Is Tritium Over-Regulated: Update
Should The TFG Support
New Tritium Threshold Values?

Tritium Focus Group Meeting
Oak Ridge, TN
May 16, 2018

Chandra Savage Marsden
Gas Transfer Systems Group (Q-7)
DOE-STD-1027-92 defines Nuclear Facility Categories and therefore the graded regulatory approach for facilities

- **Category 1**  Potential for significant **off-site** consequences
- **Category 2**  Potential for significant **on-site** consequences
  
  (1 rem @ 100 meters)
- **Category 3**  Potential for significant **localized** consequences
  
  (10 rem @ 30 meters with 24 hours exposure)
- **Radiological**  (less than Category 3 consequences)

**All but HC1 based on amounts of radionuclides in the facility**
In 2011, NNSA SD G 1027 calculated, but did not change, tritium values pending Tritium Focus Group input

<table>
<thead>
<tr>
<th>Category 3 threshold</th>
<th>Category 2 threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOE-STD-1027-92</td>
<td></td>
</tr>
<tr>
<td>1.6 grams (tritium)</td>
<td>30 grams (tritium)</td>
</tr>
<tr>
<td>8.4 grams (Pu-239)</td>
<td>900 grams (Pu-239)</td>
</tr>
<tr>
<td>NNSA SD G 1027</td>
<td></td>
</tr>
<tr>
<td>0.87 grams (tritium)</td>
<td>62.4 grams (tritium)</td>
</tr>
<tr>
<td>39 grams (Pu-239)</td>
<td>2600 grams (Pu-239)</td>
</tr>
</tbody>
</table>

In 2013, LANL proposed that the TFG accept the NNSA SD G 1027 threshold values, but the TFG voted 7 to 2 against
NNSA is still awaiting an official TFG response

2011 NNSA Requests:
“Table A.1 of DOE STD 1027-92 specifies a Hazard Category 2 threshold for tritium of 30 grams. Per discussions with Tritium Focus Group Members and other personnel involved with the development of the Standard, it appears this value was chosen based on consensus, taking into account operational considerations at the time.”

“Given that the original Hazard Category 2 value was determined by consensus, and in light the Tritium Focus Group’s past involvement with the Standard, NNSA requested that that they evaluate the revised Hazard Category 2 threshold value, and provide a recommendation to NNSA on an appropriate value to use.”

“A footnote (*) to Table A.1 of DOE STD 1027-92 states that the DOE Tritium Focus Group provided a recommendation to increase the Hazard Category 3 threshold value from 0.1 grams to 1.6 grams. In light [of] their prior involvement in recommending a Hazard Category 3 threshold of 1.6 grams, NNSA requested that the Tritium Focus Group evaluate the revised Hazard Category 3 threshold value, and provide a recommendation to NNSA on an appropriate value to use.”

2013 TFG response:
“TFG continues to endorse the Threshold Quantities as is currently while working on new values for recommendation for the upcoming TFG meeting in the Spring of 2014.”
Based on discussions at the April 2013 meeting (and since then), we have concluded that:

- The proposed change to the Release Fraction used to calculate the HC2 threshold from 1 to 0.5 was justified (consistent with NRC guidance)
- The changes to the ICRP dose model (66.6 rem/Ci) and Respiration Rates were justified
- The use of an understandable model for tritium was preferred
- A vote for the increase in Category 2 threshold from 30 to 62.4 grams would likely have passed
- A vote to decrease the Category 3 threshold from 1.6 to 0.87 grams was certain to fail
- The comparison to Pu-239 helped the Cat 2 threshold increase and hurt the Cat 3 threshold decrease.
- Further work was needed, especially on the Category 3 threshold, to gain a TFG recommendation
The justification used by the TFG for the HC3 threshold of 1.6 grams was found in a 1997 fax.
Dick:

I'm glad we had the conversation this morning (my time). Here are some pages from the documentation I've been using to support the DOE-STD-1027-92 revision for the tritium Category 3 threshold.

i. The title page for the "Technical Background Document";
ii. Page 6-6, highlighting the intention to use a Release Fraction of 1.0 for all radionuclides for the purposes of this report;
iii. The title page for the "Users Manual for the Radionuclides Database" (v. 1.01);
iv. Page 11 from that manual showing that the parameter RF in the database is Release Fraction;
v. A listing of the first 50 nuclides in the actual database, showing all the parameter columns; and
vi. An expanded listing, so that you can read it, omitting some of the columns.

