Project: PS-TGT-12-001 Hall A Tritium Target

Tittle: General tritium release calculations

Document Number: TGT-CALC-103-004

Revision: Original

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Code(s) and Standards of Record:

Reference Codes:

Description:

Calculations for accidental release of T2 cell contents into Hall A. The release is assumed to happen as a result of simultaneous loss of primary containment (cell breach) and secondary containment (scattering chamber breach). The cell is assumed to have 1100 Ci of T2 gas as the moment of release. The calculations performed are:

- Dose to exposed worker at pivot
- Time for air in Hall A to recover to acceptable levels
- Response time of fixed tritium monitor

Reference Drawing(s):

| | |
|---|---|
| TGT-103-1000-0013 | Cell assembly with shipping covers |
| TGT-103-1001-0000 | P&ID |

Units and constants

$Ci := 3.7 \cdot 10^{10} \cdot Bq$ one Curie

$rem := 0.01 \cdot Sv$ definition of rem

$M_{T2} := 6.032 \frac{gm}{mol}$ Molar mass of T2

$t_{0.5} := 12.32 \cdot yr = \left(3.888 \cdot 10^{8}\right) s$ Half life of T2

$\tau := \frac{t_{0.5}}{\ln(2)} = \left(5.609 \cdot 10^{8}\right) s$ mean lifetime

$\lambda := \frac{1}{\tau} = \left(1.783 \cdot 10^{-9}\right) \frac{1}{s}$ decay const

$R_{HTO} := \frac{5\%}{day}$ Conservative est for T2 -> HTO

$V_{hall} := 4.2 \cdot 10^{4} \cdot m^{3}$ volume of Hall A

Maximum allowable derived air concentrations (DAC). These are derived from a max does per worker of 5 rem per year and a 2000 hr working year.

$DAC_{HT} := 0.2 \cdot 10^{-6} \cdot \frac{Ci}{cm^{3}}$ DAC for HT gas

$DAC_{HTO} := 2 \cdot 10^{-11} \cdot \frac{Ci}{cm^{3}}$ DAC for HTO vapor

$DE_{max} := 5 \cdot \frac{rem}{yr}$ max allowed does per year to RAD worker

The cell is assumed to contain 1100 Ci of tritium. The molar and mass quantities and volume this occupies are:

$N_{act} := 1100 \cdot Ci = (4.07 \cdot 10^{13})\ Bq$ total target activity

$N_T := \frac{N_{act}}{\lambda} = 2.283 \cdot 10^{22}$ total number of T atoms

$n_{T2} := \frac{N_T}{2 \cdot N_A} = 0.019\ mol$ mols of T2

$m_{T2} := n_{T2} \cdot M_{T2} = 0.114\ gm$ total mass of T2

$V_{STP} := 24.2 \cdot \frac{L}{mol} \cdot n_{T2} = 0.459\ L$ Aprox volume gas occupies at STP

Scattering chamber volume:

$ID_{low} := 41 \cdot in$ ID of lower section of chamber

$ID_{mid} := 40 \cdot in$ ID of middle section of chamber

$h_{mid} := 46.313 \cdot in$ height of middle section of chamber

$h_{low} := 46 \cdot in$ height of lower section of chamber

Volume of chamber:

$$V_{scat} := \frac{\pi}{4} \cdot \left(ID_{low}^{\ 2} \cdot h_{low} + ID_{mid}^{\ 2} \cdot h_{mid}\right) = \left(1.949 \cdot 10^{3}\right)\ L$$

Inner surface area of chamber

$$A_{scat} := \pi \cdot \left(ID_{low} \cdot h_{low} + ID_{mid} \cdot h_{mid}\right) = \left(1.174 \cdot 10^{4}\right)\ in^2$$

The concentration at the breach of the chamber assuming that the contents of the cell occupies the chamber volume first:

$$C := \frac{1100\ Ci}{V_{scat}} = \left(5.644 \cdot 10^{-4}\right) \frac{Ci}{cm^3}$$

