SAND2018-9269R

Hazard Categorization Calculations Using ICRP 68, 72 Calculation SBDC-013-01, Revision 2

Marilyn S. Bange

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

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POC:

Marilyn S. Bange
ES&H Planning Department
Sandia National Laboratories
P. O. Box 5800
MS0794
Albuquerque, New Mexico 87185

Content Description

Methodology for SNL Nuclear Facility Categorization for OIG audit in FY18.

Sandia National Laboratories

Hazard Categorization Calculations Using ICRP 68, 72

Calculation SBDC-013-01, Revision 2

Prepared By: Jeffrey W. Marr Date: 7/9/2014
Jeffrey W. Marr

Reviewed By: Thomas d. Beckman Date: 7/24/14
Thomas Beckman

Approved By: Stephen A. Coffing Date: 7/31/2014
Stephen A. Coffing

Total Number of Attachments: 2

Revision Record

Revision	Date	Modified By	A = Add. M = Mod. D = Del.	Change Description: Page, Table, Figure, Paragraph
0	08/06/2013	Russell Durrer		Original Issue
1	08/29/2013	Russell Durrer	A,M	Revised to add Gd-148 and Po-208. Modified the entries for Br-80, Si-32, and Np-236
2	7/8/2014	Jeffrey Marr	M	Modified HC-2 & HC-3 threshold quantities based on changes in NNSA SD G 1027, Admin Change 1 (revised HC-2, HC-3 values and revised breathing rate). Updated references to new version of the supplemental guide. Formatting changes based per SB Manual.

Reviewer: WCS Date: 7/10/14

1.0 Objective

This calculation documents the methodology used to determine Hazard Category (HC) II and III threshold quantities for select radioisotopes in the ISMS Software Nuclide Threshold Table.

2.0 Limitations

The results of this calculation are for use in updating the tables in the ISMS software. The calculation did not include radioisotopes addressed in the DOE supplemental guidance NNSA SD G 1027.

3.0 Acceptance Criteria

There are no specific criteria that must be met by this calculation. The values determined in this document are used to compare radioactive material inventories to the thresholds associated with HC- II, and III facilities.

4.0 Methodology

The calculation of threshold quantities for HC-2 and 3 facilities were based on four exposure pathways:

- Inhalation
- Ingestion (food)
- Ingestion (water)
- Direct Exposure (point source; submersion)

The bounding value for the threshold quantity came from the pathway that resulted in the most restrictive quantity limit (gave the highest dose).

Hazard Category 2 Methodology

The formula used to calculate threshold quantities for HC-2 facilities is provided in DOE-STD-1027 (as endorsed in the supplemental guidance) as follows:

$$Q = \frac{1\,rem}{(RF \times SA \times {}^{X}/_{Q} \times (CEDE \times RR + CSDE))} \quad Eq.1$$

Where:

Q = HC-2 threshold quantity of a particular nuclide (grams)

RF = Airborne Release Fraction (unitless) averaged over an entire facility and specified in DOE-STD-1027 as follows:

- Gases: 1.0
- Highly volatile/combustible: 0.5
  (P, S, K, I, Na, and Br)
- Semi-volatile: 1E-2
  (Se, Hg, Cs, Po, Te, Ru, and C)
- Solid/Powder/Liquid: 1E-3
  (All materials not listed above)

SA = Specific Activity unique to each nuclide released (Ci/gram).

X/Q = Atmospheric dispersion parameter accounting for dilution of a release at a point under given meteorological conditions. A value of 1E-4 sec/m^3 is specified for use for HC-2 facility threshold calculations by DOE-STD-1027 and its Supplemental Guidance NNSA SD G 1027.

CEDE = Committed Effective Dose Equivalent for a particular nuclide (rem/Ci). Supplemental Guidance NNSA SD G 1027 specifies ICRP 72 as the source document for CEDE values for HC-2 threshold calculations.

RR = Respiration Rate. Supplemental Guidance NNSA SD G 1027 specifies the use of a value of 3.3E-4 m^3/sec for this parameter.

CSDE = Cloud Shine Dose Equivalent. Supplemental Guidance NNSA SD G 1027 specifies FGR 12 as the source document for CSDE values for HC-2 threshold calculations.

Hazard Category 3 Methodology

The methodology used to calculate HC 3 radionuclide threshold values was that from Attachment 1 of DOE STD 1027-92. This methodology comes from the EPA Technical Background Document (REF) and considers the four pathways listed above. The results generated by using the EPA method were increased by a factor of 20 to account for the difference in the limiting dose, 0.5 rem (EPA) versus 10 rem (DOE).

Inhalation Pathway:

The inhalation pathway threshold quantity was determined using the following equation found in the EPA Technical Background Document (page A-2, Eq. 1):

$$Q = 20 * \frac{ALI}{10 * R * {}^{x}/_{Q} * BR * 1E06 \frac{\mu Ci}{Ci}} \quad Eq.2$$

Where:

Q = Threshold Quantity for HC 3 (Ci)

ALI = Annual Limit of Intake for inhalation (μCi)

R = Airborne release fraction

x /Q = Meteorological dispersion coefficient, 30 meters from ground level release [7.2E-02 s/m^3]

BR = Breathing Rate [3.3333x10-4 m^3/s]

$$ALI = \left(\frac{0.05\ Sv}{einh(50)\frac{Sv}{Bq}} \right) * \left(\frac{1E6\ \mu Ci}{3.7E10\ Bq} \right) \quad Eq.3$$

einh (50) = Inhalation effective dose coefficient from ICRP 68 expressed in Sieverts (Sv) /Becquerel (Bq)

ICRP 68 may list several dose coefficients for a radionuclide. To provide bounding values for the threshold quantity calculation, the largest effective dose coefficient was selected. Values for airborne release values (R) were taken from Exhibit A-1 of the EPA Technical Background Document.

Ingestion Pathway (food)

The food ingestion pathway threshold quantity was determined using the following equation found in the EPA Technical Background Document (page C-9, Eq. 9)

$$Q = 20 * \frac{ALI}{(175 + 6.1Bv) * CT * R} \quad Eq.4$$

Where:

Q = Threshold Quantity (Ci)

ALI = Annual Limit of Intake for ingestion (μCi)

R = Airborne release fraction

Bv = Soil to plant concentration factor

CT = Contact time (days)

When multiple values for a radionuclide were listed, the largest effective dose coefficient was selected. Values for Bv came from Exhibit C-1 of the EPA Technical Background Document.

As specified in the EPA Technical Background Document, the values for CT were calculated using the following equation:

$$CT = \frac{1 - e^{-\left(\frac{41.6}{t\frac{1}{2}} + 3\right)}}{\left(\frac{\ln(2)}{t_{1/2}}\right) + 0.0495} \quad Eq.5$$

Where:

$t_{1/2}$ = Radioisotope half life in days (from ICRP 68)

Ingestion Pathway (water):

The ground water ingestion pathway threshold quantity was determined using the following equation from the EPA Technical Background Document (page B-16, Eq. 13)

$$Q = 20 * \frac{ALI}{2.2 * e^{\left(\frac{-4.2}{t_{1/2}}\right)} * t_{1/2} * \left\{1 - e^{\left(\frac{-6.2}{t_{1/2}}\right)}\right\}} \quad Eq.6$$

Where:

ALI = Annual Limit of Intake for ingestion (μCi)

Direct Exposure:

Direct Exposure from a Point Source

The equation used to calculate the dose resulting from the exposure to a gamma ray point source from the EPA Technical Background Document (page D-11, Eq. 11)

$$Q = \frac{25.1}{E * t_{1/2} * (1 - e^{(-\ln(2)/t1/2)})} \quad Eq.7$$

Where:

E = Net gamma energy per transformation (MeV)

Gamma energy data came from ICRP 38. If isotope was not in ICRP 38, ICRP 107 was used.

