 1990. The Compact Ignition Tokamak (CIT), also sited at Princeton, will begin using tritium as fuel around 1996. The Tritium Systems Test Assembly (TSTA) at Los Alamos National Laboratory (LANL), which simulates the proposed fuel cycle of a future full-scale D-T fusion reactor, started testing its tritium systems in 1982, began tritium operations in 1984, and reached its design capacity of 100 g of tritium in the process loop in July of 1987.

TSTA personnel have been dealing with a gas mixture simulating the effluent from a fusion reactor and other tritiated waste produced in the operation of the facility since the first introduction of tritium. TFTR, CIT and future full-scale fusion power devices using tritium will produce similar amounts and types of tritiated waste. Most of this waste will be the gaseous effluent from the fusion reactor. This gaseous waste can be treated in a cleanup and purification process (such as TSTA's processing loop) on-site or it can be sent off-site for reprocessing or disposal. The plans for TFTR do not include on-site reprocessing facilities, so all tritiated waste for the facility will have to be sent off-site for reprocessing or disposal. On-site reprocessing for CIT is still under evaluation. Full-scale fusion reactors using tritium as fuel are expected to include on-site reprocessing.

Liquid and solid wastes will most likely be sent to a disposal facility. Liquid tritiated wastes will be generated from maintenance, cleanup or emergency operations. Solid waste will also be generated in the form of, for example, tritium contaminated equipment, molecular sieve, clothing or room trash.

AMOUNT OF TRITIATED WASTE PRODUCED AT TSTA, TFTR AND CIT

TSTA is sized to handle the full flow of gaseous effluent from a fusion reactor, 360 mol D-T/day and a variety of impurities.¹ Table 1 shows the impurity gas load used as the design basis for TSTA. The processing loop will also handle the simulated flow from neutral beam vacuum pumps (275 mol D₂/day).

Table 1. Impurity Gas Load for TSTA Based on 360 mol D-T/day

Element	Mol%	Species	Grams/day
He	2-20	He	29-290
H	1	HD, HT, H ₂	7
C	0.01-0.02	C(D,T) ₄ , C ₂ (D,T) ₂ , CO ₂	1.7-9
N	0.01	N(D,T) ₃ , N ₂ , CN, NO _x	10
O	0.5	(D,T) ₂ O, CO ₂ , O ₂	57
Ar	0.00006-0.05	Ar	0.17-14

Tritiated waste from TSTA can be grouped into three types: gaseous, liquid and solid. Gaseous waste results from either releases from the Tritium Waste Treatment System, from planned maintenance operations on nonsecondarily contained systems or from accidental releases into the room air. These releases are routed to the TSTA stack where they are monitored for tritium concentration. Tritiated liquid wastes are: tritiated oil, glycol from bubblers, water from decontamination and cleaning operations, HTO from small scale experiments, and tritiated water from a cooling water loop. Oil is solidified before disposal and low level water and glycol (less than 200 mCi [7.4×10^9 Bq] per month) are released to the environment through the building drain system. Solid wastes from TSTA are: HTO adsorbed on a substrate such as molecular sieve; oil absorbed on vermiculite; used plumbing, valves, transducers, etc.; and laboratory trash such as gloves or paper. Solid trash is disposed of depending on the level of tritium contamination. Low level trash (less than 20 mCi/m³ [7.4×10^8 Bq/m³]) is placed in boxes lined with plastic bags and buried at the LANL radioactive waste disposal site. Medium level trash (greater than 20 mCi/m³ [7.4×10^8 Bq/m³] but less than 100 Ci/m³ [3.7×10^{12} Bq/m³]) is placed in an asphalt-lined metal drum, transported by LANL waste disposal group, and buried in shafts as recoverable waste. High level tritiated waste (greater than 100 Ci/m³ [3.7×10^{12} Bq/m³]) is handled the same as medium level waste except it is placed in a double drum asphalt lined container with the space between the drums filled with either asphalt or vermiculite. Table 2 shows an account of the amount of tritiated waste produced at TSTA from 1985 to 1987.

