

*Specific Activities and DOE-STD-1027-92
Hazard Category 2 Thresholds
LANL Fact Sheet*

Los Alamos
NATIONAL LABORATORY

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LANL Fact Sheet

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SPECIFIC ACTIVITIES
AND
DOE-STD-1027-92 HAZARD CATEGORY 2 THRESHOLDS
LANL FACT SHEET

by

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ABSTRACT

Data tables are presented to provide consistency in safety analysis work at the Los Alamos National Laboratory. Included are calculated specific activities and calculated hazard classification Category 2 threshold quantities for radionuclides listed in DOE-STD-1027-92. Some calculated threshold quantities differ from the DOE thresholds. Calculated specific activities are also presented for plutonium material types or mixtures.

I. Specific Activities and DOE-STD-1027-92 Hazard Category 2 Thresholds

Purpose

To ensure more consistency in Los Alamos National Laboratory (LANL) Safety Analysis Reports (SARs) and safety analysis work, ESH-3 will prepare and maintain *LANL Fact Sheets* for data used in SARs.

Scope

This fact sheet contains the following tables:

- (1) Calculated specific activities (SAs)
- (2) Calculated hazard classification Category 2 threshold quantities
- (3) Isotopic weight fractions or percents for material mixtures

Background	<p>Table 1 values of SA and threshold quantities were tabulated using the numbers in Table 2. Appropriate comments, information, and reference material are given in numbered notes following the tables.</p> <p>LANL ESH-3 will issue Fact Sheet revisions as needed.</p>
Clarification of categories	<p>The threshold for hazard classification Category 2 is defined by a formula in DOE-STD-1027-92. The formula uses several specified input values and calculates a maximum plausible radionuclide quantity that will, if released, result in a 1-rem inhalation exposure to an individual at a 300-meter distance.</p>
Category 3 DOE Nuclear Facility	<p>A DOE facility is designated a nuclear facility if there is nuclear material present in quantities exceeding Category 3 threshold values listed in DOE-STD-1027-92 Table A.1. The quantities are small but larger than those already present in the soil or in common building materials at the site.</p>
Category 2 DOE Nuclear Facility	<p>The threshold values for hazard classification Category 2 are larger than those for Category 3 and serve a dual purpose. They define an upper limit (maximum) of nuclear material allowed in a Category 3 facility and a threshold amount (minimum) at which the nuclear facility is designated Category 2. These threshold values have been defined in DOE-STD-1027-92 by a formula that uses specified parameters chosen by DOE. Numerically, threshold values represent a plausible radionuclide quantity that, if released without mitigation of any kind, could result in a 1-rem inhalation exposure to an individual at a 300-meter distance.</p>
Category 2 threshold exceeded	<p>A DOE facility designated as Category 2 must provide additional safety measures and systems to reduce the likelihood of an accident and provide mitigation to reduce the severity of the consequences if such an accident, even though unlikely, should occur. Also, the approved SAR for operation of a Category 2 facility generally contains a much more in-depth accident analysis than is expected for the Category 3 facility.</p>

Reference numbers on Tables 1 and 2 refer to Comments, Methodology, Explanations, and References on pages 8, 9, and 10.

Table 1. Calculated Specific Activities, Category 2 Threshold Quantities, and the CEDEs Used for an Expanded List of DOE-STD-1027-92 Isotopes

