Absorption 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[1,2] R12-10-103 and E12-11-112. 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. The plan 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 an installation procedure as well as calculations of the tritium uptake by materials in the Hall. In this report, we are concerned primarily with possible damage to property.

Installation of the target at JLab

An outline of a preliminary target installation procedure is given below. For protection of the Hall and its equipment, 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 a malfunctioning local exhaust fan. A summary[3] of the exhaust fans already installed in Hall A is given below in Table 1. Fan EF-3 is a dual speed fan that can operate at either 6000 or 12000 cfm. The lowest speed fan (6000 cfm) can be operated with the truck access doors closed. The higher fan speeds operate with the truck access doors open.

Table 1. Design capacity of existing Hall A exhaust fans.
Capacity is in cubic feet per minute.

Exhaust fan Hall A	Design capacity (cfm)
EF-1	12000
EF-2	12000
EF-3	6000/12000

Hydrocarbon based elements in the Hall have the largest tritium absorption rate. For example, the absorption rate[4] for elemental tritium (T_2 + ½ HT) for high density polyethylene (HDPE) is 0.13 $mCi/s/m^2$, while that for concrete is 0.01 $mCi/s/m^2$. This rate for HDPE was determined by considering the measured loss of tritium as a function of time in a closed container containing a sample of HDPE. The concrete estimate is especially conservative since the HT must convert to HTO before uptake in the concrete. The uptake rate[5] for stainless steel is an order of magnitude smaller than that of concrete. The administrative or actionable limit[6] for tritium on a surface is 10000 dpm per 100 cm^2. In making an estimate of the worst case incident, we will assume the largest absorption rate, *i.e.*, that for polyethylene. In our estimate, we assume that the entire 1000 Ci sample is lost instantaneously in Hall A. We calculate the dpm in a polyethylene surface as a function of time for various exhaust fan speeds and present these results in Fig. 1. Here, the assumption is that the fans are on within a minute when the tritium is released. In this case, the usual exhaust fans for the Hall could be used to clear as much tritium out of the Hall as quickly as possible. If we assume that the Hall A exhaust fans are turned on and produce 20,000 cfm, then the meantime to exhaust Hall A is about 67 minutes. (The actual peak capacity of all three Hall A fans in simultaneous operation is 36,000 cfm.) The level of activity should be reduced to the 0.3 Ci level after about eight mean times or nine hours of operation.