As you can see, the RF for tritium = 0.5000 in this database, and the INHAX value is 830 Curies (gives 0.5 rem at 30 meters). Our DOE threshold for Category 3 is of course 10 rem at 30 meters, i.e. 20 times the EPA calculated value.

I'm sorry for any confusion I may have caused in getting these issues straight, and I hope you have all the supporting documentation you need. Thanks for your help in this matter.

Regards

Philip G. Williams
"Technical Background Document" used by the EPA to determine radionuclide Reportable Quantities
This “EPA Model” is the source of HC3 threshold values in DOE-STD-1027-92

2.0 Methodology

DOE-STD-1027-92 states that the basis for the category 3 TQs is a modification of the U.S. Environmental Protection Agency (EPA) definition of reportable quantities (RQs) for radionuclides contained in 40 CFR 302.4, Appendix B. As discussed in the Attachment, the RQ values are based on the radionuclide activity which, if subjected to release mechanisms, would produce less than 500 mrem dose-equivalent at a receptor distance of 30 meters based on a 24-hour exposure using the most limiting of four dose pathways. The calculated activity is then rounded down into one of seven RQ categories (from 0.001 Ci to 1000 Ci).

For the purpose of category 3 TQs, DOE uses a limiting dose of 10 rem dose-equivalent but retains the other EPA parameters (30 meters, 24 hours, dose-limiting pathway). DOE does not round down this calculated value, and does not provide the option of selecting other dose pathways, release fractions, or other parameters specific to the hazards analysis. Such manipulation of the category 3 TQs is inappropriate; the methods used to determine hazard category thresholds are not intended to duplicate hazards and accident analysis techniques except as provided by WHC-CM-4-46, Chapter 4.0 for the final hazard categorization.

TFG recommendation to increase the HC3 value to 1.6 grams was consistent with other radionuclides
The EPA model calculated release amounts for four pathways and set RQ values based on the smallest

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Atom. No.</th>
<th>Ingestion (food)</th>
<th>Release Values (Ci)</th>
<th>Inhala-</th>
<th>Direct Exposure</th>
<th>Final RQ (Ci)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen-3</td>
<td>1</td>
<td>--</td>
<td>5.9E 3</td>
<td>8.3E 2*</td>
<td>--</td>
<td>100</td>
</tr>
<tr>
<td>Plutonium-238</td>
<td>94</td>
<td>2.1E 0</td>
<td>v. lg.</td>
<td>3.1E-2*</td>
<td>--</td>
<td>0.01</td>
</tr>
<tr>
<td>Plutonium-239</td>
<td>94</td>
<td>1.8E 0</td>
<td>v. lg.</td>
<td>2.6E-2*</td>
<td>1.7E 6</td>
<td>0.01</td>
</tr>
<tr>
<td>Plutonium-240</td>
<td>94</td>
<td>1.8E 0</td>
<td>v. lg.</td>
<td>2.6E-2*</td>
<td>5.0E 6</td>
<td>0.01</td>
</tr>
<tr>
<td>Plutonium-241</td>
<td>94</td>
<td>9.0E 1</td>
<td>v. lg.</td>
<td>1.6E 0*</td>
<td>1.4E 8</td>
<td>1</td>
</tr>
<tr>
<td>Plutonium-242</td>
<td>94</td>
<td>2.1E 0</td>
<td>v. lg.</td>
<td>3.1E-2*</td>
<td>4.1E 6</td>
<td>0.01</td>
</tr>
</tbody>
</table>

830 Ci = 500 mrem at 30 meters (over 24 hours)
830 Ci x 20 = 16,600 Ci ≈ 1.66 grams
The methodology used by the EPA, endorsed by DOE and recommended by the TFG does not include skin absorption in the inhalation dose path.

Inhalation
Release Value = ALI/[(10)∗(R)∗(X/Q)∗(BR)∗(1 × 10^6)].

