NRC TRITIUM REQUIREMENTS

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INTRODUCTION

This report discusses the Department of Energy (DOE) and the Nuclear Regulatory Commission (NRC) requirements with regards to tritium from a radiological, a safeguards and an accountability standpoint.

RADIOLOGICAL

Both the DOE and the NRC have existing radiation protection requirements that include tritium. In 10 CFR 20, Appendix B, Tables 1, 2 and 3[1], the NRC treats tritiated gas as tritiated water vapor with respect to radiation protection while DOE still provides separate limits for tritiated gas and tritiated water vapor.[2, 3, 4, 5] While the NRC's approach is more conservative, it does eliminate the need for trying to establish (and defend) a tritiated gas/water vapor ratio.

However, since tritium is not used on a large scale in any NRC-licensed facility, the NRC preferences on how tritium should be analyzed for transport as a result of a controlled or accident release are not known.

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1 10 CFR 20, "Standards for Protection Against Radiation," Appendix B, "Annual Limits on Intake (ALIs) and Derived Air Concentrations (DACs) of Radionuclides for Occupational Exposure: Effluent Concentrations; Concentrations for Release to Sewerage," Table 1,"Occupational Values," Table 2, "Effluent Concentrations," Table 3, "Releases to Sewers."

2 10 CFR 835, "Occupational Radiation Protection," Appendix A, "Derived Air Concentrations (DAC) for controlling Radiation Exposure to workers at DOE Facilities."

3 Proposed Rule (58FR16268, March 25, 1993) 10 CFR 834, "Radiation Protection of the Public and the Environment," Appendix A, "Derived Concentration Guides for Air and Water," Table A-1a, "Derived Concentration Guides (DCGs) for Members of the Public from Ingested Water and Inhalation Resulting in an EDE of 100 mrem/yr," Table A-1b, "Derived Concentration Guides (DCGs) for Members of the Public from Ingested Water and Inhalation Resulting in an EDE of 1 mSv/yr," Table A-2, "Alternate Absorption Factors and Lung Retention Classes for Specific Compounds."

4 DOE Order 5400.5, "Radiation Protection of the Public and the Environment," Chapter III, "Derived Concentration Guides for Air and Water," Figure III-1, "Derived Concentration Guides (DCGs) for Members of the Public from Ingested Water and Inhalation Resulting in 100 mrem/yr," Figure III-2, "Alternative Absorption Factors and Lung Retention Classes for Specific Compounds."

5 DOE Order 5480.11, "Radiation Protection for Occupational Workers," Attachment 1, "Derived Air Concentrations for Controlling Radiation Exposure to Workers at DOE Facilities," Table 1, "Derived Air Concentrations (DAC) for Controlling Radiation Exposure to Workers at DOE Facilities," Table 2, "Alternative Absorption Factors and Lung Retention Classes for Specific Compounds."

If the release is essentially tritiated gas (i.e., HT, DT and T_2) the plume may never return to the ground. However, if the release is essentially tritiated water vapor (i.e., HTO, DTO and T_2O) the plume may remain on or return to the ground. This initial release is not only dependent on how the tritium is stored but also on the accident location.

In the case of the existing Savannah River Production Reactors or the CANDU Reactors, there is the presence of large amounts of water for cooling and/or neutron moderation in the area where tritium is produced. Therefore, an accident in such a location would probably release tritium as tritiated water vapor. A tritiated water vapor release would probably be a valid assumption in a fusion facility, if the tritium breeding areas are water-cooled and these areas are the tritium release source. In addition, the production of tritiated water vapor is possible if hydrogen recombiners are to be used to control hydrogen concentrations for explosion prevention purposes.

Even when the release starts out as tritiated gas, it will convert to tritiated water vapor over time. This is due to the weather (i.e.,fog, high humidity, rain, etc.), which has an effect on the conversion of tritiated gas to tritiated water vapor. Both experimental and modelling work has been undertaken to determine the conversion rate.[6] However, there is indication that some of the conversion rates are too conservative and further work on this subject is needed.[7]

As can be seen, the concentration limits are clearly known but there are no clear guidelines on what should be used for the dispersion of a tritium release.

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6 Fusion Technology, Vol. 14, No. 2, Part 2B, September, 1988, "Proceedings of the Third Topical Meeting on Tritium Technology in Fission, Fusion and Isotopic Applications," Toronto, Ontario, Canada, May 1-6, 1988, pp 1111 - 1269.