Isotope	SA ⁽²⁾ (Ci/gm)	Calculated Cat-2 Th. ⁽⁵⁾ (gm)	1027-A.1 Cat-2 Th. ⁽⁶⁾ (gm)	Recommended LANL Cat-2 Threshold Values	-----Inhalation ⁽³⁾ -----		
					CEDE Class-D (rem/Ci)	CEDE Class-W (rem/Ci)	CEDE Class-Y (rem/Ci)
H-3	9.669E+03		3.00E+01	3.00E+01 ⁽¹⁾		4.40E-03	
H-3, water	9.669E+03		3.00E+01	3.00E+01 ⁽¹⁾		6.30E+01	
C-14	4.459E+00	3.05E+05	3.10E+05	3.10E+05		2.10E+03	
Na-22	6.248E+03	1.01E+00	1.00E+00	1.00E+00	8.00E+03		
P-32 ^(6b)	2.857E+05	1.54E-02	1.50E-04	1.54E-02	5.50E+03	1.30E+04	
P-33	1.564E+05	1.92E-01	1.90E-01	1.90E-01	6.10E+02	1.90E+03	
P-32, acid ^(6b)	2.857E+05	7.69E+00	7.70E-02	7.69E+00	5.50E+03	1.30E+04	
P-33, acid	1.564E+05	9.62E+01	9.60E+01	9.60E+01	6.10E+02	1.90E+03	
S-35	4.268E+04	5.82E-01	5.80E-01	5.80E-01	2.90E+02	2.30E+03	
Cl-36	3.312E-02	4.31E+04	4.30E+04	4.30E+04	2.10E+03	2.00E+04	
K-40	6.986E-06	6.78E+08	6.80E+08	6.80E+08	1.20E+04		
Ca-45	1.758E+04	2.66E+02	2.60E+02	2.60E+02		6.10E+03	
Ca-47	6.124E+05	7.78E+00	7.80E+00	7.80E+00		5.50E+03	
Sc-46	3.387E+04	4.03E+01	4.00E+01	4.00E+01			2.00E+04
Ti-44	1.730E+02	1.86E+02	1.90E+02	1.90E+02	4.50E+05	1.70E+05	8.90E+05
V-48	1.703E+05	1.79E+01	1.80E+01	1.80E+01	4.60E+03	8.00E+03	
Cr-51	9.242E+04	1.13E+03	1.10E+03	1.10E+03	1.10E+02	2.10E+02	2.60E+02
Mn-52 ^(6c)	4.494E+05	8.80E+00	3.90E+01	8.80E+00	4.50E+03	5.60E+03	
Fe-55	2.409E+03	4.56E+03	4.60E+03	4.60E+03	2.60E+03	1.20E+03	
Fe-59	4.962E+04	3.70E+01	3.70E+01	3.70E+01	1.50E+04	9.90E+03	
Co-60	1.131E+03	1.67E+02	1.70E+02	1.70E+02		3.00E+04	1.50E+05
Ni-63	5.677E+01	7.99E+04	8.00E+04	8.00E+04		6.30E+03	vapor
Zn-65	8.229E+03	1.90E+02	1.90E+02	1.90E+02			1.80E+04
Ge-68	6.667E+03	8.75E+01	8.80E+01	8.80E+01	1.30E+03	4.90E+04	
Se-75 ^(6b)	1.469E+04	2.32E+01	2.40E+02	2.32E+01	7.10E+03	8.20E+03	
Kr-85	3.933E+02	7.16E+04	7.20E+04	7.20E+04			
Sr 89	2.905E+04	2.66E+01	2.70E+01	2.70E+01	5.90E+03		3.70E+04
Sr-90	1.380E+02	1.59E+02	1.60E+02	1.60E+02	2.30E+05		1.30E+06
Y-91	2.453E+04	2.65E+01	2.70E+01	2.70E+01		2.90E+04	4.40E+04
Zr-9 3	2.564E-03	3.48E+07	3.60E+07	3.60E+07	3.20E+05	8.10E+04	7.40E+04
Zr-9 5	2.147E+04	6.88E+01	6.90E+01	6.90E+01	1.90E+04	1.30E+04	1.80E+04
Nb-94	1.903E-01	4.54E+05	4.60E+05	4.60E+05		2.60E+04	3.30E+05