(Ci)

where:

ALI = annual limit of intake for inhalation (microcuries);

10 factor to convert the annual limit of intake which is based on 5 rem dose-equivalent to a worker in a nuclear facility to 0.5 rem, the Federal Radiation Protection Guideline for exposure to members of the general public;

R = airborne release fraction;

X/Q = atmospheric relative concentration value at a position 30 meters downwind (8.4 × 10^{-13} day/cubic cm);

BR = breathing rate for reference man (2.3 × 10^7 cubic cm/day); and

1 x 10^6 conversion factor between microcuries and curies.

The inhalation ALIs used in the calculations are taken from ICRP's Publication 30^1 after being converted from becquerels to microcuries. Where more than one ALI was given for a particular radionuclide, the lowest value was used for the calculations. This assures that the most hazardous chemical form of a radionuclide is used in the release value calculations.
Using the same methodology that gave a tritium HC3 threshold of 1.6 grams in 1997 would result in a new value of 1.3 grams

- **1997: 830 Ci x 10 rem/0.5 rem = 16,600 Ci, rounded to 1.6 grams**
  - DCF = 62.5 rem/Ci, ALI = 80 mCi
  - Breathing Rate = 2.3 x10^7 cm^3/day (2.66 x10^-4 m^3/sec)
  - \(\chi/Q = 8.4 \times 10^{-13}\) day/cm^3 (30 meters, wind 1 m/s, Class D stability, ground level)

- **2011/2014 NNSA SD G 1027: 0.87 grams**
  - DCF = 99.9 rem/Ci (including skin absorption) ALI = 75 mCi
  - Breathing Rate = 3.33 x10^-4 m^3/sec or 2.88 x10^7 cm^3/day
  - \(\chi/Q = 8.4 \times 10^{-13}\) day/cm^3 (30 meters, wind 1 m/s, Class D stability, ground level)

- **Today, using 1997 methodology with ICRP 68 values: 1.3 grams**
  - DCF = 66.6 rem/Ci (no skin absorption) ALI = 75 mCi
  - Breathing Rate = 3.33 x10^-4 m^3/sec or 2.88 x10^7 cm^3/day
  - \(\chi/Q = 8.4 \times 10^{-13}\) day/cm^3 (30 meters, wind 1 m/s, Class D stability, ground level)
Despite discounting skin absorption this model is consistent with accepted EPA and DOE methodology and is still very conservative

- EPA methodology consistently excluded non dose-limiting pathways
- Gaussian Dispersion model remains very conservative for tritium
  - Point source release at ground level, no plume buoyancy
  - All tritium oxide in the plume
  - The material remains suspended in the plume during the 24 hours of exposure
  - The receptor stays in the centerline of the plume (at a single point) for 24 hours with a consistent breathing rate of $2.66 \times 10^{-4} \text{ m}^3/\text{sec}$ (“light work”)
  - $\chi/Q$ for HC3 uses wind speed of 1 m/s, considered “overly conservative” by DOE
  - $\chi/Q$ value for HC2 is based on wind speed of 4.5 m/s

“Near the ground the increase of wind speed with height due to the surface friction is such that it is not possible to select a single wind speed which will be appropriate as a dilution speed. The turbulence is not homogeneous in the vertical due to the presence of the surface. Therefore **Gaussian techniques are not appropriate**” – Turner 1994, page 5-2
Expanding the EPA methodology to HC2 yields a tritium threshold of 96.3 grams

Category 2 Threshold Quantity:

\[ Q \text{ (g)} = \frac{1 \text{ rem}}{(RF \times SA \times \chi/Q \times (CEDE \times RR + CDSE))} \]

- \( RF = 0.5 \)
- \( SA = \text{Specific Activity} = 9630 \text{ Ci/g} \)
- \( \chi/Q = 1 \times 10^{-4} \text{ sec/m}^3 \) (300m, Class D, wind 4.5 m/s)
- \( CEDE = 66.6 \text{ rem/Ci} \) (no skin absorption)
- \( RR = \text{Respiration Rate} = 3.33 \times 10^{-4} \text{ m}^3/\text{sec} \) (during plume passage)
- \( CDSE = \text{Cloud Shine Dose Equivalent} = 0 \) for tritium

\[ Q = \text{Threshold Value} = 96.3 \text{ grams} \]
TFG Choices For Hazard Category 3 Threshold Quantity