Table 2. Amount and Type of Tritiated Waste Produced at TSTA by Year

Year	Gaseous (total Ci)		Solid (m ³ [total Ci])		
	HTO	HT	Low	Mid	High
1985	2.9	0.7	7 (<0.14)	0	0
1986	6.1	4.7	6 (<0.12)	0.2 (0.1)	0.6 (1300)
1987	14.4	0.4	4 (<0.8)	0.2 (1)	2.0 (26000)

The total amount of liquid waste produced during the three years was <0.5 Ci (1.8×10^{10} Bq). The maximum activity level of the cooling water during that time was 0.2 μ C/m³ (7.4×10^3 Bq/m³).

The amount of tritiated waste produced at TFTR and CIT on a regular basis is expected to be comparable to the actual amounts listed above for TSTA, except that TFTR and possibly CIT will send the effluent gas from their reactors off-site for reprocessing (the waste generated at the time of decommissioning of TFTR and CIT is not considered here). The amount of effluent gas expected to be produced by TFTR is 150,000 torr-liter/day. The amount expected from CIT is 343,000 torr-liter/day.

TRITIUM CONTAINER STUDY CONDUCTED AT PPPL

A tritium container study has been conducted at Princeton Plasma Physics Laboratory specifically to deal with means of handling the tritium transport needs of TFTR.² This study was produced after extensive conversations with and site visits to Savannah River Plant (SRP), Oak Ridge National Laboratory (ORNL), Westinghouse Waste Management Plant (Westinghouse Hanford Corporation, WHC), Los Alamos National Laboratory, Mound facility and the Department of Energy in Washington. The study reviews and summarizes the tritium shipping containers presently available in the United States.

Current United States Department of Transportation regulations allow transport of gaseous tritium as air freight in approved 12-liter (LP-12) and 50-liter (LP-50) containers at a maximum pressure of 850 torr (16.44 psia) and 1200 torr (23.2 psia) at 25°C (77°F), respectively. These containers are currently used by the Savannah River Plant for transporting tritiated gas in the United States (Savannah River is the only DOE-owned tritium production facility in the U.S.).

The LP-12 container is a package for handling medium quantities of tritium. Figure 1 is a schematic of the LP-12 containment vessel (without the shipping drum).

Figure 1. Schematic of LP-12 containment vessel (without shipping drum).

ASSEMBLY
 3rd. 8' 1' 0'

FIG. 1

The containment vessel is a nominal 12 liter, 347 stainless steel vessel fitted with a stainless steel vacuum valve assembly. It has a 9-1/2" O.D. and is 11" high with a 0.062" wall thickness. The containment vessel is secured within a closed and sealed aluminum bucket with 10" O.D., 20" high, and a minimum wall thickness of 3/16". The aluminum bucket is centered and supported with an 18-gage, 19 1/4" O.D. by 30" high steel drum using celotex insulation. The shipping drum is secured by use of a bolted locking ring. The gross weight is 130 pounds. The maximum allowable tritium activity for shipping purposes is 32,800 Ci (1.2×10^{15} Bq).

The LP-50 is a package for large quantities of tritium. Its construction closely parallels the LP-12 construction taking into account the larger capacity of the LP-50. The package gross weight is 260 pounds. The maximum allowable tritium activity for shipping purposes is 193,500 Ci (7.16×10^{15} Bq).

Another type of container for tritiated gas has been designed by Oak Ridge National Laboratory. The ORNL gas containers have shipping capacities from 10 ml to 20,000 ml with a maximum internal fill pressure of 610 torr (11.8 psia) at 25°C (77°F). Oak Ridge has designed 12 gas containers. Those containers most commonly used are described in Table 3. The dimensions A and B in Table 2 are defined in Figure 2, which is a schematic of the container design, not including the overpack.

Table 3. Shipping Capacities of Most Commonly Used ORNL Gas Containers

Capacity (ml)	A (cm[inches])	B (cm[inches])	Radioactivity Limit at STP (Ci[Bq])
50	35.18 (13.85)	8.89 (3.50)	130 (4.8×10^{12})
300	46.38 (18.26)	10.16 (4.00)	800 (3.0×10^{13})
2000	58.27 (22.94)	18.42 (7.25)	5300 (2.0×10^{14})
5000	66.52 (26.19)	21.92 (8.63)	13300 (4.9×10^{14})
16000	75.90 (29.88)	26.04 (10.25)	not to exceed 30000 (1.1×10^{15})

Figure 2. Schematic of ORNL Gas Container (without shipping drum).