7 O. A. Griesbach and J. R. Stencel, "Operational Experience with the DATS Sampler During the Canadian Tritium Modeling Experiment," Section IV, Fusion Technology, Vol. 14, No. 2, Part 2B, September, 1988, "Proceedings of the Third Topical Meeting on tritium Technology in Fission, Fusion and Isotopic Applications," Toronto, Ontario, Canada, May 1-6, 1988, pp 1200 - 1201.

SAFEGUARDS

In DOE Order 5633.3B,[8] tritium is classified as "Other Nuclear Material"[9]. While this classification has no basis in law and only applies to facilities that are required to conform to DOE Order 5633.3B, DOE implements its safeguards for the use of tritium by means of this classification. Finally, due to the use of tritium at the Tokomak Fusion Test Reactor (TFTR) at the Princeton Plasma Physics Laboratory (PPPL), some experience exists on how DOE Order 5633.3B would be implemented at a fusion facility.

Currently, the NRC has no safeguards requirements for tritium. However, with the development of fusion power reactors that breed tritium, the NRC has several options open to it:

- The NRC could do nothing,

- The NRC could increase its control of tritium safeguards and inventory in a fashion similar to what the DOE implemented in DOE Order 5633.3B, or

- The NRC could increase its control of tritium safeguards and inventory by undertaking an approval process to declare Lithium a source material and tritium a special nuclear material.[10] If under this option the NRC's petition is denied by the President or the Congress, the other two options remain viable.

The first option, based on proliferation concerns, it is probably not viable. Thus, it should be assumed that the NRC will develop some sort of tritium safeguards requirements.

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8 DOE Order 5633.3B, "Control and Accountability of Nuclear Materials," September 7, 1994.

9 DOE Order 5633.3B; Chapter I, Figure I-1, page I-2.

10 G. G. Hofer,"NRC Jurisdiction of Fusion Power," Raytheon Engineers & Constructors, May 1995.

Since NRC tritium safeguards are presently nonexistent, the following CFR listing includes the safeguards requirements for Special Nuclear Materials and the physical security requirements for present-day light water reactors. This listing represents the maximum level of NRC-related CFR requirements that would be applied to a fusion facility and its tritium inventory.

10 CFR 2	Rules of Practice for Domestic Licensing Proceedings [§2.790(d)(1)]
10 CFR 11	Criteria and Procedures for Determining Eligibility for the Access to or Control Over Special Nuclear Material
10 CFR 25	Access Authorization for Licensee Personnel
10 CFR 26	Fitness for Duty Programs
10 CFR 50	Domestic Licensing of Production and Utilization Facilities [§50.34(c), §50.34(d), §50.54(p), §50.70(d)(1)]
10 CFR 70	Domestic Licensing of Special Nuclear Material
10 CFR 73	Physical Protection of Plants and Materials
10 CFR 74	Material Control and Accounting of Special Nuclear Material
10 CFR 75	Safeguards on Nuclear Material — Implementation of US/IAEA Agreement
10 CFR 95	Security Facility Approval and Safeguarding of National Security Information and Restricted Data

Also, are following environmental-related CFR requirements would apply:

40 CFR 61 (Subpart H)	Clean Air Act Standards for Annual Public Dose Due to Airborne Radionuclide Releases
40 CFR 302	CERCLA Reportable Quantities for Radionuclides

In addition, NUREG-0800, Standard review Plan (SRP) 13.6, "Physical Security" and the Division 5 Regulatory Guides, "Materials and Plant Protection" (as applicable) would also apply to a fusion facility and its tritium inventory. Individual applicability of the Division 5 Regulatory Guides depends on the configuration of the systems and processes employed for producing, transporting, storing and utilizing the tritium.

ACCOUNTABILITY

Accountability is actually part of safeguards (i.e., you have to know what quantity you're protecting and be able to detect any diversion of the material) and thus the applicable requirements (or lack thereof) have already been discussed. The following discussion on accountability is focused on the present DOE requirements. These requirements were developed with respect to tritium production in fission reactors and thus do not reflect the constraints imposed by tritium production in a fusion facility.