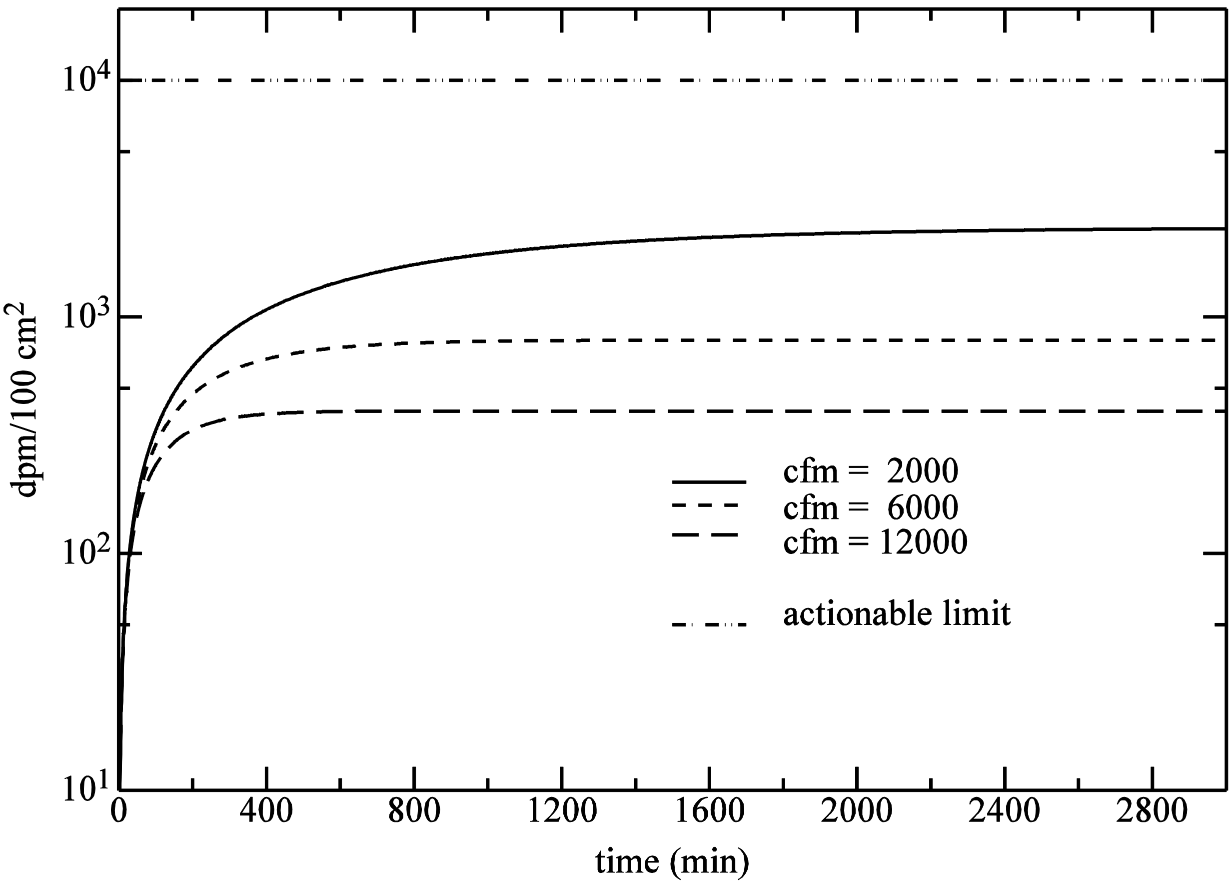

Fig. 1. The dpm per 100 cm^2 in polyethylene in Hall A as a function of time after a full release of 1000 Ci of tritium and for various exhaust fan speeds in cubic feet per minute.

The algorithm for calculation of the absorption on surfaces with the exhaust fans is given by the equations below. In the absence of an exhaust fan the absorption on to polyethylene is just assumed to be linear in time, *i.e.*, $T_i < T_d$ where T_d is the delay in turning on the exhaust fan.

$$A_i = A_{poly} T_i$$

where A_{poly} is the absorption rate in CH_2, and T_i is the time at step *i*. In subsequent steps in time after the fan is turned on, the absorption rate is given by:

$$A_i = A_{i-1} + A_{poly}\exp[-(T_i-T_d)/(V_H/F)]$$

where $T_i > T_d$, V_H is the volume of Hall A and is taken to be 38000 m^3, and F is the exhaust fan speed in units of volume per time.

It is clear from Fig. 1 that if the exhaust fan speed is greater than 2000 cfm (cubic feet per minute) then the contamination remains well below the actionable limit. Thus, our first and most important proposed step in the installation is to ensure that at least a 2000 cfm exhaust fan speed is turned on when the target container arrives in Hall A and is being installed. Note that Table 1 lists the design capacities of the fans and not the actual. Carroll Jones at JLab has stated that the actual values could be measured if necessary.

For reference, the dpm for polyethylene is estimated assuming that the fans are turned on one hour after a full release. These results are shown in Fig. 2. Here the dpm rises linearly for the first 8 hours and then levels out at a value and a time that depend on the fan speed. Again, the value remains below the actionable level with a 2000 cfm fan speed.

Based on these findings, a target installation procedure was developed. Outline of proposed target installation procedure:

- Turn on special ventilation fan (2000 cfm should be sufficient)
- When target container is received at JLab, survey with a hand-held tritium monitor
- Move the shipping cask under the ventilation hood
- When opening the target cask, survey with hand-held monitor
- Carefully unpack target, one person continuously surveying for tritium
- Remove protective shipping covers
- Attach W mask to target frame if this has not been done
- Two target-trained installers with proper PPE will carefully guide target into chamber
- Check target alignment, make adjustments as necessary
- Begin pumpdown of target in chamber after all seals have been made
- Begin monitoring pump exhaust for tritium
- Set up rad-hard RGA on mass 6 peak and remote monitor/interlock
- Hook up target cooling, monitors and all interlocks; activate cooling and interlocks
- Test all monitors and interlocks
- Perform special checklist before leaving hall – two target operators
- Target should be ready for beam alignment

The de-installation of the target would be approximately the reverse steps.

