Analysis of a tritium target release 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] E12-10-103 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 design for the JLab tritium target makes use of 1000 Ci of tritium gas. In this report we present an analysis of a full release of the tritium target and the dose expected beyond the site boundary from such a release. The methodology is to use both the HotSpot and the GENII software and models for this study. In particular, we investigate the dose rates expected as a function of stack height for the target.

Description of the JLab site

Jefferson Laboratory (JLab) operates a facility, formally Thomas Jefferson National Accelerator Facility. This facility is operated for the Department of Energy and provides a 6-GeV CW electron accelerator that produces about 200 μA of beam current or 1.2 MW of beam power. JLab is located in Newport News, VA in an urban environment. An aerial view of the facility is given in Fig. 1. For this reason special care is taken to estimate the dose that might be received beyond the site boundary of the facility in the event of the worst case accident of a full release of the tritum gas target. The experiments that make use of the tritium target are to be performed in Hall A at JLab. Hall A is the largest and leftmost circular mound in the lower right hand portion of the figure. The center of Hall A is located about 95 m from the site boundary.

Description of GENII

The GENII software was developed[3,4,5,6,7,8,9] to calculate the dose and risk from radionuclides released into the environment. The U. S. Department of Energy released GENII Version 1.0 in 1988. The U. S. Environmental Protection Agency released a new version of the software in 2002, GENII Version 2.0. The new version has improved transport models as well as dose and risk estimations. In 2002, a new edition GENII-NESHAPS was developed specifically for demonstrating compliance with the dose limits specified in 40 CFR 61.93(a), the National Emission Standards for Hazardous Air Pollutants for radionuclides. In 2003, the software was peer reviewed. GENII incorporates the internal dosimetry models recommended by the International Commission on Radiological Protection in ICRP 56-72 and the radiological risk estimating procedures of Federal Guidance Report 13. The radial grid used in GENII permits consideration of both distance and direction of target individuals and populations. The model includes direct exposure from surface sources (soil) and air as well as inhalation and ingestion.

The tritium model includes consideration of both gas and vapor, conversion into vapor, and biological conversion of both into organically-bound tritium.

Calculation with GENII

For the GENII estimate, a target of 1600 Ci was assumed and that 100% of the tritium converted immediately to HTO for conservatism. This estimate assumed a 15 m stack height, an exit velocity of 1 m/s, and a release time of one hour. Also, 8760 hours of weather data at Norfolk, VA for the year 2000 were used to determine the 95 percentile meteorology. In other words, the estimated dose of 0.8 mrem at a distance of 300 meters is not exceeded more than 5% of the time in this scenario. This result gives good agreement with that (0.75 mrem scaled from Table 2 below) of HotSpot for similar conditions.

Fig. 1. Aerial photograph of the JLab site. Hall A is the leftmost circular mound in the lower part of the figure. For scale, the diameter of Hall A is 52 m.

Description of HotSpot

The HotSpot health physics codes[10] were created to provide emergency response personnel and emergency planners with software tools for evaluating incidents involving radioactive material. The HotSpot atmospheric dispersion models are designed for near-surface releases, short-range (<10 km) dispersion and short-term (<24 hours) release durations in unobstructed terrain and simple meteorological conditions. These models proved a fast and usually conservative means for estimates. The HotSpot radionuclide library incorporates General Guidance Reports 11, 12 and 13 Dose Conversion Factors for inhalation, submersion and ground shine. HotSpot contains tools to deal with the release of plutonium, uranium and tritium.

Calculations with HOTSPOT

In the examples below, we used HotSpot 2.07.1 and assumed that the target was in the range of 600 Ci to 1600 Ci of tritium. We also assumed varying amounts of conversion to HTO. For example, we have assumed 100% of the T_2 target to be converted to HTO in the worst case scenario, and in a more reasonable scenarios, 6% is converted to HTO following Peterson and Davis[11]. We have also investigated stack heights and locations of maximum dose rates. It is not reasonable to expect that the maximum dose occurs at the site boundary. The maximum dose might be located further out depending on the stack height and weather conditions.

First, we assume a 600 Ci target that immediately converts to 100% HTO and is fully released. We assume in general a worst case weather scenario: a wind speed of 1 m/s at a height of 10 m and stability class F, *ie.* a stable atmosphere with minimal dispersion. We also assume a 120 minute sampling time and a receptor at 300 m. The sampling time is a measure of the meander of the wind. Longer times give a lower estimated average air concentration. The results are shown in Table 1.

Table 1: HotSpot calculations with worst case weather scenario, 600 Ci target, 100% immediate conversion to HTO, 120 min sampling time. The right hand column is the maximum dose scaled for a 1000 Ci target.