Direct Exposure from Submersion in a Radioactive Cloud of Noble Gas

The equation used to calculate the dose from noble gases was from EPA Technical Background Document (page D-13, Eq. 17)

$$Q = 20 * \frac{DAC}{(1E-07)} \quad Eq.8$$

Where:

DAC = Derived Air Concentration ($\mu Ci/cm^3$)

ICRP 68 uses the Cloud Shine Dose Equivalent (CSDE) instead of the DAC. The units for the CSDE are $\left.\frac{Sv}{day}\right/(Bq * m^3)$. The relationship between the two quantities can be expressed by

$$CSDE = \frac{\left(\frac{Dose}{t_{exposure}}\right)}{DAC} \quad Eq.9$$

Rearranging to solve for DAC,

$$DAC = \frac{\left(\frac{Dose}{t_{exposure}}\right)}{CSDE} \quad Eq.10$$

Converting hours to days, μCi to Bq, cm3 to m3, and rem to Sv leads to

$$DAC = \frac{\frac{5\ rem}{2000\ hr}}{CSDE * \left(\frac{100\ rem}{Sv}\right) * \left(\frac{3.7E10\ Bq}{Ci}\right) * \left(\frac{Ci}{1E6\ \mu Ci}\right) * \left(\frac{1e6\ cm^3}{m^3}\right) * \left(\frac{d}{24\ hr}\right)} \quad Eq.11$$

Simplification yields

$$DAC = \frac{1.62E-14}{CSDE}\left(\left.\mu Ci\right/_{cm^3}\right) \quad Eq.12$$

Substitution back into the TQ equation yields

$$Q = 20 * \left(\frac{1}{(6.17E6) * CSDE}\right) \quad Eq.13$$

Conversion to Grams of Material

Specific activity for the affected radionuclides was calculated with the following equation

$$Specific\ Activity = \frac{\lambda * N_a}{AW * 3.7E10\ \left(\frac{Bq}{Ci}\right)} \quad Eq.14$$

Na = Avogadro's Number (6.02E23)

AW = Atomic Weight (grams/mole)

λ = Decay constant (per sec) = $\frac{\ln 2}{t_{1/2}}$

5.0 Assumptions

- The RF value for each nuclide in the calculation was selected based on the guidance given above for each particular element of interest.
- The CEDE value for each nuclide was selected from ICRP 72 as follows:
  If a default lung absorption type (e.g., F, M, or S) was specified in Table 2 of ICRP 72 for inhalation, this value was used. If no default value was specified in Table 2, the most conservative lung absorption type was used.

  CEDE values for ingestion and inhalation were then compared and the largest value of the two was selected for use in the calculation. This is more conservative than using only inhalation CEDE values as was done in the supplemental guidance to DOE-STD-1027.
- The CSDE values provided in FGR 12 were adjusted to reflect the air density at SNL (≈5000 feet above MSL) by using the following expression as provided in FGR 12:

  $CSDE_{SNL} = CSDE_{FGR12} \times (1.2/\rho)$ where ρ is the SNL air density in kg/m^3 ($1.03\ kg/m^3$).
- Natural Thorium is assumed to be entirely composed of Th-232 per SNL guidance.
- Natural Uranium is assumed to be entirely composed of U-238 per SNL guidance. U-235 and U-234 constituents of natural Uranium are ignored.

Calculation for Po-208 (not included in ICRP data)

Develop a method to determine the ICRP 68 and 72 dose coefficients for Po-208 as none are provided in those documents.

The instantaneous committed effective dose rate (per decay or transformation) for Po-208 and Po-210 are the same. Both Po-208 and 210 will behave the same chemically in the dose receptor. For both radioisotopes, alpha particle emission is the predominate decay mode with the Q value of the decay at 5.2153 and 5.4075 MeV for Po-208 and Po-210 respectively. The energies of the alpha particles are 5.215 and 5.304 MeV respectively for Po-208 and 210 (LANL 2013). The

balance of the release is in the form of low energy electrons and photons. The difference in the alpha energies coupled with a high quality factor would cause the electrons and photons to have minimal impact on the resultant dose equivalent by comparison. A possible error is introduced because this assumption would be modeled as a single compartment using the effective elimination rate for the whole body. The ICRP model uses multiple compartments and multiple effective half lives.

Replace the multi-compartment ICRP metabolic models with a single compartment model (effective half-life for elimination from the body). Each compartment in the ICRP models has its own effective half-life and cancer risk weighting factor. The computation assumes that this relationship is linear by using the single effective half-life.

If the instantaneous dose equivalent rate is represented by D_i, the dose delivered over time interval dt is:

$$dD = \int_0^t D_i \, e^{-\lambda_E t} \, dt \qquad \text{Equation 1}$$

Where D is the dose from time equals zero to t and λ_E is the effective elimination constant (biological and radiological). Integrating this equation will give you the committed dose at time t:

$$D = \frac{D_i}{\lambda_E} (1 - e^{-\lambda_E t}) \qquad \text{Equation 2}$$

The biological half life (t_{bio}) of polonium is 50 days (IAEA 2013). The radiological half lives (t_{rad})of Po-208 and Po-210 are 1,058.5 and 138.4 days respectively (LANL 2013). The effective half life, t_{eff}, is determined by:

$$\frac{1}{t_{eff}} = \frac{1}{t_{rad}} + \frac{1}{t_{bio}} \qquad \text{Equation 3}$$

Using this equation, t_{eff} for Po-208 is 47.7 days and 36.7 days for Po-210. The effective elimination constant, λ_E, is found by:

$$\lambda_E = \frac{\ln 2}{t_{eff}} \qquad \text{Equation 4}$$

This equation yields $\lambda_{E\,208}$ as 1.45e-02 per day and $\lambda_{E\,210}$ as 1.89e-02 per day. Using a time of 50 years, Equation 2 can be simplified to:

$$D = \frac{D_i}{\lambda_E} \qquad \text{Equation 5}$$

$$D_{Po-208} = \frac{D_{i208}}{\lambda_{E208}} \qquad \text{Equation 6}$$

$$D_{Po-210} = \frac{D_{i210}}{\lambda_{E210}} \qquad \text{Equation 7}$$

Using the assumption listed above, dividing Equation 6 by 7 results in:

$$\frac{D_{Po-208}}{D_{Po-210}} = \frac{\lambda_{E210}}{\lambda_{E208}} \qquad \text{Equation 8}$$

Substituting the respective effective elimination constants results in:

$$D_{Po\text{-}208} = 1.3\ D_{Po\text{-}210}$$

For the same initial activity, the committed effective dose equivalent delivered by Po-208 is 30% higher than that of Po-210. The Po-210 dose coefficients from ICRP68/72 would be increased by 30% to get the estimated dose coefficients for Po-208.

6.0 Design Inputs

There were no design inputs for this calculation.

7.0 Calculation

The calculations were performed using Microsoft Excel, with data from ICRP, EPA, and DOE publications listed in the reference section.

8.0 Results

The results of the calculations are presented in Appendix B. The Calculation/Analysis Review Checklist results are presented in Appendix A.

9.0 Conclusion

The calculation provides hazard categorization values using dose coefficients from ICRP 68 and 72 for HC-2 and HC-3 facilities for radioisotopes not addressed in the DOE supplemental guidance documents, NNSA SD G 1027. The table in Appendix B combines the values from this calculation and those of the supplemental guidance.

10.0 References

1. Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports, DOE-STD-1027-92 CN-1, U.S. Department of Energy, Washington, D.C., 1997.
2. Table of DOE-STD-1027-92 Hazard Category 3 Threshold Quantities for the ICRP-30 List of 757 Radionuclides, Los Alamos National Laboratory, report number LA-12981-MS, November 1994.
3. Guidance On Using Release Fraction And Modern Dosimetric Information Consistently With DOE STD 1027-92, *Hazard Categorization And Accident Analysis Techniques For Compliance With DOE Order 5480.23, Nuclear Safety Analysis Reports, Change Notice No. 1,* NNSA SD G 1027, U.S. Department of Energy, Admin Change 1, May 2014.
4. External Exposure To Radionuclides In Air, Water, And Soil, EPA-402-R-93-081, U. S. Environmental Protection Agency, September 1993.
5. Radionuclide Transformations Energy and Intensity of Emissions, ICRP-38, International Commission of Radiation Protection, 1983.
6. Age-dependent Doses to the Members of the Public from Intake of Radionuclides - Part 5 Compilation of Ingestion and Inhalation Coefficients, ICRP-72, International Commission on Radiation Protection, 1995.
7. Dose Coefficients for Intakes of Radionuclides by Workers, ICRP-68, International Commission on Radiation Protection, 1994.
8. Nuclear Decay Data for Dosimetric Calculations, ICRP-107, International Commission on Radiation Protection, 2008.
9. Technical Background Document to Support Final Rulemaking Pursuant to Section 102 of the Comprehensive Environmental Response, Compensation, and Liability Act: Radionuclides, 102Q-RN-5-13, ICF Incorporated and C-E Environmental, February 1989.
10. Los Alamos National Laboratory, Nuclear and Particle Physics, Astrophysics and Cosmology, ENDF/B-VII.1 Decay Data, http://t2.lanl.gov/nis/data/endf/index.html, 2013.
11. Polonium-210 Factsheet, IAEA Publications, www.iaea.org/Publications/Factsheets/English/polonium210.html, 2013.