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Table 1—Continued

Isotope	SA ⁽²⁾ (Ci/gm)	Calculated Cat-2 Th. ⁽⁵⁾ (gm)	1027-A.1 Cat-2 Th. ⁽⁶⁾ (gm)	Recommended LANL Cat-2 Threshold Values	-----Inhalation ⁽³⁾ -----		
					CEDE Class-D (rem/Ci)	CEDE Class-W (rem/Ci)	CEDE Class-Y (rem/Ci)
Mo-99	4.794E+05	1.62E+01	1.60E+01	1.60E+01	2.00E+03		3.60E+03
Tc-99	1.688E-02	2.26E+08	2.30E+08	2.30E+08	8.40E+02	7.50E+03	
Ru-106	3.356E+03	1.93E+00	1.90E+00	1.90E+00	5.70E+04	9.30E+04	4.40E+05
Ag-110m	4.710E+03	1.12E+02	1.10E+02	1.10E+02	3.80E+04	2.70E+04	5.30E+04
Cd-109	2.644E+03	1.08E+02	1.10E+02	1.10E+02	1.00E+05	3.60E+04	4.20E+04
Cd-113	3.517E-13	5.08E+16	5.30E+16	5.30E+16	1.60E+06	4.70E+05	3.70E+05
In-114m	2.313E+04	1.58E+01	1.60E+01	1.60E+01	7.80E+04	4.90E+04	
Sn-113	1.004E+04	3.20E+02	3.20E+02	3.20E+02	3.90E+03	8.90E+03	
Sn-123	8.229E+03	1.16E+02	1.20E+02	1.20E+02	7.90E+03	3.00E+04	
Sn-126	2.839E-02	1.17E+07	1.20E+07	1.20E+07	8.60E+04	7.40E+04	
Sb-124	1.749E+04	7.46E+01	7.50E+01	7.50E+01	5.50E+03	2.10E+04	
Sb-126 ^(6a)	8.357E+04	3.03E+01	3.00E+00	3.03E+01	4.60E+03	1.00E+04	
Te-127m ^(6a)	9.432E+03	1.59E+01	1.60E-01	1.59E+01	1.20E+04	1.90E+04	
Te-129m	3.021E+04	4.72E+00	4.70E+00	4.70E+00	8.00E+03	2.00E+04	
I-125	1.735E+04	1.37E-01	1.40E-01	1.40E-01	2.40E+04		
I-131	1.240E+05	1.43E-02	1.40E-02	1.40E-02	3.20E+04		
Xe-133	1.870E+05	9.58E+00	9.60E+00	9.60E+00			
Cs-134	1.294E+03	4.62E+01	4.60E+01	4.60E+01	4.70E+04		
Cs-137	8.653E+01	1.03E+03	1.00E+03	1.00E+03	3.20E+04		
Ba-133	2.513E+02	1.61E+04	1.60E+04	1.60E+04	6.90E+03		
Ba-140	7.292E+04	1.06E+02	1.10E+02	1.10E+02	3.60E+03		
Ce-141	2.849E+04	1.17E+02	1.20E+02	1.20E+02		7.10E+03	8.50E+03
Ce-144	3.193E+03	2.56E+01	2.60E+01	2.60E+01		1.90E+05	3.50E+05
Pm-145	1.394E+02	7.59E+03	7.60E+03	7.60E+03		2.30E+04	2.70E+04
Pm-147	9.275E+02	9.06E+02	8.00E+02	9.06E+02		2.50E+04	3.40E+04
Sm-151	2.632E+01	3.74E+04	3.70E+04	3.70E+04		2.90E+04	
Eu-152	1.810E+02	7.16E+02	7.50E+02	7.50E+02		2.20E+05	
Eu-154	2.732E+02	4.01E+02	4.20E+02	4.20E+02	2.60E+05		
Eu-155	4.709E+02	1.55E+03	1.60E+03	1.60E+03		3.90E+04	
Gd-153	3.532E+03	3.84E+02	3.90E+02	3.90E+02	2.10E+04	8.40E+03	
Tb-160	1.132E+04	1.12E+02	1.10E+02	1.10E+02		2.20E+04	
Ho-166m	1.796E+00	2.21E+04	2.20E+04	2.20E+04		7.20E+05	
Tm-170	5.972E+03	2.08E+02	2.10E+02	2.10E+02		2.30E+04	
Hf-181	1.701E+04	1.27E+02	1.30E+02	1.30E+02	1.30E+04	1.10E+04	
Ir-192	9.165E+03	1.33E+02	1.30E+02	1.30E+02	1.80E+04	1.30E+04	2.30E+04
Au-198	2.446E+05	3.79E+01	3.80E+01	3.80E+01	2.90E+03	2.00E+03	1.80E+03