Under DOE Order 5633.3B, tritium is accountable in quantities as small as 0.01 gram.[11] However, the DOE Order does not consider tritium contained in water (H_2O or D_2O) used as a moderator in a nuclear reactor as accountable material.[12] Finally, the DOE Order requires, as a minimum, that tritium be inventoried at least annually.[13]

Accounting for tritium, per the requirements of DOE Order 5633.3B, is difficult as discussed by Jim Anderson of the Los Alamos National Laboratory (LANL) Tritium Systems Test Assembly (TSTA):[14]

> "[L]et me assure you that tritium accounting, inventory control and measurement consumes a tremendous amount of time and resources at DOE tritium facilities. Virtually every DOE tritium facility (Savannah River, Mound, Lawrence Livermore, Oak Ridge, Los Alamos (TSTA and the Weapons Tritium Salt Facility) have suffered through periods where the operations have been shut down while inventory discrepancies were resolved. Some of these shutdowns were for a few days, but in the worst cases, several months. The problem results from the fact that tritium is a hydrogen isotope. It sorbs on surfaces, permeates through materials, undergoes oxidation and/or exchange reactions to form tritiated water, methane, ammonia, etc. All of these products tend to adsorb or absorb on/in structural materials. It is very difficult to maintain accurate knowledge of tritium inventories to +/-0.01 gram (the reporting quantity). The situation is further complicated at a fusion reactor, where tritium implantation in and tritium uptake by first wall materials (e.g., graphite) leaves much of the tritium in unmeasurable locations. This results in a fairly large MIP (material in process)."

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11 DOE Order 5633.3B; Chapter I, Figure I-1, page I-2.

12 DOE Order 5633.3B; Chapter I, Figure I-1, page I-2, Note 4.

13 DOE Order 5633.3B; Chapter II, § 3.a(4), pages II-3 and II-4.

14 Private communication, dated May 24, 1995.

"The bottom line, it [i.e., tritium accounting] is not simple, the standards and requirements are somewhat unrealistic and it is frequently difficult or impossible to make the measurements required by the Order."

For a 2500 MW_t demonstration fusion power facility, the tritium burnup rate is 380 g/fpd (i.e., grams per full power day) and the extra breeding need is 4 g/fpd (to account for decay and doubling time). This makes the tritium production rate to be 384 g/fpd. However, this rate has an uncertainty of ~40 g/fpd.[15] Since it is imperative that the facility produce more tritium than it consumes, the uncertainty has to be added to the production rate. However, when modeling this revised production rate, there still is an uncertainty of ~40 g/fpd. Therefore, the goal becomes ~425±40 g/fpd, or ~155±15 kg/fpy (i.e., kilograms per full power year [365 days]).

Since the fusion reaction will have to be shut down in order to "bake-out" the plasma chamber (i.e.,heat up the chamber under vacuum to promote desorbsion of the tritium from internal structures), capacity factors will necessitate that the tritium accountability be performed no more often then the annual tritium accountability requirement. This leads to the following problems in tritium accountability:

Ratios of Annual Tritium Production to Accountability Requirement
(Calculated Annual Production of ~155±15 kg for a 2500 MW_t Fusion Facility vs. 0.01 Gram Accountability Requirement)

Total amount	1.55×10^{7}
Uncertainty	1.5×10^{6}

While the uncertainty should be much smaller once a fusion facility is built, it's not clear that it could be reduced 6 to 7 orders of magnitude.

Not only does this require very high accuracy in the measuring of tritium quantities, but unfortunately, the result provides no assurance that all the tritium has been accounted for due to the large uncertainties in the calculated value.

It is apparent that the tritium accountability requirements of DOE Order 5633.3B need to be revisited with respect to the production of tritium by fusion.

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15 Private communications (Dai-Kai Sze, Argonne National Laboratory and Laila A. El-Guebaly, Fusion Technology Institute, University of Wisconsin-Madison), both dated June 28, 1995.

SUMMARY

Very little tritium is currently under the NRC's jurisdiction. Therefore, with the exception of the NRC's tritium concentration limits, NRC tritium requirements must be extrapolated from the NRC's current requirements on other radionuclides. Also no NRC guidance exists on what should be the dispersion characteristics for a tritium release. It is thus not possible to determine at this time, based on the existing NRC regulatory record, what radiological, safeguards and accountability requirements the NRC would impose on fusion facilities and their tritium inventories.

DOE's present tritium accountability requirements are not well suited for fusion tritium production. Further assessment is necessary for the development of requirements that reflect the constraints of a fusion facility.

It is not too early, however, to begin to study these issues and develop recommendations in order to influence the process.