Tritium Inhalation Risks for a Tritium Gas Target at Jefferson Lab

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Introduction

The goal is to develop a safe tritium target for use in Hall A at Jefferson Lab for the 12-GeV experiments E12-10-103 and E12-11-112.[1, 2] Our overall philosophy for developing the conceptual design and safety devices has been to minimize the amount and density of tritium necessary for the experiment and to keep the systems and procedures as simple and reliable as possible. One of the plans is to fill the tritium target cell at Savannah River National Lab and ship the target to Jefferson Lab. In this report we discuss the issue of tritium loss in Hall A and possible mitigating procedures. Perhaps one of the highest risk time periods for the tritium target is when the target is removed from its shipping cask and installed in the target chamber as well as the reverse steps. In particular, we present here calculations of the tritium uptake in worst case scenarios by a worker in the Hall. In this report we are concerned primarily with a possible health risk for a worker if the entire tritium target is accidently released in Hall A. A simple estimate for the volumetric air flow for a local fume hood is given to achieve the recommended capture velocity for tritium gas.

Dose Estimate for a Worker Installing Target During a Full Release

For protection of the Hall and the workers in the Hall, the most important element is a ventilation system. Of course, when the target is being installed or in normal operation, a local exhaust system will be in place. Here we deal with the event of a full target release and malfunctioning exhaust equipment, the worst case scenario. Although Hall A will have the local task exhaust system and the already installed exhaust fans, we assume here a confinement factor of 10, *i.e.*, the number used for an open work area with unknown ventilation conditions. The annual limit of intake is calculated from information in 10 CFR 835 Defined Air Concentration (DAC) and converted as follows to the annual limit of intake: DAC(microCi/ml)*2400 m^3/yr*(100 cm/m)^3*1E-6. The DAC is taken to be 0.5 microCi/ml. Here, we calculate the potential intake as a fraction, I_f, of the annual limit of intake (ALI), from the following formula:[3]

$$I_f = (Q \times 10^{-6} \times R \times C \times D)/ALI$$

where

I_f = the potential intake expected as a fraction of the ALI.

Q = the total amount of unencapsulated radioactive material processed during the year in curies (Ci) in a given work location.

10^{-6} = a conversion factor based on the conclusion that the fractional amount of radioactivity inhaled by a worker is generally less than one millionth (10^{-6}) of the amount of radioactivity processed.

R = the fraction of the radioactive material likely to be released to the workplace based on material characteristics, such as physical and chemical form. See the Appendix.

C = the confinement factor is dependent on the operation performed or the physical layout of the facility. See the Appendix.

D = the dispersibility factor takes into account processes such as grinding, milling, boiling, or exothermic material being dispersed into the air. See the Appendix.

ALI = the annual limit of intake is calculated from information in 10 CFR 835 and is specific for the radionuclide. The unit for the ALI in these calculations is curies.

For the 1000 Ci target, the information in the appendix, a conversion factor based on the conclusion that the fractional amount of radioactivity inhaled by a worker is generally less than one millionth of the amount of radioactivity processed and using the most conservative dispersibility factor, 10, we would then have

$$I_f = (1000\ \text{Ci})(1\text{E-}6)(1)\,(10)(10)/1.2\text{E}3 = 8.3\text{E-}5$$

Thus the fraction of the annual limit on intake is extremely small. Even if we assume that the entire tritium sample is in the form of HTO and conservatively multiply the above I_F by 10000, the I_f is still less than unity. Please note that this is a conservative estimate because we have used a dispersability of 10 whereas it is customary to use 1 for tritium gas.

In another approach to estimating the dose that a worker might receive in the worst case scenario, we suppose the exhaust systems do not work and all 1000 Ci were released into Hall A at JLab. Assuming that the release was elemental hydrogen (HT), the dose conversion factor for inhalation is 1.83E-15 Sv/Bq = 0.00677 rem/Ci. Hall A has a diameter of 53.5 m and a height to crane of about 16.9 m. If you have 1000 Ci immediately released in a 38,000 m^3 room, that is 0.026 Ci/m^3. A typical worker breathing rate is 1.2 m^3/hour. Thus 1.2 m^3/hr * 0.026 Ci/m^3 * 0.00677 rem/Ci = 0.21 mrem/hour. A worker would be receiving about 0.21 mrem/hour. If we assume a work year of 2000 hours in the unventilated Hall, then the dose to a worker in a year would be 0.42 mrem or 8.4E-5 of the yearly DOE limit of 5 rem.

Vent Hood

The use of a local vent hood could greatly mitigate risk of inhalation or contamination from a full release of the tritium target. For routine work with tritium samples in a fume hood, face velocities of 100 to 150 linear feet per minute (lfm) are recommended.[4] Higher linear velocities produce turbulent flow and can result in backstreaming of the tritium gas. For a fume hood, the volume flow rate, Q, can be estimated from the following formula[5]:

$$Q = V_H(10D^2 + A)$$

where V_H is the face or capture velocity, D is the distance from the hood where the pollutant is released, A is the area of the hood opening. If we design the hood in such a way that V_H=100 lfm, D=1ft, A=20 ft^2, then Q is 3000 cfm.

Conclusions

It is likely that even without any mitigation a 1000 Ci target released in Hall A would not lead to a worker exceeding the DOE or JLab dose limits in the area. Nevertheless the use of a local task fan or the Hall A exhaust system should dramatically reduce the dose from a full release to a very small level.

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Appendix

Release Fractions (R)

Gases or volatile material	1.0
Nonvolatile powders	0.01
Solid (*e.g*. uranium fuel pellets, cobalt or iridium metal)	0.001
Liquids	0.01
Encapsulated material	0

Release fractions are taken from NUREG 1400, Table 1.1

Confinement Factors (C) and Dispersibility Factors (D)

Confinement Factors (C)

DOT Drums & Steel Waste Boxes, Storage canal with greater than 16 feet of water	0.001
Hot Cells, Cargo Containers, Wooden Boxes	0.01
Glovebox [a]	0.01
Hood (well ventilated)[a]	0.1
Open bench; normal ventilation[a]	1
Non-routine or special jobs where the ventilation is unknown	10

[a] Taken from NUREG 1400, section 1.2.2

Dispersibility Factors (D)

Cutting, grinding, heating, or exothermic chemical reactions	10
All other operations	1

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[1] G. G. Petratos *et al.*, JLab MARATHON Collaboration, JLab Experiment E12-10-103, 2010.

[2] P. Solvignon *et al.*, Jlab Experiment E12-06-112, 2011.

[3] E. E. Hickey *et al.*, "Air Sampling in the Workplace", U. S. Nuclear Regulatory Commission, NUREG-1400 (1993).

[4] R. W. Parkhill, "Standard Review Plan for Transportation Packages for Irradiated Tritium-Producing Burnable Absorber Rods", U. S. Nuclear Regulatory Commission, NUREG-1609, supplement 2 (2006).

[5] Fume hood basics, http://www.ehow.com/how_7995042_calculate-fume-hood-velocity.html.