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Table 1—Continued

Isotope	SA ⁽²⁾ (Ci/gm)	Calculated Cat-2 Th. ⁽⁵⁾ (gm)	1027-A.1 Cat-2 Th. ⁽⁶⁾ (gm)	Recommended LANL Cat-2 Threshold Values	-----Inhalation ⁽³⁾ -----		
					CEDE Class-D (rem/Ci)	CEDE Class-W (rem/Ci)	CEDE Class-Y (rem/Ci)
Hg-203 ^(6a)	1.374E+04	3.15E+01	3.10E+00	3.15E+01		6.50E+03	
Pb-210	7.638E+01	2.88E+01	2.90E+01	2.90E+01		1.30E+07	
Bi-207 ^(6e)	5.173E+01	3.75E+04	3.80E+04	3.80E+04	2.90E+03	1.40E+04	
Bi-210	1.241E+05	1.21E+00	1.20E+00	1.20E+00	1.30E+04	1.90E+05	
Po-210	4.493E+03	7.85E-02	7.80E-02	7.80E-02	8.00E+06	8.10E+06	
Rn-222	1.538E+05	1.05E+03	1.10E+03	1.10E+03			
Ra-223	5.120E+04	7.44E-02	7.40E-02	7.40E-02		7.50E+06	
Ra-224	1.593E+05	6.19E-02	6.10E-02	6.10E-02		2.90E+06	
Ra-225	3.921E+04	9.72E-02	9.60E-02	9.60E-02		7.50E+06	
Ac-225	5.803E+04	4.92E-02	4.90E-02	4.90E-02	1.00E+07	7.50E+06	8.00E+06
Ac-227	7.237E+01	5.89E-02	5.90E-02	5.90E-02	6.70E+09	1.70E+09	1.20E+09
Th-228	8.200E+02	1.12E-01	1.10E-01	1.10E-01		2.50E+08	3.10E+08
Th-230	1.944E-02	4.59E+03	4.40E+03	4.40E+03		3.20E+08	2.60E+08
Th-232	1.093E-07	1.63E+08	1.60E+08	1.60E+08		1.60E+09	1.10E+09
U-233 ⁽⁷⁾	9.642E-03	2.28E+04	2.30E+04	2.30E+04	2.70E+06	7.10E+06	1.30E+08
U-234	6.239E-03	3.52E+04	3.50E+04	3.50E+04	2.70E+06	7.10E+06	1.30E+08
U-235 ⁽⁷⁾	2.163E-06	1.10E+08	1.10E+08	1.10E+08	2.50E+06	6.70E+06	1.20E+08
U-238	3.364E-07	7.08E+08	7.10E+08	7.10E+08	2.40E+06	6.20E+06	1.20E+08
Np-237	7.052E-04	8.27E+04	8.30E+04	8.30E+04		4.90E+08	
Np-238	2.591E+05	3.53E+00	3.50E+00	3.50E+00		3.10E+04	
Pu-238	1.713E+01	3.63E+00	3.60E+00	3.60E+00		4.60E+08	3.00E+08
Pu-239 ⁽⁷⁾	6.133E-02	9.13E+02	9.00E+02	9.00E+02		5.10E+08	3.30E+08
Pu-240 ^(6d)	2.268E-01	2.47E+02		2.47E+02		5.10E+08	3.30E+08
Pu-241	1.031E+02	2.77E+01	2.80E+01	2.80E+01		1.00E+07	5.70E+06
Pu-242 ^(6d)	3.931E-03	1.51E+04		1.51E+04		4.80E+08	3.10E+08
Am-241	3.428E+00	1.60E+01	1.60E+01	1.60E+01		5.20E+08	
Am-242m	9.724E+00	5.76E+00	5.80E+00	5.80E+00		5.10E+08	
Am-243	1.997E-01	2.75E+02	2.80E+02	2.80E+02		5.20E+08	
Cm-242	3.314E+03	5.07E-01	5.10E-01	5.10E-01		1.70E+07	
Cm-245	1.718E-01	3.08E+02	3.10E+02	3.10E+02		5.40E+08	
Cf-252	5.376E+02	4.09E-01	7.00E-01	4.09E-01		1.20E+08	1.30E+08

Table 2. Half-Lives, CSDEs, and Other Numerical Values Used for Calculations

Isotope	Half-life ⁽²⁾ (yr)	CSDE ⁽⁴⁾ (rem × m ³)/ (Ci × s)	RF ⁽⁵⁾ Specified By DOE-STD-1027-92	Dose Factor ⁽⁴⁾ (DOE/EH-0070) (mrem/yr)/(micro Ci/m ³)	Atomic Weight
H-3	1.233E+01	0.00E+00	1.000E+00	0.00E+00	3
H-3, water	1.233E+01	0.00E+00	1.000E-03	0.00E+00	3
C-14	5.730E+03	0.00E+00	1.000E-02	0.00E+00	14
Na-22	2.602E+00	3.55E-01	5.000E-01	1.12E+04	22
P-32 ^(6b)	3.912E-02	0.00E+00	5.000E-01	0.00E+00	32
P-33	6.931E-02	0.00E+00	5.000E-01	0.00E+00	33
P-32, acid ^(6b)	3.912E-02	0.00E+00	1.000E-03	0.00E+00	32
P-33, acid	6.931E-02	0.00E+00	1.000E-03	0.00E+00	33
S-35	2.394E-01	0.00E+00	5.000E-01	0.00E+00	35
Cl-36	3.000E+05	1.34E-09	1.000E+00	4.24E-05	36
K-40	1.280E+09	2.57E-02	5.000E-01	8.11E+02	40
Ca-45	4.520E-01	2.59E-12	1.000E-03	8.17E-08	45
Ca-47	1.243E-02	1.74E-01	1.000E-03	5.49E+03	47
Sc-46	2.296E-01	3.33E-01	1.000E-03	1.05E+04	46
Ti-44	4.700E+01	2.13E-02	1.000E-03	6.73E+02	44
V-48	4.376E-02	4.79E-01	1.000E-03	1.51E+04	48
Cr-51	7.588E-02	5.01E-03	1.000E-03	1.58E+02	51
Mn-52	1.531E-02	5.68E-01	1.000E-03	1.79E+04	52
Fe-55	2.700E+00	3.65E-06	1.000E-03	1.15E-01	55
Fe-59	1.222E-01	1.96E-01	1.000E-03	6.17E+03	59
Co-60	5.271E+00	4.12E-01	1.000E-03	1.30E+04	60
Ni-63	1.000E+02	0.00E+00	1.000E-03	0.00E+00	63
Zn-65	6.687E-01	9.58E-02	1.000E-03	3.02E+03	65
Ge-68	7.889E-01	1.43E-05	1.000E-03	4.52E-01	68
Se-75 ^(6b)	3.246E-01	6.28E-02	1.000E-02	1.98E+03	75
Kr-85	1.070E+01	3.55E-04	1.000E+00	1.12E+01	85
Sr-89	1.383E-01	2.27E-05	1.000E-03	7.17E-01	89
Sr-90	2.880E+01	0.00E+00	1.000E-03	0.00E+00	90
Y-91	1.603E-01	5.93E-04	1.000E-03	1.87E+01	91
Zr-9 3	1.500E+06	0.00E+00	1.000E-03	0.00E+00	93
Zr-9 5	1.753E-01	1.21E-01	1.000E-03	3.81E+03	95
Nb-94	2.000E+04	2.60E-01	1.000E-03	8.20E+03	94
Mo-99	7.536E-03	2.53E-02	1.000E-03	7.99E+02	99
Tc-99	2.140E+05	8.40E-08	1.000E-03	2.65E-03	99
Ru-106	1.005E+00	0.00E+00	1.000E-02	0.00E+00	106
Ag-110m	6.903E-01	4.50E-01	1.000E-03	1.42E+04	110
Cd-109	1.241E+00	3.49E-04	1.000E-03	1.10E+01	109