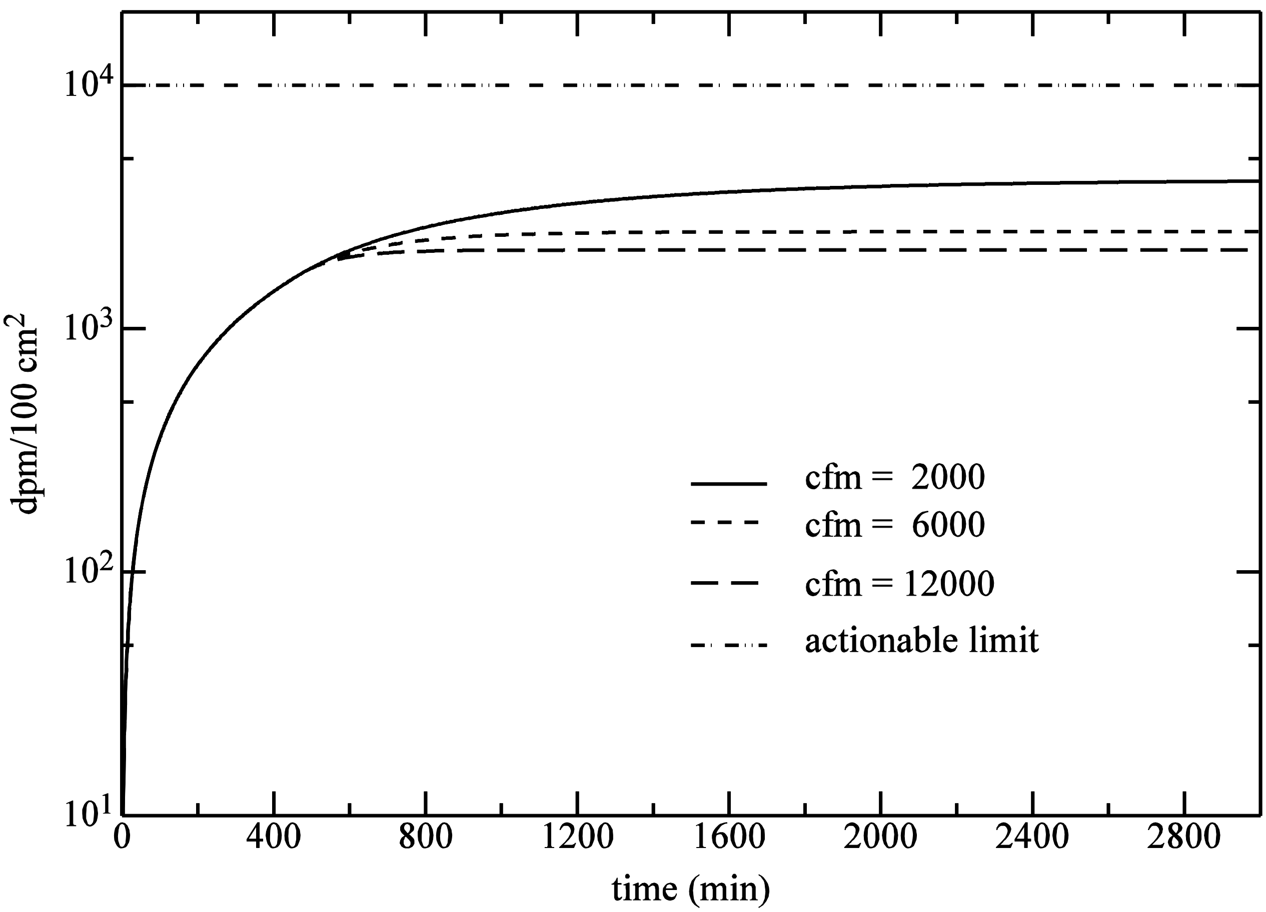

Fig. 2. The dpm per 100 cm^2 in polyethylene in Hall A as a function of time after a full release of 1000 Ci and for various exhaust fan speeds in cubic feet per minute. Here it is assumed that the exhaust fans are turned on 8 hours after the tritium release.

Conclusions

It is likely that without any mitigation a 1000 Ci target released in Hall A would lead to actionable contamination. However, activating only a 2000 cfm exhaust fan in Hall A within 8 hours of the release would keep the contamination well below the actionable level.

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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] Carroll Jones and David Kausch, JLab, private communication (2009).
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