11.0 Computer Specifications

- Microsoft Excel Version 14.0.7116.5000
- Dell Precision T5600, SNL #S952436, Windows 7 Enterprise (64-bit), Service Pack 1.

Appendix A

Review Comments

Calculation/Analysis ID SBDC-013-01 Rev. 2

Title Hazard Categorization Calculations Using ICRP 68, 72

	Yes	No	NA	Comments
CALCULATION/ANALYSIS CHECKLIST				
1. Does calculation/analysis have a unique number and revision? **Note:** Calculations included or embedded within a DSA do not require a unique calculation number unless the calculation is to be published separately	✓			
2. Is the objective clearly stated?	✓			
3. Are limitations appropriately documented?	✓			
4. Are the acceptance criteria valid and appropriate?	✓			
5. Are analytical methods valid and appropriate?	✓			
6. Does the calculation/analysis employ the given methodology?	✓			
7. Are required formulas documented in the analytical methods section?	✓			
8. Are assumptions complete, reasonable, adequately justified, and appropriately conservative?	✓			
9. Is the analysis or calculation complete?	✓			
10. Is the analysis or calculation mathematically accurate? **Note:** The numerical results of hand calculations are accurate by checking each line and performing each mathematical computation or by performing an independent calculation. The numerical results of spreadsheet calculations are accurate by verifying that the input values and computational formulas are correct if the spreadsheet is an approved standard spreadsheet that has undergone a comprehensive quality assurance	✓			

	Yes	No	NA	Comments
CALCULATION/ANALYSIS CHECKLIST				
program (QAP) or is a widely accepted off-the-shelf commercially available software such as EXCEL, the Reviewer may instead use the QAP review by reference. Alternatively, the Reviewer may perform an independent calculation.				
11. Do parameters comply with design criteria/dimensions of the facility?			✓	
12. Are design inputs appropriate and do they accurately reflect the design and operation (no transcription errors have occurred)? Does the calculation use the documented design inputs and assumptions?			✓	
13. Does the analysis or calculation cross-reference or list applicable assumptions and major equation sources?	✓			
14. Are references current and defendable?	✓			
15. Is the calculation complete from start to finish (no gaps are present); do the results correspond to the objective; and are the results correctly evaluated against the acceptance criteria?	✓			
16. Does the input data seem reasonable?	✓			
17. Do the results seem reasonable?	✓			
COMPUTER CODE CHECKLIST				
18. Was a toolbox code used?		✓		
19. If not, was an applicable and valid computer program used?	✓			
20. Are the input parameters used in the software appropriate and consistent with Safety Basis manual requirements?	✓			
21. Was the input entered correctly?	✓			

Attach detailed reviewer comments, and comment responses.

All review comments have been resolved to my satisfaction.

William E. Schwinkendorf	4126	7/10/14
Name	Organization	Date

W. E. Schwinkendorf

Signature

REVIEWER

Appendix B

Hazard Categorization Thresholds

Threshold Quantities					
	HC-2		HC-3		
Isotope	HC-2(Ci)	HC-2(g)	HC-3(Ci)	HC-3(g)	Specific Activity (Ci/g)
Ac-225*	9.54E+02	1.64E-02	1.43E+01	2.46E-04	5.81E+04
Ac-227*	1.47E+01	2.04E-01	1.78E-01	2.45E-03	7.26E+01
Ac-228	3.22E+05	1.44E-01	2.26E+03	1.01E-03	2.24E+06
Ag-106m	4.09E+06	2.79E+01	2.70E+02	1.84E-03	1.47E+05
Ag-108m	1.06E+06	4.05E+04	3.22E+02	1.23E+01	2.61E+01
Ag-110m*	1.01E+06	2.13E+02	2.63E+02	5.54E-02	4.75E+03
Ag-111	5.39E+06	3.41E+01	1.67E+03	1.06E-02	1.58E+05
Al-26	3.96E+05	2.06E+07	2.30E+02	1.20E+04	1.92E-02
Am-241*	1.93E+02	5.63E+01	2.89E+00	8.42E-01	3.43E+00
Am-242	4.77E+05	5.90E-01	7.04E+03	8.71E-03	8.08E+05
Am-242m*	2.19E+02	2.09E+01	3.22E+00	3.07E-01	1.05E+01
Am-243*	1.98E+02	9.90E+02	2.89E+00	1.45E+01	1.99E-01
Am-244	3.80E+06	2.99E+00	1.84E+03	1.44E-03	1.27E+06
Am-245	1.21E+08	1.94E+01	1.82E+05	2.92E-02	6.24E+06
Am-246	4.49E+07	2.29E+00	2.66E+04	1.36E-03	1.96E+07
Ar-37	1.83E+10	1.81E+05	7.91E+08	7.84E+03	1.01E+05
Ar-39	2.55E+08	7.47E+06	2.95E+05	8.64E+03	3.41E+01
Ar-41	1.47E+03	3.51E-05	6.12E+02	1.46E-05	4.18E+07
As-72	3.85E+06	2.29E+00	5.55E+02	3.30E-04	1.68E+06
As-73	8.10E+06	3.63E+02	3.55E+03	1.59E-01	2.23E+04
As-74	3.64E+06	3.67E+01	9.76E+02	9.83E-03	9.92E+04
As-76	4.84E+06	3.10E+00	2.29E+03	1.46E-03	1.56E+06
As-77	2.02E+07	1.93E+01	1.84E+04	1.76E-02	1.05E+06
At-211	7.37E+04	3.58E-02	1.02E+03	4.97E-04	2.06E+06
Au-194	1.34E+07	3.29E+01	8.53E+02	2.09E-03	4.08E+05
Au-195	4.74E+06	1.29E+03	3.38E+03	9.24E-01	3.66E+03
Au-198*	8.83E+06	3.61E+01	2.03E+03	8.30E-03	2.45E+05
Au-199	1.01E+07	4.82E+01	9.09E+03	4.35E-02	2.09E+05
Ba-131	9.73E+06	1.15E+02	1.64E+03	1.94E-02	8.45E+04
Ba-133*	2.57E+06	1.01E+04	7.85E+02	3.07E+00	2.56E+02

Threshold Quantities					
	HC-2		HC-3		
Isotope	HC-2(Ci)	HC-2(g)	HC-3(Ci)	HC-3(g)	Specific Activity (Ci/g)
Ba-133m	1.48E+07	2.43E+01	1.33E+04	2.20E-02	6.06E+05
Ba-135m	1.85E+07	2.29E+01	1.59E+04	1.97E-02	8.06E+05
Ba-139	6.36E+07	3.89E+00	2.04E+05	1.25E-02	1.63E+07
Ba-140*	1.58E+06	2.16E+01	6.44E+02	8.80E-03	7.32E+04
Ba-141	3.76E+07	5.16E-01	4.75E+04	6.51E-04	7.29E+07
Ba-142	3.77E+07	3.02E-01	6.54E+04	5.25E-04	1.25E+08
Be-10	2.32E+05	1.04E+07	3.52E+02	1.58E+04	2.23E-02
Be-7	1.28E+08	3.67E+02	1.48E+04	4.23E-02	3.49E+05
Bi-206	3.29E+06	3.24E+01	2.35E+02	2.32E-03	1.02E+05
Bi-207*	1.39E+06	3.06E+04	4.71E+02	1.04E+01	5.41E+01
Bi-210*	8.72E+04	7.01E-01	1.34E+02	1.08E-03	1.24E+05
Bi-212	2.61E+05	1.79E-02	2.89E+02	1.97E-05	1.46E+07
Bi-213	2.70E+05	1.40E-02	2.75E+02	1.42E-05	1.93E+07
Bi-214	5.68E+05	1.29E-02	5.36E+02	1.22E-05	4.41E+07
Bk-249	5.07E+04	3.09E+01	7.51E+01	4.58E-02	1.64E+03
Bk-250	7.03E+06	1.81E+00	4.25E+03	1.09E-03	3.89E+06
Br-77	1.09E+05	1.50E-01	2.64E+03	3.63E-03	7.28E+05
Br-80	3.65E+05	2.70E-03	3.65E+05	2.70E-03	1.35E+08
Br-80m	1.46E+05	1.65E-02	1.13E+05	1.27E-02	8.87E+06
Br-82	1.50E+04	1.38E-02	3.45E+02	3.19E-04	1.08E+06
Br-83	3.29E+05	2.08E-02	1.68E+05	1.06E-02	1.58E+07
Br-84	3.89E+04	5.52E-04	1.28E+04	1.82E-04	7.04E+07
C-11	4.16E+06	4.97E-03	3.47E+04	4.15E-05	8.37E+08
C-14*	4.05E+05	9.07E+04	3.88E+02	8.69E+01	4.46E+00
Ca-41	4.27E+07	6.84E+08	2.47E+03	3.96E+04	6.24E-02
Ca-45*	3.00E+06	1.68E+02	9.94E+02	5.57E-02	1.78E+04
Ca-47*	3.93E+06	6.42E+00	7.37E+02	1.20E-03	6.14E+05
Cd-109*	1.00E+06	3.86E+02	3.96E+02	1.53E-01	2.59E+03
Cd-113*	6.76E+04	1.92E+17	3.09E+01	8.77E+13	3.52E-13
Cd-113m	7.37E+04	3.16E+02	3.44E+01	1.48E-01	2.33E+02
Cd-115	5.63E+06	1.11E+01	3.63E+03	7.13E-03	5.09E+05
Cd-115m	1.05E+06	4.13E+01	3.05E+02	1.20E-02	2.55E+04
Cd-117	1.72E+07	1.60E+00	4.57E+03	4.25E-04	1.08E+07
Cd-117m	1.25E+07	1.57E+00	1.79E+03	2.24E-04	7.98E+06
Ce-139	4.70E+06	6.91E+02	3.36E+03	4.94E-01	6.81E+03
Ce-141*	2.53E+06	8.86E+01	1.54E+03	5.41E-02	2.85E+04