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Table 2—Continued

Isotope	Half-life (2) (yr)	CSDE (4) (rem × m ³)/ (Ci × s)	RF (5) Specified By DOE-STD-1027-92	Dose Factor (4) (DOE/EH-0070) (mrem/yr)/(micro Ci/m ³)	Atomic Weight
Cd-113	9.000E+15	0.00E+00	1.000E-03	0.00E+00	113
In-114m	1.356E-01	1.46E-02	1.000E-03	4.59E+02	114
Sn-113	3.153E-01	1.33E-03	1.000E-03	4.19E+01	113
Sn-123	3.534E-01	1.14E-03	1.000E-03	3.60E+01	123
Sn-126	1.000E+05	7.74E-03	1.000E-03	2.44E+02	126
Sb-124	1.649E-01	3.15E-01	1.000E-03	9.95E+03	124
Sb-126(6a)	3.397E-02	4.47E-01	1.000E-03	1.41E+04	126
Te-127m(6a)	2.986E-01	4.95E-04	1.000E-02	1.56E+01	127
Te-129m	9.177E-02	5.45E-03	1.000E-02	1.72E+02	129
I-125	1.649E-01	1.77E-03	5.000E-01	5.57E+01	125
I-131	2.202E-02	6.06E-02	5.000E-01	1.91E+03	131
Xe-133	1.438E-02	5.58E-03	1.000E+00	1.76E+02	133
Cs-134	2.062E+00	2.54E-01	1.000E-02	8.01E+03	134
Cs-137	3.017E+01	0.00E+00	1.000E-02	0.00E+00	137
Ba-133	1.070E+01	5.83E-02	1.000E-03	1.84E+03	133
Ba-140	3.504E-02	2.98E-02	1.000E-03	9.41E+02	140
Ce-141	8.903E-02	1.22E-02	1.000E-03	3.86E+02	141
Ce-144	7.780E-01	2.88E-03	1.000E-03	9.09E+01	144
Pm-145	1.770E+01	2.65E-03	1.000E-03	8.37E+01	145
Pm-147	2.623E+00	5.80E-07	1.000E-03	1.83E-02	147
Sm-151	9.000E+01	1.45E-07	1.000E-03	4.56E-03	151
Eu-152	1.300E+01	1.87E-01	1.000E-03	5.90E+03	152
Eu-154	8.500E+00	2.06E-01	1.000E-03	6.50E+03	154
Eu-155	4.900E+00	9.10E-03	1.000E-03	2.87E+02	155
Gd-153	6.618E-01	1.41E-02	1.000E-03	4.46E+02	153
Tb-160	1.975E-01	1.78E-01	1.000E-03	5.61E+03	160
Ho-166m	1.200E+03	2.60E-01	1.000E-03	8.21E+03	166
Tm-170	3.523E-01	7.39E-04	1.000E-03	2.33E+01	170
Hf-181	1.162E-01	8.62E-02	1.000E-03	2.72E+03	181
Ir-192	2.033E-01	1.30E-01	1.000E-03	4.11E+03	192
Au-198	7.385E-03	6.44E-02	1.000E-03	2.03E+03	198
Hg-203(6a)	1.282E-01	3.65E-02	1.000E-02	1.15E+03	203
Pb-210	2.230E+01	2.12E-04	1.000E-03	6.70E+00	210
Bi-207(6e)	3.340E+01	2.52E-01	1.000E-03	7.96E+03	207
Bi-210	1.372E-02	0.00E+00	1.000E-03	0.00E+00	210
Po-210	3.791E-01	1.41E-06	1.000E-02	4.44E-02	210
Rn-222	1.047E-02	6.18E-05	1.000E+00	1.95E+00	222