- **Leave unchanged at 1.6 grams**
  - Uses EPA/DOE “Most limiting dose pathway” methodology
  - Uses RF = 0.5
  - Does not use latest ICRP values for Dose Conversion or Breathing Rate

- **Adopt 1.3 grams**
  - Uses EPA/DOE “Most limiting dose pathway” methodology
  - Uses RF = 0.5
  - Uses latest ICRP values for Dose Conversion or Breathing Rate

- **Develop, utilize and justify a different and less conservative model**
  - Less conservative dispersion model ($\chi/Q$ with wind at 4.5 m/s = 5.85 g HC3 TQ)
  - Less conservative Breathing Rate
  - Exposure time
  - Implementation process?
TFG Choices For Hazard Category 2 Threshold

- **Leave unchanged at 30 grams**
  - Uses Original DOE STD-1027-92 model with RF = 1.0
  - Does not use latest ICRP values for Dose Conversion or Breathing rate

- **Adopt 31.2 grams**
  - Uses Original DOE STD-1027-92 model with RF = 1.0
  - Uses latest ICRP values for Dose Conversion and Breathing Rate

- **Adopt 62.4 grams**
  - Uses NNSA SD G 1027 methodology with RF= 0.5 and skin absorption
  - Uses latest ICRP values for Dose Conversion and Breathing Rate

- **Adopt 96.3 grams**
  - Uses EPA/DOE “Most limiting dose pathway” model
  - Uses RF = 0.5 and latest ICRP values for Dose Conversion and Breathing Rate
  - Most consistent with choice of 1.3 grams for HC3 threshold
### Table: Technical Basis for STD-1027 Revision

<table>
<thead>
<tr>
<th>Quantity</th>
<th>HazCat 2 Maximum</th>
<th>HazCat 2 Recommended</th>
<th>HazCat 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>R (dimensionless)</td>
<td>1.0</td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>$\chi/Q$ (s/m³)</td>
<td>1.0E-4</td>
<td>1.0E-4</td>
<td>7.2E-02</td>
</tr>
<tr>
<td>RR (m³/s)</td>
<td>3.3333E-4</td>
<td>3.3333E-4</td>
<td>3.3333E-4</td>
</tr>
<tr>
<td>CEDE (rem/Ci)</td>
<td>962</td>
<td>166.5</td>
<td>151.7</td>
</tr>
<tr>
<td>SA (Ci/g)</td>
<td>9600</td>
<td>9600</td>
<td>9600</td>
</tr>
<tr>
<td>Q (grams)</td>
<td>3.25</td>
<td>18.77</td>
<td>0.57</td>
</tr>
<tr>
<td></td>
<td>ICRP 72 public dose coefficient for slow-absorption (Type S) particulates</td>
<td>ICRP 72 public dose coefficient for moderate-absorption (Type M) particulates</td>
<td>ICRP 68 worker dose coefficient for organically bound tritium</td>
</tr>
</tbody>
</table>

While it is recognized that the use of the tritium HC-2 and HC-3 TQs is limited to the thresholds as recommended by the TFG, this report will calculate the HC-2 and HC-3 TQs using the methodology as specified in Sections 4.1 and 4.2, respectively, of this report. The calculation of tritium HC-2 and HC-3 thresholds is provided solely for reference purposes only with the understanding they cannot be used without the review and approval of the TFG.
Special Thanks to Mike Rogers
Mound 1974 - 2001, LANL 2001 - 2018
Hazard Category 2 Calculation (DOE and NNSA)

\[
Q = \frac{1 \text{ rem}}{RF \cdot SA \cdot \chi/Q \cdot (CEDE \cdot RR + CSDE)}
\]

Q  = Quantity of material used as threshold (grams)
RF  = Airborne release fraction of material averaged over an entire facility (unitless)
SA  = Specific activity of radionuclide released (Ci/g)
\[\chi/Q\]  = Expression accounting for dilution of release at a point under given meteorological conditions (sec/m³) (300 m, Stability Class D, wind 4.5 m/s)
CEDE = Committed effective dose equivalent for a given radionuclide (rem/Ci)
RR  = Respiration rate (m³/sec)
CSDE = Cloud shine dose equivalent (rem·m³/Ci·sec) – 0 for tritium
## Comparison of Hazard Category 2 Values