Threshold Quantities					
	HC-2		HC-3		
Isotope	HC-2(Ci)	HC-2(g)	HC-3(Ci)	HC-3(g)	Specific Activity (Ci/g)
Ce-143	7.08E+06	1.07E+01	3.30E+03	4.99E-03	6.62E+05
Ce-144*	2.25E+05	7.06E+01	1.58E+02	4.95E-02	3.19E+03
Cf-248	9.21E+02	5.85E-01	1.37E+01	8.72E-03	1.58E+03
Cf-249	1.16E+02	2.82E+01	1.71E+00	4.16E-01	4.10E+00
Cf-250	2.38E+02	2.18E+00	3.52E+00	3.22E-02	1.09E+02
Cf-251	1.14E+02	7.20E+01	1.68E+00	1.06E+00	1.59E+00
Cf-252*	4.05E+02	7.56E-01	6.26E+00	1.17E-02	5.35E+02
Cf-253	6.24E+03	2.15E-01	9.38E+01	3.24E-03	2.90E+04
Cf-254	1.98E+02	2.33E-02	3.04E+00	3.58E-04	8.49E+03
Cl-36*	1.11E+03	3.36E+04	2.49E+02	7.55E+03	3.30E-02
Cl-38	2.05E+04	1.54E-04	1.30E+04	9.80E-05	1.33E+08
Cm-242*	1.56E+03	4.71E-01	2.35E+01	7.08E-03	3.32E+03
Cm-243	2.62E+02	5.07E+00	3.88E+00	7.52E-02	5.16E+01
Cm-244	3.00E+02	3.72E+00	4.50E+00	5.58E-02	8.08E+01
Cm-245*	1.93E+02	1.12E+03	2.82E+00	1.64E+01	1.72E-01
Cm-246	1.93E+02	6.28E+02	2.82E+00	9.16E+00	3.07E-01
Cm-247	2.08E+02	2.24E+06	3.13E+00	3.37E+04	9.28E-05
Cm-248	5.41E+01	1.27E+04	8.04E-01	1.89E+02	4.25E-03
Cm-249	2.24E+08	1.90E+01	5.90E+05	5.01E-02	1.18E+07
Cm-250	9.65E+00	4.66E+01	1.43E-01	6.88E-01	2.07E-01
Co-56	1.49E+06	5.03E+01	2.04E+02	6.89E-03	2.97E+04
Co-57	1.42E+07	1.68E+03	5.80E+03	6.86E-01	8.46E+03
Co-58	4.59E+06	1.44E+02	7.47E+02	2.35E-02	3.18E+04
Co-58m	3.38E+08	5.72E+01	7.78E+05	1.32E-01	5.91E+06
Co-60*	7.81E+05	6.90E+02	2.90E+02	2.56E-01	1.13E+03
Co-60m	3.30E+09	1.10E+01	1.01E+07	3.35E-02	3.00E+08
Co-61	9.24E+07	2.96E+00	8.06E+04	2.59E-03	3.12E+07
Cr-49	3.42E+07	3.75E-01	1.63E+04	1.79E-04	9.12E+07
Cr-51*	1.95E+08	2.11E+03	2.26E+04	2.44E-01	9.26E+04
Cs-129	7.85E+06	1.04E+01	3.31E+03	4.38E-03	7.56E+05
Cs-131	1.37E+07	1.33E+02	3.22E+04	3.12E-01	1.03E+05
Cs-132	1.31E+06	8.61E+00	1.09E+03	7.12E-03	1.53E+05
Cs-134*	1.19E+05	9.18E+01	4.20E+01	3.24E-02	1.30E+03
Cs-134m	3.50E+07	4.34E+00	1.56E+05	1.93E-02	8.07E+06
Cs-135	4.05E+05	3.52E+08	4.01E+02	3.48E+05	1.15E-03
Cs-136	2.41E+05	3.28E+00	3.46E+02	4.72E-03	7.33E+04

Threshold Quantities					
	HC-2		HC-3		
Isotope	HC-2(Ci)	HC-2(g)	HC-3(Ci)	HC-3(g)	Specific Activity (Ci/g)
Cs-137*	1.76E+05	2.03E+03	6.04E+01	6.95E-01	8.69E+01
Cs-138	1.57E+06	3.71E-02	9.73E+03	2.30E-04	4.24E+07
Cu-61	3.13E+07	2.07E+00	4.34E+03	2.88E-04	1.51E+07
Cu-64	5.34E+07	1.38E+01	6.84E+03	1.77E-03	3.86E+06
Cu-67	1.29E+07	1.71E+01	7.18E+03	9.50E-03	7.56E+05
Dy-157	6.87E+07	2.79E+01	4.81E+03	1.95E-03	2.46E+06
Dy-165	7.10E+07	8.71E+00	1.29E+05	1.59E-02	8.15E+06
Dy-166	4.26E+06	1.84E+01	2.44E+03	1.06E-02	2.31E+05
Er-169	8.11E+06	9.76E+01	5.18E+03	6.23E-02	8.31E+04
Er-171	1.92E+07	7.88E+00	4.76E+03	1.95E-03	2.44E+06
Es-253	3.00E+03	1.19E-01	4.50E+01	1.79E-03	2.52E+04
Es-254	9.43E+02	5.06E-01	1.41E+01	7.56E-03	1.86E+03
Es-254m	1.72E+04	5.50E-02	2.56E+01	8.17E-05	3.13E+05
Eu-152*	1.92E+05	1.11E+03	2.89E+02	1.66E+00	1.74E+02
Eu-152m	1.48E+07	6.67E+00	5.32E+03	2.40E-03	2.21E+06
Eu-154*	1.52E+05	5.64E+02	2.25E+02	8.33E-01	2.70E+02
Eu-155*	1.17E+06	2.41E+03	1.73E+03	3.56E+00	4.86E+02
Eu-156	2.23E+06	4.05E+01	5.66E+02	1.03E-02	5.51E+04
F-18	3.52E+04	3.70E-04	6.46E+03	6.79E-05	9.51E+07
Fe-52	5.32E+06	7.30E-01	2.27E+03	3.12E-04	7.28E+06
Fe-55*	2.13E+07	8.95E+03	2.41E+03	1.01E+00	2.39E+03
Fe-59*	2.09E+06	4.20E+01	5.61E+02	1.13E-02	4.96E+04
Fm-254	1.33E+05	3.49E-02	1.46E+03	3.84E-04	3.81E+06
Fm-255	3.00E+04	4.91E-02	4.33E+02	7.09E-04	6.11E+05
Fr-223	3.37E+06	8.70E-02	8.66E+03	2.24E-04	3.87E+07
Ga-66	4.91E+06	9.71E-01	6.31E+02	1.25E-04	5.06E+06
Ga-67	3.06E+07	5.11E+01	5.09E+03	8.51E-03	5.98E+05
Ga-68	3.12E+07	7.64E-01	1.12E+04	2.75E-04	4.08E+07
Ga-72	5.11E+06	1.65E+00	4.60E+02	1.49E-04	3.09E+06
Gd-148	3.12E+02	1.20E+01	3.75E-01	1.44E-02	2.60E+01
Gd-152	4.27E+02	1.96E+13	5.12E-01	2.35E+10	2.18E-11
Gd-153*	3.84E+06	1.09E+03	3.06E+03	8.66E-01	3.53E+03
Gd-159	1.63E+07	1.54E+01	2.20E+04	2.08E-02	1.06E+06
Ge-68*	5.79E+05	8.16E+01	6.24E+02	8.79E-02	7.10E+03
Ge-71	6.76E+08	4.33E+03	1.38E+05	8.82E-01	1.56E+05
Ge-77	1.46E+07	4.05E+00	1.32E+03	3.66E-04	3.60E+06