TYPICAL RADIOACTIVE GAS CONTAINER (USED AT ORNL)

FIG. 2

The inner and outer containers for this package are built from 304 L stainless steel. The gasketed lid of the overpack is secured by 8, 3/8" bolts. The weight of the 2000 ml container is 50 lbs, the 5000 ml container is 76 lbs, and the 16000 ml container is 106 lbs. The maximum gross weight of a container with its overpack (24" diameter, 41 1/8" high) is 750 lbs.

Tritiated gas can also be transported on depleted uranium beds as UT_3 and then it is handled as if it were radioactive waste. ORNL has designed a getter bed container which uses 250 g of depleted U-238 as getter material. The maximum quantity of material per package is 50000 Ci (1.85×10^{15} Bq, ~ 5 grams of tritium). The assembly is made from 316 stainless steel. The overpack consists of a nominal 10 gallon metal drum 15" O.D. by 18" high. Figure 3 shows the container with overpack. The outer drum has a 16-gauge locking ring with a 5/16" diameter bolt. The gross weight of the package is 60 lbs.

Tritiated water destined to be reprocessed can be transported in approved containers if it is solidified by adsorption onto molecular sieve beds. This is also handled as if it were tritiated waste. This method of transporting tritiated water has not yet been used to our knowledge.

Tritiated water destined for disposal is commonly solidified on molecular sieve material and shipped to Hanford in a DOT type A or type B package. Molecular sieve material is solidified in a Std 90 mil 2S poly liner. The liner is placed in a 17C 30 gallon steel drum which is asphalt lined. Figure 4 shows the 30 gallon drum. The 30 gallon steel drum is packaged in a 17C asphalt lined 55 gallon drum. The 55 gallon drum and closure is the same design as the 30 gallon drum. The annulus between the exterior of the 30 gallon inner drum and the interior of the 55 gallon drum is filled with additional asphalt. The container is placed in a N-55 overpack for shipment to the burial site at Hanford.

All of these transport methods can be used by fusion facilities to transport tritium to another site for reprocessing or disposal. In the case of tritiated gas in approved 12-liter or 50-liter containers, shipment by air freight is a common, well-proven and fairly inexpensive method of transport for high activity gas or for small amounts of gas. ORNL containers for gas solidified on uranium beds can also be shipped by air. All other forms of tritiated waste, whether they are being shipped for reprocessing or for waste disposal, must be shipped using land transport and are handled in the same manner as any other radioactive waste. In most cases, the container must be transported on a truck which is dedicated to that shipment and an "Exclusive Use Rate" is charged for the vehicle. All radioactive waste transported on public roads which contains more than 30,000 Ci (1.1×10^{15} Bq) per container is designated "Highway Route Controlled Material" and requires a specially trained driver.

Figure 3. Schematic of ORNL Getter Bed Container (with shipping drum).

TRITIUM SHIPPING CONTAINER (USED AT ORNL)

Figure 4. DOT 7A type A Steel Drum, 17C, 30 gallon.

DOT 7A Type A
49CFR 178.350
Steel Drum - 17C - 30 gal
49CFR 178.115

Fig 1

The shipper is responsible for all of the paperwork involved in a shipment. This includes a hazardous waste manifest, which is required for all radioactive waste. The completion of the paperwork involved in a shipment should present no problem if this type of paperwork is being done on a routine basis at the facility shipping the tritiated waste. It can represent a substantial amount of effort for new or infrequent shippers.

TRITIUM SHIPPING REQUIREMENTS FOR TFTR

Specific tritium shipping needs for TFTR include:

1. Delivery of tritium to TFTR for plasma fueling.
2. Shipping of plasma exhaust gases consisting of hydrogen isotopes and impurities.
3. Shipping of tritiated water absorbed on molecular sieve beds.
4. Shipping of tritiated waste including room trash, clothing and contaminated equipment.

The selection of containers to be used at TFTR takes into account the container design, container certification, and transportation rules and regulations.