Continued on next page

Table 2—Continued

Isotope	Half-life ⁽²⁾ (yr)	CSDE ⁽⁴⁾ (rem × m ³)/ (Ci × s)	RF ⁽⁵⁾ Specified By DOE-STD-1027-92	Dose Factor ⁽⁴⁾ (DOE/EH-0070) (mrem/yr)/(micro Ci/m ³)	Atomic Weight
Ra-223	3.132E-02	2.13E-02	1.000E-03	6.72E+02	223
Ra-224	1.003E-02	1.60E-03	1.000E-03	5.06E+01	224
Ra-225	4.054E-02	1.08E-03	1.000E-03	3.40E+01	225
Ac-225	2.739E-02	2.15E-03	1.000E-03	6.79E+01	225
Ac-227	2.177E+01	1.99E-05	1.000E-03	6.29E-01	227
Th-228	1.913E+00	3.14E-04	1.000E-03	9.89E+00	228
Th-230	8.000E+04	6.21E-05	1.000E-03	1.96E+00	230
Th-232	1.410E+10	2.96E-05	1.000E-03	9.33E-01	232
U-233 ⁽⁷⁾	1.592E+05	3.80E-05	1.000E-03	1.20E+00	233
U-234	2.450E+05	2.43E-05	1.000E-03	7.65E-01	234
U-235 ⁽⁷⁾	7.038E+08	2.44E-02	1.000E-03	7.70E+02	235
U-238	4.468E+09	1.65E-05	1.000E-03	5.19E-01	238
Np-237	2.140E+06	3.65E-03	1.000E-03	1.15E+02	237
Np-238	5.799E-03	9.16E-02	1.000E-03	2.89E+03	238
Pu-238	8.774E+01	1.40E-05	1.000E-03	4.41E-01	238
Pu-239 ⁽⁷⁾	2.440E+04	1.30E-05	1.000E-03	4.11E-01	239
Pu-240 ^(6d)	6.570E+03	1.37E-05	1.000E-03	4.32E-01	240
Pu-241	1.440E+01	0.00E+00	1.000E-03	0.00E+00	241
Pu-242 ^(6d)	3.760E+05	1.16E-05	1.000E-03	3.67E-01	242
Am-241	4.330E+02	3.01E-03	1.000E-03	9.50E+01	241
Am-242m	1.520E+02	7.55E-05	1.000E-03	2.38E+00	242
Am-243	7.370E+03	8.12E-03	1.000E-03	2.56E+02	243
Cm-242	4.460E-01	1.55E-05	1.000E-03	4.90E-01	242
Cm-245	8.500E+03	1.13E-02	1.000E-03	3.57E+02	245
Cf-252	2.640E+00	1.19E-05	1.000E-03	3.75E-01	252

Comments, Methodology, Explanations, and References

1. The tritium Category 2 threshold given in DOE-STD-1027-92 Table A.1 is not a calculated quantity; DOE set the value recommended by a special committee.
2. In Table 2, LANL calculated the SAs in curies per gram directly from the half-life and atomic weight using the following formula:

$$T_{1/2} = \text{half-life (yr)}$$

$$AW = \text{atomic weight of the isotope}$$

$N_o = 6.023 \times 10^{23} = \text{Avagadro's number}$

$SA(\text{Bq/gm}) = (0.693 \times N_o) / (AW \times T_{1/2} \times 3.154 \times 10^7 \text{ s/yr})$ or,

$SA(\text{Ci/gm}) = SA(\text{Bq/gm}) / (3.7 \times 10^{10} \text{ Bq/Ci})$.

The half-life values in Table 2 were obtained from *Table of Isotopes, Seventh Edition*, C. Michael Lederer and Virginia S. Shirley, Eds. (A Wiley-Interscience Publication, John Wiley & Sons, Inc., New York, 1978).