<table>
<thead>
<tr>
<th>Quantity</th>
<th>DOE-STD-1027-92</th>
<th>NNSA SD G 1027</th>
<th>New RR and CEDE</th>
<th>ORNL/TM-2017/467</th>
</tr>
</thead>
<tbody>
<tr>
<td>R (dimensionless)</td>
<td>1.0</td>
<td>0.5</td>
<td>0.5</td>
<td>1.0</td>
</tr>
<tr>
<td>(\chi/Q) (s/m(^3))</td>
<td>1.0E-4</td>
<td>1.0E-4</td>
<td>1.0E-4</td>
<td>1.0E-4</td>
</tr>
<tr>
<td>RR (m(^3)/s)</td>
<td>3.5E-4</td>
<td>3.3333E-4</td>
<td>3.3333E-4</td>
<td>3.3333E-4</td>
</tr>
<tr>
<td>CEDE (rem/Ci)</td>
<td>92.5*</td>
<td>99.9*</td>
<td>66.7</td>
<td>166.5</td>
</tr>
<tr>
<td>SA (Ci/g)</td>
<td>10000</td>
<td>9619</td>
<td>9619</td>
<td>9600</td>
</tr>
<tr>
<td>Q (grams)</td>
<td>30.89</td>
<td>62.44</td>
<td>93.66</td>
<td>18.77</td>
</tr>
</tbody>
</table>

*Includes 1.5x skin absorption factor
Hazard Category 3 Calculation (EPA Model)

\[ Q = \frac{10 \text{ rem}}{RF \cdot SA \cdot \chi/Q \cdot CEDE \cdot RR} \]

- **Q** = Quantity of material used as threshold (grams)
- **RF** = Release fraction (unitless)
- **SA** = Specific activity of radionuclide released (Ci/g)
- **\( \chi/Q \)** = Expression accounting for dilution of release at a point under given meteorological conditions (sec/m³) (30 m, Stability Class D, wind 1 m/s)
- **CEDE** = Committed effective dose equivalent for a given radionuclide (rem/Ci)
- **RR** = Respiration rate (m³/sec)
Comparison of Hazard Category 3 Values

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<tbody>
<tr>
<td>R (dimensionless)</td>
<td>0.5</td>
<td>0.5</td>
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<td>0.5</td>
</tr>
<tr>
<td>$\chi/Q$ (s/m³)</td>
<td>7.2E-2</td>
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</tr>
<tr>
<td>RR (m³/s)</td>
<td>2.7E-4</td>
<td>3.3333E-4</td>
<td>3.3333E-4</td>
<td>3.3333E-4</td>
</tr>
<tr>
<td>CEDE (rem/Ci)</td>
<td>63</td>
<td>100</td>
<td>66.7</td>
<td>151.7</td>
</tr>
<tr>
<td>SA (Ci/g)</td>
<td>10000</td>
<td>9619</td>
<td>9619</td>
<td>9600</td>
</tr>
<tr>
<td>Q (grams)</td>
<td>1.63</td>
<td>0.87</td>
<td>1.30</td>
<td>0.57</td>
</tr>
</tbody>
</table>
Another Potential Methodology

- NNSA SD G 1027 allows for “Adjusted Release Fractions” (Airborne Release Fraction x Respirable Fraction), although not for tritium
  - Only certain size particles are respirable
  - All tritium is respirable but only the oxide fraction is retained
  - CEDE for elemental tritium is $\sim 10^4$ times smaller than that for oxide
  - For tritium if ARF= 0.5 and RF(oxide fraction) = 0.5 then RF in the model would be 0.25 and the Threshold Quantities would increase by a factor of 2
  - Pu-239 ARF x RF is $1 \times 10^{-3}$

- Tritium in different forms will have different Release Fractions
  - Tritium as gas would have a high release fraction (0.5 or 1.0)
  - Tritium oxide as liquid would have a low release fraction ($10^{-3}$)
  - Tritium oxide as a solid/molecular sieve would have a low release fraction
  - Tritium as a metal hydride would have a very low release fraction
  - Different hydrides could have different ARFs and RFs
  - Could require a more complex model and/or complex inventory controls
  - Need to compile data, could help with revision of DOE-HDBK-3010-94