Threshold Quantities					
	HC-2		HC-3		
Isotope	HC-2(Ci)	HC-2(g)	HC-3(Ci)	HC-3(g)	Specific Activity (Ci/g)
H-3*	3.00E+05	3.00E+01	1.60E+04	1.60E+00	1.00E+04
Hf-175	6.44E+06	6.04E+02	1.98E+03	1.86E-01	1.07E+04
Hf-181*	1.60E+06	9.38E+01	9.28E+02	5.45E-02	1.70E+04
Hg-197	2.62E+06	1.06E+01	2.56E+03	1.03E-02	2.48E+05
Hg-197m	1.49E+06	2.23E+00	1.94E+03	2.91E-03	6.68E+05
Hg-203*	3.33E+05	2.41E+01	5.06E+02	3.67E-02	1.38E+04
Ho-166	5.77E+06	8.21E+00	7.37E+03	1.05E-02	7.02E+05
Ho-166m*	6.74E+04	3.75E+04	1.02E+02	5.70E+01	1.79E+00
I-123	6.89E+04	3.57E-02	1.07E+03	5.55E-04	1.93E+06
I-124	1.23E+03	4.88E-03	5.09E+00	2.02E-05	2.52E+05
I-125*	3.18E+03	1.81E-01	1.26E+00	7.17E-05	1.76E+04
I-126	5.58E+02	6.99E-03	1.09E+00	1.37E-05	7.98E+04
I-128	2.68E+05	4.55E-03	3.47E+03	5.88E-05	5.89E+07
I-129	1.47E+02	8.34E+05	1.46E-01	8.23E+02	1.77E-04
I-130	6.86E+03	3.53E-03	1.19E+02	6.09E-05	1.95E+06
I-131*	2.18E+03	1.75E-02	1.93E+00	1.56E-05	1.24E+05
I-132	2.38E+04	2.30E-03	7.27E+02	7.04E-05	1.03E+07
I-133	3.68E+03	3.25E-03	5.63E+01	4.97E-05	1.13E+06
I-134	2.87E+04	1.08E-03	1.50E+03	5.62E-05	2.67E+07
I-135	1.34E+04	3.82E-03	2.45E+02	6.97E-05	3.51E+06
In-113m	1.15E+08	6.90E+00	2.82E+04	1.69E-03	1.67E+07
In-114m*	8.71E+05	3.76E+01	2.40E+02	1.04E-02	2.31E+04
In-115	2.08E+04	3.41E+16	2.51E+01	4.12E+13	6.10E-13
In-115m	7.25E+07	1.19E+01	1.71E+04	2.81E-03	6.07E+06
In-116m	1.62E+07	5.40E-01	5.43E+03	1.81E-04	3.00E+07
In-117	5.53E+07	1.51E+00	2.39E+04	6.51E-04	3.67E+07
In-117m	6.02E+07	4.36E+00	6.86E+04	4.96E-03	1.38E+07
Ir-190	3.07E+06	5.41E+01	5.18E+02	9.11E-03	5.68E+04
Ir-190m1	2.14E+07	4.03E+00	2.52E+03	4.73E-04	5.32E+06
Ir-190m2	8.11E+08	5.90E+01	5.23E+06	3.80E-01	1.37E+07
Ir-192*	1.21E+06	1.31E+02	8.82E+02	9.57E-02	9.22E+03
Ir-193m	6.24E+06	1.10E+02	1.34E+04	2.36E-01	5.69E+04
Ir-194	6.16E+06	7.28E+00	1.22E+04	1.44E-02	8.46E+05
Ir-194m	6.05E+05	1.54E+02	3.12E+02	7.91E-02	3.94E+03
K-40*	7.63E+03	1.10E+09	1.23E+02	1.77E+07	6.95E-06
K-42	3.37E+04	5.60E-03	4.77E+03	7.92E-04	6.02E+06

Threshold Quantities					
	HC-2		HC-3		
Isotope	HC-2(Ci)	HC-2(g)	HC-3(Ci)	HC-3(g)	Specific Activity (Ci/g)
K-43	3.92E+04	1.22E-02	1.06E+03	3.27E-04	3.23E+06
Kr-79	8.01E+03	7.07E-03	3.55E+03	3.14E-03	1.13E+06
Kr-81	8.69E+06	4.13E+08	1.54E+05	7.33E+06	2.10E-02
Kr-83m	3.77E+07	1.82E+00	2.46E+06	1.19E-01	2.06E+07
Kr-85*	1.06E+07	2.70E+04	1.46E+05	3.71E+02	3.92E+02
Kr-85m	1.32E+04	1.60E-03	5.49E+03	6.67E-04	8.24E+06
Kr-87	2.29E+03	8.06E-05	9.53E+02	3.36E-05	2.84E+07
Kr-88	9.26E+02	7.38E-05	3.86E+02	3.08E-05	1.25E+07
La-138	5.40E+04	2.81E+12	6.26E+01	3.26E+09	1.92E-08
La-140	3.37E+06	6.06E+00	3.83E+02	6.89E-04	5.55E+05
La-141	2.20E+07	3.89E+00	5.12E+04	9.05E-03	5.66E+06
La-142	1.19E+07	8.28E-01	2.92E+03	2.04E-04	1.43E+07
Lu-172	4.22E+06	3.72E+01	4.12E+02	3.64E-03	1.13E+05
Lu-176	1.16E+05	2.05E+12	1.71E+02	3.02E+09	5.65E-08
Lu-177	6.73E+06	6.12E+01	4.45E+03	4.05E-02	1.10E+05
Lu-177m	5.02E+05	1.09E+02	5.08E+02	1.11E-01	4.58E+03
Mg-28	3.33E+06	6.21E-01	7.67E+02	1.43E-04	5.36E+06
Mn-52*	4.23E+06	9.41E+00	2.23E+02	4.97E-04	4.49E+05
Mn-52m	1.66E+07	9.69E-02	1.42E+04	8.29E-05	1.71E+08
Mn-53	1.50E+08	8.22E+10	2.66E+04	1.46E+07	1.83E-03
Mn-54	4.94E+06	6.36E+02	8.68E+02	1.12E-01	7.76E+03
Mn-56	1.47E+07	6.78E-01	2.77E+03	1.27E-04	2.17E+07
Mo-101	2.88E+07	2.27E-01	3.74E+04	2.94E-04	1.27E+08
Mo-93	2.62E+06	2.38E+06	3.07E+02	2.79E+02	1.10E+00
Mo-99*	8.89E+06	1.85E+01	3.76E+03	7.84E-03	4.81E+05
Na-22*	9.99E+03	1.60E+00	2.48E+02	3.98E-02	6.23E+03
Na-24	1.36E+04	1.56E-03	2.91E+02	3.34E-05	8.71E+06
Nb-90	4.14E+06	1.73E+00	2.89E+02	1.21E-04	2.39E+06
Nb-93m	1.59E+07	5.62E+04	6.72E+03	2.37E+01	2.83E+02
Nb-94*	7.22E+05	3.79E+06	2.49E+02	1.33E+03	1.90E-01
Nb-95	4.97E+06	1.27E+02	9.55E+02	2.44E-02	3.92E+04
Nb-95m	1.01E+07	2.66E+01	6.65E+03	1.75E-02	3.81E+05
Nb-96	5.32E+06	3.80E+00	4.10E+02	2.93E-04	1.40E+06
Nb-97	4.53E+07	1.68E+00	1.54E+04	5.72E-04	2.69E+07
Nd-147	3.35E+06	4.14E+01	1.58E+03	1.96E-02	8.08E+04
Nd-149	4.42E+07	3.64E+00	1.85E+04	1.52E-03	1.22E+07