3. The 50-year committed effective dose equivalents (CEDEs) in Table 1 were obtained from DOE/EH-0071, "Internal Dose Conversion Factors for Calculation of Dose to the Public," (July 1988).

In DOE-STD-1027-92 Table A.1, DOE apparently used the largest values of the Inhalation Class D, W, or Y in the interest of conservatism in calculating their Category 2 thresholds. To reproduce their results, we have done the same for this document.

4. Values for calculating the Cloud Shine Dose Equivalent (CSDE) for external exposure from a contaminated cloud of airborne particulates were obtained from DOE/EH-0070, "External Dose-Rate Conversion Factors for Calculation of Dose to the Public," (July 1988).

Table 2 contains dose factors for all isotopes. Multiplication of these Dose Factors by $3.171\text{E-}05$ (rems \times microcuries \times yr/Ci \times mrem \times s) converts the units and gives the CSDEs in rems \times m³/ Ci \times s, which are also tabulated in Table 2.

5. DOE-STD-1027-92 Attachment 1 specifies a formula and numerical values to be used when calculating hazard Category 2 thresholds. The formula is

$$Q(\text{grams}) = 1 (\text{rems}) / \{ \text{RF} \times \text{SA} \times (\text{X/Q}) \times [\text{CEDE} \times \text{RR} + \text{CSDE}] \},$$

where

SA = (Ci/gm)

(X/Q) = Atmospheric Dispersion Factor (s/m³) = 1.0 E-04 for all isotopes (cf. DOE-STD-1027 for DOE's discussion of why this is a suitably conservative value to use)

RR = Respiration Rate: 3.5 E-4 m³/s

CSDE = Cloud Shine Dose Equivalent. The units are: rem \times m³/Ci \times s.

RF = Release Fraction: DOE-STD-1027-92 uses four different numerical values as follows:

- 1.0 for gases such as tritium, the noble gases, chlorine, etc.
- 0.5 for phosphorus, sulfur, potassium, iodine, sodium, and bromine
- 0.01 for selenium, mercury, cesium, polonium, tellurium ruthenium, and carbon
- 0.001 for other solids, powders, and liquids not listed above

This classification for the RF is based on classes of materials adopted by NRC. DOE reduced the number of classes and built in some additional conservatism (cf. DOE-STD-1027-92 Attachment 1). Table 2 contains the RF for each isotope in Table 1.

6. The hazard Category 2 thresholds from DOE-STD-1027-92 Table A.1 are tabulated in our Table 1, column 4. For DOE values that disagree with calculated values, the following comments are in order.
 - a. Consider Sb-126, Te-127m, and Hg-203. Hazard Category 2 thresholds are given in DOE-STD-1027-92 Table A.1 both *in curies and grams*. Dividing the two numbers gives the SA that DOE used. For these three materials, the SA obtained by DOE's method differs from the value of SA calculated from half-life data by almost 10 times. The spread for published half-life data, however, is only a few percent. Therefore, one of the two threshold values given in DOE-STD-1027-92 Table A.1 is probably in error. The authors of this document suspect that the Category 2 gram-thresholds in DOE-STD-1027-92 Table A.1 for these three materials contains an exponential clerical error.
 - b. For P-32 and Se-75, the SA that DOE used agrees with our half-life calculated SA. *However*, our calculated threshold values and the DOE values differ by about a factor of 100 and of 10 respectively.
 - c. Also, significant disagreement (not factors of 10) exists for Pm-147, Mn-52, and Cf-252.
 - d. For LANL use, we have added the isotopes Pu-240 and Pu-242 to the DOE-STD-1027-92 Table A.1 list. DOE-STD-1027-92 Table A.1 does not contain Category 2 threshold values for Pu-240 and Pu-242, which we need for mixture calculations.
 - e. The half-life of Bi-207 is 38 yr according to the most current reference cited earlier (*Table of Isotopes*). However, the *Radiological Health Handbook, U.S.*, (Department of Health Education and Welfare, Rockville, MD, 1970) and DOE/EH-0070, "External Dose-Rate Conversion Factors for Calculation of Dose to the Public," (July 1988) both give half-lives that are significantly lower, (e.g., 28-33.4 yr). The 33.4-yr half-life value leads to a calculated threshold value that agrees with DOE-STD-1027-92 Table A.1. The most recent value of 38 yr leads to a Category 2 threshold value of 4.27E+04 gm—about 12.4% larger than the DOE-STD-1027-92 Table A.1 value of 3.80E+04.