Stack height (m)	Dose at 300 m (mrem)	Distance at max dose (m)	Max dose 600 Ci (mrem)	Max dose 1000 Ci (mrem)
0	140	<100	770	1283
5	47	200	59	98
10	5.7	500	8.4	14
15	0.24	750	2.8	4.7
20	0.0032	1000	1.2	2.0

If instead, a sampling time of 60 minutes is chosen, then the estimates are shown in Table 2.

Table 2: HotSpot calculations with worst case weather scenario, 600 Ci target, 100% conversion to HTO, 60 min sampling time. The right hand column is the maximum dose scaled for a 1000 Ci target.

Stack height (m)	Dose at 300 m (mrem)	Distance at max dose (m)	Max dose 600 Ci (mrem)	Max dose 1000 Ci (mrem)
0	160	<100	890	1483
5	54	200	67	112
10	6.5	500	9.7	16
15	0.28	750	3.2	5.3
20	0.0036	1000	1.4	2.3

To have a better understanding about the spatial distribution of the dose rate, we made calculations as a function of distance from the stack. With the same assumptions as for Table 2, the results are shown for a 20 m stack height in Fig. 2. The maximum occurs at 1 km and is well under the 10 mrem limit.

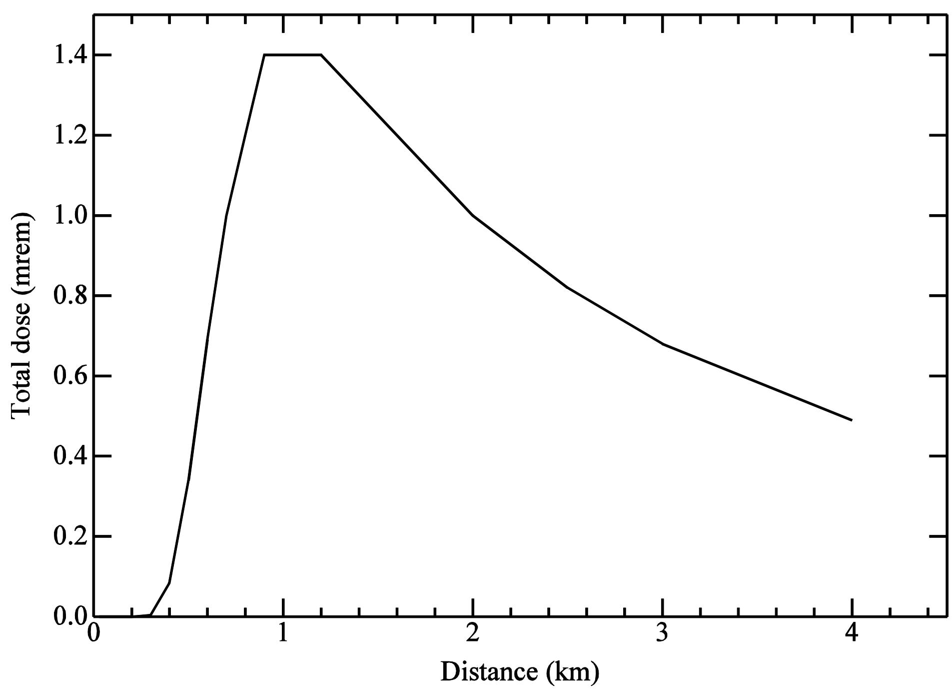

Fig. 2: HotSpot calculation of the total dose rate from the release of 600 Ci tritium target (100% HTO conversion) with a stack height of 20 m and a sampling time of 60 minutes.

If we now assume a 1600 Ci source, an immediate conversion of 6% of the target to HTO (a more reasonable assumption[11]), and a 60 minute sampling time, then these results are given in Table 3.

Table 3: HotSpot calculations with worst case weather scenario, 1600 Ci target, 6% conversion to HTO, 60 min sampling time. The right hand column is the maximum dose scaled for a 1000 Ci target.

Stack height (m)	Dose at 300 m (mrem)	Distance at max dose (m)	Max dose 1600 Ci (mrem)	Max dose 1000 Ci (mrem)
0	25	<100	140	87.5
5	8.7	200	11	6.9
10	1.0	500	1.6	1.0
15	0.044	750	0.5	0.3
20	0.0006	1000	0.23	0.14

Summary

Estimates of worst case scenarios using both HotSpot and GENII software for a possible release of a tritium target in Hall A at JLab were performed. The results indicate that for a 1000 Ci target in the worst case scenario, the dose can be limited to less than 10 mrem not only at the site boundary but also at much larger distances if the release height is 15 m. Also, in going from a 10 m to 15 m stack height, the calculated dose rate diminishes by approximately a factor of three. In going from a 15 m to a 20 m stack height, the improvement was a factor of approximately two. We also found reasonable agreement between the GENII and HotSpot estimates.

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