Threshold Quantities					
	HC-2		HC-3		
Isotope	HC-2(Ci)	HC-2(g)	HC-3(Ci)	HC-3(g)	Specific Activity (Ci/g)
Ni-56	6.97E+06	1.82E+01	4.46E+02	1.16E-03	3.83E+05
Ni-57	6.71E+06	4.39E+00	4.74E+02	3.10E-04	1.53E+06
Ni-59	6.24E+07	7.71E+08	1.27E+04	1.57E+05	8.09E-02
Ni-63*	1.69E+07	2.97E+05	5.24E+03	9.21E+01	5.69E+01
Ni-65	2.92E+07	1.53E+00	8.72E+03	4.55E-04	1.91E+07
Np-235	1.93E+07	1.37E+04	3.81E+04	2.70E+01	1.41E+03
Np-236	2.53E+03	1.92E+05	3.75E+01	2.85E+03	1.32E-02
Np-236m	1.53E+06	2.59E+00	2.25E+03	3.82E-03	5.90E+05
Np-237*	3.53E+02	5.00E+05	5.36E+00	7.60E+03	7.05E-04
Np-238*	3.72E+06	1.43E+01	1.54E+03	5.93E-03	2.60E+05
Np-239	8.47E+06	3.66E+01	4.86E+03	2.10E-02	2.31E+05
Np-240	2.65E+07	2.20E+00	8.52E+03	7.05E-04	1.21E+07
Os-185	4.71E+06	6.28E+02	1.01E+03	1.35E-01	7.51E+03
Os-191	4.24E+06	9.56E+01	2.57E+03	5.78E-02	4.44E+04
Os-191m	5.04E+07	3.99E+01	7.51E+04	5.95E-02	1.26E+06
Os-193	9.87E+06	1.82E+01	1.15E+04	2.13E-02	5.41E+05
P-32 (acid)*	2.38E+06	8.34E+00	1.13E+01	3.95E-05	2.86E+05
P-32*	4.77E+03	1.67E-02	1.13E+01	3.95E-05	2.86E+05
P-33 (acid)*	5.41E+06	3.45E+01	8.84E+01	5.64E-04	1.57E+05
P-33*	1.08E+04	6.91E-02	8.84E+01	5.64E-04	1.57E+05
Pa-230	1.07E+04	3.27E-01	1.59E+02	4.86E-03	3.26E+04
Pa-231	5.79E+01	1.22E+03	8.66E-01	1.83E+01	4.73E-02
Pa-233	2.06E+06	9.94E+01	2.98E+03	1.44E-01	2.07E+04
Pa-234	9.69E+06	4.85E+00	1.12E+03	5.61E-04	2.00E+06
Pb-203	2.79E+07	9.42E+01	2.71E+03	9.15E-03	2.96E+05
Pb-205	2.90E+07	2.37E+11	2.87E+03	2.35E+07	1.22E-04
Pb-209	1.42E+08	3.08E+01	3.52E+05	7.63E-02	4.61E+06
Pb-210*	7.37E+03	9.78E+01	1.16E+00	1.53E-02	7.58E+01
Pb-211	7.37E+05	2.98E-02	2.01E+03	8.14E-05	2.47E+07
Pb-212	4.77E+04	3.42E-02	3.41E+02	2.45E-04	1.39E+06
Pb-214	5.77E+05	1.76E-02	2.35E+03	7.16E-05	3.28E+07
Pd-103	1.80E+07	2.41E+02	7.33E+03	9.82E-02	7.46E+04
Pd-107	1.37E+07	2.67E+10	2.05E+04	3.98E+07	5.15E-04
Pd-109	1.47E+07	6.85E+00	2.25E+04	1.05E-02	2.15E+06
Pm-143	5.23E+06	1.52E+03	2.30E+03	6.68E-01	3.45E+03
Pm-144	9.58E+05	3.83E+02	4.65E+02	1.86E-01	2.50E+03

Threshold Quantities					
	HC-2		HC-3		
Isotope	HC-2(Ci)	HC-2(g)	HC-3(Ci)	HC-3(g)	Specific Activity (Ci/g)
Pm-145*	2.25E+06	1.61E+04	3.31E+03	2.37E+01	1.40E+02
Pm-146	3.84E+05	8.66E+02	5.93E+02	1.34E+00	4.43E+02
Pm-147*	1.62E+06	1.75E+03	2.40E+03	2.58E+00	9.30E+02
Pm-148	2.89E+06	1.76E+01	1.02E+03	6.21E-03	1.64E+05
Pm-148m	1.34E+06	6.28E+01	3.67E+02	1.72E-02	2.14E+04
Pm-149	8.17E+06	2.06E+01	5.66E+03	1.43E-02	3.97E+05
Pm-151	1.04E+07	1.41E+01	3.13E+03	4.27E-03	7.33E+05
Po-208	1.45E+02	2.45E-01	2.61E+00	4.39E-03	5.93E+02
Po-210*	2.46E+02	5.47E-02	3.57E+00	7.94E-04	4.50E+03
Pr-142	6.18E+06	5.35E+00	1.09E+04	9.45E-03	1.16E+06
Pr-143	3.38E+06	5.03E+01	1.30E+03	1.93E-02	6.72E+04
Pr-144	1.43E+08	1.89E+00	3.75E+05	4.97E-03	7.56E+07
Pt-191	2.10E+07	8.58E+01	2.72E+03	1.11E-02	2.44E+05
Pt-193	2.62E+08	7.05E+06	2.59E+04	6.98E+02	3.71E+01
Pt-193m	1.80E+07	1.15E+02	7.17E+03	4.59E-02	1.56E+05
Pt-195m	1.27E+07	7.61E+01	5.42E+03	3.25E-02	1.67E+05
Pt-197	2.01E+07	2.31E+01	3.69E+04	4.24E-02	8.69E+05
Pt-197m	8.43E+07	8.32E+00	9.25E+04	9.13E-03	1.01E+07
Pu-236	4.05E+02	7.62E-01	6.26E+00	1.18E-02	5.32E+02
Pu-237	2.27E+07	1.87E+03	1.40E+04	1.15E+00	1.22E+04
Pu-238*	1.76E+02	1.03E+01	2.62E+00	1.53E-01	1.71E+01
Pu-239*	1.62E+02	2.61E+03	2.40E+00	3.86E+01	6.22E-02
Pu-240*	1.62E+02	7.14E+02	2.40E+00	1.05E+01	2.29E-01
Pu-241*	9.01E+03	8.74E+01	1.32E+02	1.29E+00	1.02E+02
Pu-242*	1.69E+02	4.29E+04	2.56E+00	6.49E+02	3.94E-03
Pu-243	9.15E+07	3.51E+01	9.89E+04	3.80E-02	2.60E+06
Pu-244	1.73E+02	9.72E+06	2.56E+00	1.44E+05	1.77E-05
Pu-245	1.03E+07	8.43E+00	3.54E+03	2.91E-03	1.22E+06
Pu-246	1.09E+06	2.24E+01	1.16E+03	2.38E-02	4.87E+04
Ra-223*	1.10E+03	2.14E-02	1.63E+01	3.19E-04	5.11E+04
Ra-224*	2.70E+03	1.70E-02	3.88E+01	2.44E-04	1.59E+05
Ra-225*	1.29E+03	3.30E-02	1.94E+01	4.99E-04	3.89E+04
Ra-226	2.32E+03	2.34E+03	7.08E+00	7.16E+00	9.89E-01
Ra-228	3.12E+03	1.14E+01	2.97E+00	1.09E-02	2.73E+02
Rb-81	5.15E+07	6.09E+00	4.35E+03	5.15E-04	8.45E+06
Rb-82m	1.29E+07	2.09E+00	7.22E+02	1.17E-04	6.17E+06