The assumed time for a person near the pivot to exit hall once the alarm sounds is:

$$t_{exit} := 10 \cdot min$$

Assuming a 5%/day conversion to HTO. Note that this is a conservative estimate for conversion.

$$C_{HT} := 1.00 \cdot C = \left(5.644 \cdot 10^{-4}\right) \frac{Ci}{cm^3}$$ concetration of HT

$$C_{HTO} := R_{HTO} \cdot t_{exit} \cdot C = \left(1.96 \cdot 10^{-7}\right) \frac{Ci}{cm^3}$$ concentration of HTO

$$X_{HT} := \frac{C_{HT}}{DAC_{HT}} = 2.822 \cdot 10^3$$ DAC multiple for HT

$$X_{HTO} := \frac{C_{HTO}}{DAC_{HTO}} = 9.799 \cdot 10^3$$ DAC multiple for HTO

$$\left(X_{HT} + X_{HTO}\right) \cdot DE_{max} \cdot t_{exit} = 1.2\ rem$$ Dose to worker at pivot

This assumes that the exposed worker breaths air directly out of the scattering chamber for 10 min prior to exiting the Hall. Thus, this estimate is conservative especially considering that the concentration is rapidly dropping with distance from the pivot area. This, none the less, indicates that the thin sections of the scattering chamber should be protected when personnel are in Hall working near the pivot.

A breach of the scattering chamber while under vacuum is loud and and should indicate to workers in the area that there is a problem. However, tritium is colorless and odorless thus, workers may not realize that a release has occured. In this case, the fixed or portable tritium monitors will have to alarm to notify personnel to evacuate and turn on the exhaust system. The fixed monitor is an air monitor (Technical Associates PTG-7L4) which draws air from the hall. It is assumed that the time for the monitor to alarm is negligable once the T2 reaches the detector. The response time of the fixed T2 monitoring system is estimated below:

$$Q_{spl} := 40 \cdot \frac{L}{min}$$ Sample rate of air (flow)

$$ID := (0.5 - 2 \cdot 0.035) \cdot in$$ Tube ID

$$A_{tube} := \frac{\pi}{4} \cdot ID^2$$ cross area of tube

$$v := \frac{Q_{spl}}{A_{tube}} = 7.116\ \frac{m}{s}$$ velocity in tube

$$L_{tube} := 250 \cdot ft$$ Length of sample tube

$$t_{res} := \frac{L_{tube}}{v} = 10.709\ s$$ response time of detector

The time to restore the air quality in the Hall to acceptable levels for a release of the entire cell contents to the Hall. We assume that the exhaust system is fully functional and is stacking the air from the Hall.

The initial concentration:

$$C_0 := \frac{N_{act}}{V_{hall}} = \left(2.619 \cdot 10^{-8}\right) \frac{\mathbf{Ci}}{\mathbf{cm}^3}$$

Note that this is about the limit for the DAC for HT.

$$Q_{fan} := 12000\ \mathbf{cfm}$$ fan speed on exhaust system

The DAC for HTO shall be considered the required activity concentration

$$C_f := DAC_{HTO} = \left(2 \cdot 10^{-11}\right) \frac{\mathbf{Ci}}{\mathbf{cm}^3}$$ required DAC for HTO

$$t := \frac{-V_{hall}}{Q_{fan}} \cdot \ln\left(\frac{C_f}{C_0}\right) = 14.786\ \mathbf{hr}$$ Time required to reach HTO DAC

For 1/100 of DAC

$$C_f := \frac{1}{100} \cdot DAC_{HTO} = \left(2 \cdot 10^{-13}\right) \frac{\mathbf{Ci}}{\mathbf{cm}^3}$$

The time for the air in the hall to reach 1% of the DAC for HTO is:

$$t := \frac{-V_{hall}}{Q_{fan}} \cdot \ln\left(\frac{C_f}{C_0}\right) = 24.272\ \mathbf{hr}$$