All the tritium handling will take place in the TFTR Tritium Vault, the Tritium Waste Handling Area, and the Tritium Clean-Up System Room. These facilities are located in the TFTR basement. With the existing equipment, all of the rooms are very congested. It is therefore imperative that the tritium containers which are used are small, easy to handle, and have a large capacity. An additional requirement at TFTR is that shipments of tritium may not exceed 25,000 Ci (9.2×10^{14} Bq, ~ 2.5 grams of tritium) per container.

TFTR has determined that the LP-12 will be used for incoming shipments of tritium. Outgoing shipments could be handled by one of the containers outlined in Table 4.

Table 4. Method of Handling TFTR Outgoing Shipments of Tritiated Gas for Reprocessing or Tritiated Waste for Disposal.

Type	Shipment	Comments
LP-50	Exhaust Gas	Certified container with overpack
ALM-1 (Conf.#5)	Molecular Sieve	Tritiated water to 105 Ci (3.7x10 ¹⁵ Bq) or 10g
	Uranium tritide	Certified container for large shipments
DOT 17H or 17C 55 gal. drum	Various solid waste	With asphalt and/or absorbant as required Add N55 overpack for type B shipments
N55	Overpack	For use with type B shipments
M-3A	Various solid waste	Add a Polypanther overpack for type B shipments
Polypanther	Various waste	Can be used with type B shipments, generally rented.
Strong-tight boxes	Low-level waste	Wipes, shoe covers, paper products

Asphalt has been found to inhibit migration of tritium. A typical packaging procedure is to encase the container holding the tritium waste in a thin layer of asphalt and then place this container inside a 55 gallon drum or other overpack for shipment and/or burial. Any waste shipped to Hanford for burial must meet Hanford requirements and these are covered in Hanford procedure RHO-MA-222. Any container used in transportation must be either DOE certified (ref. Directory of DOE Certificates of Compliance) or DOE/NRC certified. The State of New Jersey also has a requirement that shipments above 20 Ci (7.4x10¹¹ Bq) must be reported to the Department of Environmental Protection/Bureau of Radiation Protection for an approved transportation route.

DEPARTMENT OF TRANSPORTATION APPROVAL OF TRITIUM SHIPPING CONTAINERS

A final point which must be dealt with is Department of Transportation (DOT) approval of containers for radioactive material. Tritium packaging requirements are outlined in U.S. Department of Transportation, Title 49, Part 173.³ The LP-12 and LP-50 gas containers are not in general a problem. They have a long history of safe performance and there are many containers available. Tritiated waste water is usually shipped after it has been solidified. The DOT requirements on shipping containers for solid waste include maintainance of integrity during specified temperature excursions, drop tests, compression tests, pressure differential and water spray. The severity of the requirements depends on the activity of the water in the container. Mound Laboratories has designed and extensively tested containers and procedures for solidifying liquid tritiated wastes (not destined to be reprocessed) which meet the DOT requirements for solid waste and has used these containers for several years.⁴ There are a limited number of Mound containers available and more will be needed if they are to be used for liquid waste from fusion facilities. Tritiated water which is destined to be reprocessed rather than buried as waste will have to be treated somewhat differently, for example, it may be solidified by adsorption on molecular sieve beds and then put into an approved container. The ORNL containers for tritiated gas which is shipped as a solid on uranium beds are DOT approved but have not yet been used extensively by others.

CONCLUSIONS

For TFTR, the conclusions of the Tritium Container Study were that:

1. Tritium must be delivered in LP-12 containers.
2. Plasma exhaust gas would be best handled by use of the Oak Ridge getter bed container.
3. Tritiated water should be transported in the molecular sieve containers, i.e. kegs.

Tritiated waste such as room trash, clothing and contaminated equipment will be handled as Class A or Class B waste and transported to a waste disposal facility in standard waste containers.

CIT will employ tritium handling techniques which are very similar to those used by TFTR. Indeed, CIT will incorporate TFTR's tritium handling equipment in its design and utilize many of the procedures set up by TFTR for handling tritiated waste.

For future full-scale fusion facilities in the U.S. with on-site gas reprocessing, the waste handling requirements for tritium transport are expected to be very similar to those currently used by TSTA.

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