Threshold Quantities					
	HC-2		HC-3		
Isotope	HC-2(Ci)	HC-2(g)	HC-3(Ci)	HC-3(g)	Specific Activity (Ci/g)
Rb-83	4.09E+06	2.24E+02	4.81E+02	2.63E-02	1.83E+04
Rb-84	2.74E+06	5.78E+01	3.93E+02	8.29E-03	4.74E+04
Rb-86	2.88E+06	3.54E+01	4.78E+02	5.88E-03	8.13E+04
Rb-87	5.41E+06	6.17E+13	5.34E+02	6.09E+09	8.76E-08
Rb-88	3.91E+07	3.26E-01	6.48E+04	5.40E-04	1.20E+08
Rb-89	1.94E+07	1.39E-01	2.32E+04	1.67E-04	1.39E+08
Re-182	4.71E+06	1.75E+01	7.09E+02	2.64E-03	2.69E+05
Re-182m	1.72E+07	1.27E+01	1.12E+03	8.26E-04	1.36E+06
Re-184	3.96E+06	2.12E+02	8.22E+02	4.40E-02	1.87E+04
Re-184m	1.24E+06	2.87E+02	5.47E+02	1.27E-01	4.30E+03
Re-186	5.39E+06	2.90E+01	2.28E+03	1.23E-02	1.86E+05
Re-187	1.29E+09	3.36E+16	1.50E+05	3.92E+12	3.83E-08
Re-188	5.75E+06	5.86E+00	1.08E+04	1.10E-02	9.81E+05
Rh-101	1.49E+06	1.34E+03	1.47E+03	1.33E+00	1.11E+03
Rh-102m	1.13E+06	1.82E+02	7.05E+02	1.14E-01	6.19E+03
Rh-105	2.12E+07	2.50E+01	1.17E+04	1.38E-02	8.47E+05
Rn-222*	1.60E+08	1.10E+03	1.00E+01	6.50E-05	1.54E+05
Ru-103	3.27E+05	1.01E+01	1.44E+03	4.47E-02	3.23E+04
Ru-105	2.06E+06	3.07E-01	3.59E+03	5.33E-04	6.73E+06
Ru-106*	2.90E+04	8.74E+00	1.15E+02	3.49E-02	3.30E+03
Ru-97	4.31E+06	9.28E+00	3.41E+03	7.34E-03	4.65E+05
S-35*	1.16E+04	2.70E-01	2.21E+01	5.18E-04	4.28E+04
Sb-117	1.77E+08	1.85E+01	2.34E+04	2.45E-03	9.57E+06
Sb-122	4.57E+06	1.15E+01	1.87E+03	4.71E-03	3.97E+05
Sb-124*	1.21E+06	6.94E+01	3.77E+02	2.16E-02	1.75E+04
Sb-125	1.66E+06	1.61E+03	7.35E+02	7.11E-01	1.03E+03
Sb-126*	2.53E+06	3.02E+01	2.64E+02	3.15E-03	8.36E+04
Sb-126m	2.72E+07	3.46E-01	2.45E+04	3.12E-04	7.85E+07
Sb-127	4.46E+06	1.67E+01	1.16E+03	4.32E-03	2.67E+05
Sb-129	1.21E+07	2.15E+00	1.99E+03	3.54E-04	5.63E+06
Sc-44	1.13E+07	6.23E-01	1.45E+03	8.02E-05	1.81E+07
Sc-46*	1.14E+06	3.37E+01	3.63E+02	1.07E-02	3.39E+04
Sc-47	1.08E+07	1.31E+01	7.33E+03	8.83E-03	8.30E+05
Sc-48	3.55E+06	2.37E+00	2.60E+02	1.74E-04	1.50E+06
Sc-49	9.81E+07	1.46E+00	1.85E+05	2.76E-03	6.70E+07
Se-73	2.08E+06	3.46E-01	1.73E+03	2.88E-04	6.01E+06

Threshold Quantities					
	HC-2		HC-3		
Isotope	HC-2(Ci)	HC-2(g)	HC-3(Ci)	HC-3(g)	Specific Activity (Ci/g)
Se-75*	7.68E+05	5.28E+01	3.33E+02	2.29E-02	1.45E+04
Se-79	2.80E+05	4.01E+06	2.06E+02	2.96E+03	6.97E-02
Si-31	5.05E+07	1.31E+00	1.41E+05	3.65E-03	3.86E+07
$Si\text{-}32_2$	7.37E+04	2.96E+03	1.02E+02	4.12E+00	2.49E+01
Sm-147	8.45E+02	3.68E+10	1.27E+00	5.51E+07	2.30E-08
Sm-151*	2.03E+06	7.70E+04	3.04E+03	1.16E+02	2.62E+01
Sm-153	1.08E+07	2.48E+01	8.45E+03	1.93E-02	4.38E+05
Sn-113*	3.00E+06	2.99E+02	1.19E+03	1.19E-01	1.00E+04
Sn-117m	3.35E+06	4.07E+01	2.19E+03	2.66E-02	8.21E+04
Sn-119m	3.68E+06	9.83E+02	2.46E+03	6.56E-01	3.75E+03
Sn-121	3.53E+07	3.69E+01	4.02E+04	4.21E-02	9.56E+05
Sn-121m	1.80E+06	3.35E+04	2.12E+03	3.93E+01	5.38E+01
Sn-123*	1.00E+06	1.22E+02	4.10E+02	4.98E-02	8.23E+03
Sn-125	2.57E+06	2.37E+01	6.05E+02	5.58E-03	1.08E+05
Sn-126*	2.90E+05	1.02E+07	1.67E+02	5.89E+03	1.24E-02
Sr-82	9.11E+05	1.43E+01	1.82E+02	2.85E-03	6.37E+04
Sr-85	1.12E+07	4.72E+02	1.43E+03	6.01E-02	2.37E+04
Sr-85m	1.89E+08	5.95E+00	4.74E+04	1.49E-03	3.18E+07
Sr-87m	9.75E+07	7.57E+00	1.35E+04	1.05E-03	1.29E+07
Sr-89*	1.33E+06	4.57E+01	3.48E+02	1.20E-02	2.90E+04
Sr-90*	2.25E+05	1.63E+03	2.59E+01	1.87E-01	1.39E+02
Sr-91	1.05E+07	2.90E+00	2.21E+03	6.10E-04	3.63E+06
Sr-92	1.22E+07	9.66E-01	3.32E+03	2.64E-04	1.26E+07
Ta-182	7.93E+05	1.27E+02	5.63E+02	9.03E-02	6.24E+03
Ta-183	3.78E+06	2.70E+01	2.65E+03	1.90E-02	1.40E+05
Tb-157	6.76E+06	4.45E+05	1.02E+04	6.74E+02	1.52E+01
Tb-160*	1.13E+06	1.00E+02	5.76E+02	5.10E-02	1.13E+04
Tc-101	1.08E+08	8.22E-01	1.53E+05	1.17E-03	1.31E+08
Tc-95	2.58E+07	1.56E+01	1.34E+03	8.14E-04	1.65E+06
Tc-95m	8.17E+06	3.62E+02	1.08E+03	4.80E-02	2.25E+04
Tc-96	5.31E+06	1.67E+01	3.15E+02	9.91E-04	3.18E+05
Tc-96m	4.09E+08	1.07E+01	2.75E+05	7.22E-03	3.81E+07
Tc-97	3.68E+07	2.59E+10	7.28E+03	5.13E+06	1.42E-03
Tc-97m	2.53E+06	1.64E+02	1.04E+03	6.73E-02	1.55E+04
Tc-98	9.49E+05	1.09E+09	2.63E+02	3.02E+05	8.70E-04
Tc-99*	2.03E+06	1.19E+08	7.61E+02	4.48E+04	1.70E-02

Threshold Quantities					
	HC-2		HC-3		
Isotope	HC-2(Ci)	HC-2(g)	HC-3(Ci)	HC-3(g)	Specific Activity (Ci/g)
Tc-99m	1.90E+08	3.62E+01	1.70E+04	3.22E-03	5.26E+06
Te-121	1.55E+06	2.43E+01	1.28E+03	2.02E-02	6.35E+04
Te-121m	1.91E+05	2.73E+01	3.77E+02	5.37E-02	7.01E+03
Te-123	1.84E+05	6.33E+14	1.83E+02	6.28E+11	2.91E-10
Te-123m	2.02E+05	2.28E+01	6.31E+02	7.13E-02	8.85E+03
Te-125m	2.38E+05	1.32E+01	1.12E+03	6.20E-02	1.80E+04
Te-127	4.75E+06	1.80E+00	6.26E+04	2.37E-02	2.64E+06
Te-127m*	1.10E+05	1.16E+01	3.80E+02	4.03E-02	9.43E+03
Te-129	1.12E+07	5.33E-01	1.76E+05	8.39E-03	2.10E+07
Te-129m*	1.23E+05	4.07E+00	3.61E+02	1.20E-02	3.01E+04
Te-131	5.12E+06	8.92E-02	6.96E+04	1.21E-03	5.74E+07
Te-131m	3.78E+05	4.74E-01	6.89E+02	8.63E-04	7.98E+05
Te-132	2.11E+05	6.96E-01	1.09E+03	3.60E-03	3.04E+05
Te-133	3.48E+06	3.06E-02	6.27E+04	5.51E-04	1.14E+08
Te-133m	1.20E+06	4.68E-02	5.73E+03	2.24E-04	2.55E+07
Te-134	3.14E+06	9.34E-02	1.96E+04	5.83E-04	3.36E+07
Th-226	1.33E+05	4.94E-03	1.44E+03	5.36E-05	2.69E+07
Th-227	8.11E+02	2.64E-02	1.17E+01	3.81E-04	3.08E+04
Th-228*	2.03E+02	2.47E-01	2.89E+00	3.52E-03	8.21E+02
Th-229	1.14E+02	5.37E+02	1.14E+00	5.35E+00	2.13E-01
Th-230*	5.79E+02	2.81E+04	2.82E+00	1.36E+02	2.07E-02
Th-231	2.37E+07	4.45E+01	3.87E+04	7.26E-02	5.33E+05
Th-232*	3.24E+02	2.96E+09	2.68E+00	2.44E+07	1.10E-07
Th-234	1.05E+06	4.55E+01	7.87E+02	3.40E-02	2.31E+04
Th-nat	3.24E+02	2.96E+09	2.68E+00	2.44E+07	1.10E-07
Ti-44*	6.76E+04	3.93E+02	9.38E+01	5.46E-01	1.36E+02
Ti-45	2.74E+07	1.21E+00	4.52E+03	2.00E-04	2.26E+07
Tl-200	1.91E+07	3.19E+01	7.59E+02	1.27E-03	5.99E+05
Tl-201	7.49E+07	3.51E+02	8.69E+03	4.07E-02	2.14E+05
Tl-202	1.54E+07	2.91E+02	1.60E+03	3.01E-02	5.30E+04
Tl-204	6.76E+06	1.46E+04	6.24E+02	1.35E+00	4.64E+02
Tm-170*	1.16E+06	1.94E+02	6.63E+02	1.11E-01	5.97E+03
Tm-171	5.79E+06	5.31E+03	7.44E+03	6.82E+00	1.09E+03
U-230	6.24E+02	2.29E-02	7.51E+00	2.75E-04	2.73E+04
U-231	2.08E+07	1.54E+02	9.58E+03	7.12E-02	1.35E+05
U-232*	1.04E+03	4.71E+01	3.21E+00	1.49E-01	2.33E+01

Threshold Quantities					
	HC-2		HC-3		
Isotope	HC-2(Ci)	HC-2(g)	HC-3(Ci)	HC-3(g)	Specific Activity (Ci/g)
U-233*	2.25E+03	2.34E+05	1.29E+01	1.34E+03	9.63E-03
U-234*	2.32E+03	3.73E+05	1.32E+01	2.13E+03	6.20E-03
U-235*	2.62E+03	1.21E+09	1.46E+01	6.76E+06	2.16E-06
U-236*	2.53E+03	3.92E+07	1.43E+01	2.20E+05	6.50E-05
U-237	4.71E+06	5.77E+01	5.37E+03	6.58E-02	8.16E+04
U-238*	2.80E+03	8.32E+09	1.54E+01	4.59E+07	3.36E-07
U-239	2.34E+08	7.01E+00	6.01E+05	1.80E-02	3.34E+07
U-240	7.37E+06	7.96E+00	1.34E+05	1.45E-01	9.26E+05
U-nat	2.80E+03	8.32E+09	1.54E+01	4.59E+07	3.36E-07
V-48*	2.86E+06	1.68E+01	2.54E+02	1.49E-03	1.70E+05
V-49	2.38E+08	2.95E+04	4.63E+04	5.73E+00	8.08E+03
W-181	1.00E+08	1.68E+04	1.08E+04	1.81E+00	5.96E+03
W-185	1.84E+07	1.96E+03	1.86E+03	1.98E-01	9.40E+03
W-187	1.14E+07	1.63E+01	2.10E+03	3.00E-03	7.01E+05
W-188	3.86E+06	3.86E+02	4.10E+02	4.10E-02	1.00E+04
Xe-122	4.08E+04	3.19E-02	1.56E+04	1.22E-02	1.28E+06
Xe-123	3.24E+03	2.64E-04	1.35E+03	1.10E-04	1.23E+07
Xe-125	8.35E+03	5.65E-03	3.49E+03	2.36E-03	1.48E+06
Xe-127	1.86E+05	6.57E+00	3.34E+03	1.18E-01	2.83E+04
Xe-129m	9.57E+04	7.56E-01	1.48E+04	1.17E-01	1.27E+05
Xe-131m	2.43E+05	2.90E+00	3.73E+04	4.45E-01	8.38E+04
Xe-133*	1.95E+06	1.04E+01	2.67E+04	1.43E-01	1.88E+05
Xe-133m	7.06E+04	1.57E-01	2.08E+04	4.63E-02	4.49E+05
Xe-135	8.10E+03	3.17E-03	3.41E+03	1.34E-03	2.55E+06
Xe-138	1.65E+03	1.72E-05	6.90E+02	7.18E-06	9.60E+07
Y-86	5.11E+06	2.06E+00	3.46E+02	1.39E-04	2.48E+06
Y-87	1.30E+07	2.89E+01	1.75E+03	3.91E-03	4.48E+05
Y-88	1.66E+06	1.20E+02	2.71E+02	1.95E-02	1.39E+04
Y-90	3.00E+06	5.52E+00	1.77E+03	3.25E-03	5.44E+05
Y-90m	2.95E+07	2.70E+00	6.05E+03	5.54E-04	1.09E+07
Y-91*	9.11E+05	3.71E+01	3.98E+02	1.62E-02	2.46E+04
Y-91m	8.10E+07	1.95E+00	2.75E+04	6.60E-04	4.16E+07
Y-92	1.51E+07	1.57E+00	1.37E+04	1.42E-03	9.63E+06
Y-93	6.66E+06	2.00E+00	1.66E+04	4.98E-03	3.34E+06
Yb-169	2.66E+06	1.10E+02	1.57E+03	6.50E-02	2.41E+04
Yb-175	1.10E+07	6.18E+01	7.54E+03	4.23E-02	1.78E+05

Reviewer: WGS Date: 2/10/14

Threshold Quantities					
	HC-2		HC-3		
Isotope	HC-2(Ci)	HC-2(g)	HC-3(Ci)	HC-3(g)	Specific Activity (Ci/g)
Zn-62	8.01E+06	1.47E+00	3.57E+03	6.53E-04	5.46E+06
Zn-65*	4.81E+06	5.83E+02	2.01E+02	2.44E-02	8.24E+03
Zn-69	2.61E+08	5.45E+00	2.62E+05	5.47E-03	4.78E+07
Zn-69m	2.03E+07	6.16E+00	3.00E+03	9.10E-04	3.29E+06
Zr-86	8.96E+06	4.05E+00	3.99E+03	1.81E-03	2.21E+06
Zr-88	3.04E+06	1.71E+02	1.81E+03	1.02E-01	1.78E+04
Zr-89	8.20E+06	1.83E+01	6.93E+02	1.54E-03	4.49E+05
Zr-93*	8.11E+05	3.16E+08	3.92E+02	1.56E+05	2.52E-03
Zr-95*	1.65E+06	7.69E+01	9.93E+02	4.62E-02	2.15E+04
Zr-97	3.80E+06	1.99E+00	6.36E+03	3.32E-03	1.91E+06

*The threshold quantities for isotopes with an asterisk are directly from the DOE STD 1027 supplemental guidance document.

[1] For Br-80, the HC-2 calculation resulted in a lower material limit than the HC-3 method. The HC-2 values were used for both categorization levels. The primary difference in the two methods for this isotope is found in the release fractions.

[2] For Si-32, the half life used was 450 years as indicated in ICRP 68/72.

Cell colors represent the following changes:

	Values from spreadsheet which incorporated revised breathing rate.
	Changes to values in NNSA SD G 1027 Admin Change 1.
	Values based on calculation assumptions or Appendix B table footnotes.