In summary:

We believe our calculated values of the Category 2 threshold to be correct. The "Recommended Category 2 Threshold" values in Table 1, Column 5 are from two sources.: (1) P-32, Mn-52, Se-75, Sb-126, Te-127m, Pm-147, Hg-203, Pu-240, Pu-242, and Cf-252 are LANL-calculated values. (2) All others are DOE values that come within a percent or two of the LANL-calculated values.

7. Criticality considerations further restrict the calculated threshold quantities for some materials. DOE-STD-1027-92 Table A.1 gives values. This Fact Sheet gives total facility threshold values—configured so that criticality is not possible. For example, for pure Pu-239, the criticality limit is 450 gm. The Category 2 threshold limit of 900 gm given here and in DOE-STD-1027-92 Table A.1. means that a Category 3 facility could have two separated batches of less than 450 grams each.

II. Mass Fractions, Specific Activities, and Specific Doses for Mixtures and Material Types

Scope

A number of LANL facilities process, store, or utilize plutonium and uranium *mixtures* that contain various isotopes. This section provides recommended numbers and calculations for these mixtures. NMT-4 currently recommends the weight-percent values listed in Tables 3a and 3b. (cf. Joseph R. Wachter, "Correction to Memorandum," Los Alamos National Laboratory memorandum NMT-04-93-536 November 23, 1993).

Table 3. Recommended Specific Activities, Specific Doses, and Mass Fractions for Individual Plutonium Isotopes and Plutonium Material Types or Mixtures

Table 3a. Data for Individual Plutonium Isotopes

Isotope	SA (Ci/g) (Ci/gm)	CEDE (rem/Ci)	Specific Dose (rem/gm)
Pu-238	1.713E+01	4.60E+08	7.88E+09
Pu-239	6.133E-02	5.10E+08	3.13E+07
Pu-240	2.268E-01	5.10E+08	1.16E+08
Pu-241	1.031E+02	1.00E+07	1.03E+09
Pu-242	3.931E-03	4.80E+08	1.89E+06
Am-241	3.428E+00	5.20E+08	1.78E+09

Table 3b. Data for Plutonium Material Types or Mixtures

Material Type	Pu-238 (weight %)	Pu-239 (weight %)	Pu-240 (weight %)	Pu-241 (weight %)	Pu-242 (weight %)	Pu-244 (weight %)	Percent (Total)	Specific Activity (Ci/gm)	Specific Dose (rem/gm)
MT42 84%	1.02	1.37	10.32	3.13	84.14	0.02	100	3.428136	1.27E+08
MT42 90%	0.72	1.26	6.4	1.86	89.77		100.01	2.059113	8.54E+07
MT42 95%	0.45	0.56	2.47	0.906	95.58	0.029	99.995	1.020531	4.96E+07
MT51	0.006	96.77	3.13	0.076	0.018		100	0.145808	3.51E+07
MT52	0.01	93.78	6	0.2	0.02		100.01	0.278968	3.91E+07
MT53	0.03	91.08	8.45	0.366	0.071		99.997	0.457382	4.44E+07
MT54	0.046	87.42	11.5	0.81	0.22		99.996	0.922401	5.26E+07
MT55	0.06	83.88	14.73	1.03	0.304		100.004	1.156697	5.86E+07
MT56	0.061	81.9	16.51	1.18	0.355		100.006	1.314288	6.17E+07
MT57	0.433	74.63	20.7	2.55	1.69		100.003	2.795066	1.08E+08
MT83 83%	83.89	13.8	1.9	0.32	0.09		100	14.7113	6.62E+09
MT83 89%	89.26	10.07	0.633	0.021	0.015		99.999	15.31775	7.04E+09

Dominant isotope method for initial hazard categorization

For purposes of initial hazard categorization to determine hazard Category 2 quantities, DOE recommends using the dominant isotope Category 2 threshold value. For example, use 900 gm for the Pu-239-dominant MT52 and 3.6 gm for the Pu-238-dominant MT83. The other trace isotopes are ignored.

Sum-of-fractions method for final hazard categorization

DOE-STD-1027-92 Attachment 1 specifies that a sum-of-fractions method be used for mixtures as follows. Divide the weight percent (Table 3) of each isotope in the mixture by its individual Category 2 isotopic threshold value. When the ratios are added together, the sum must be less than one. In effect, less than the maximum allowable amount of one or several isotopes means that the potential exposure (in rems) for the combined isotopes will be the same as the value that has been established as acceptable for any one of them (i.e., less than 1 rem at a 300-meter distance).

We have calculated separately that the sum-of-fractions method generally reduces the allowed gram loading for the Pu-239-dominant mixtures and allows increased amounts for the heat-source mixtures such as MT83.

Time-dependent change of Category 2 thresholds

Remember, when calculating the Category 2 threshold value for mixtures and comparing this value to the initial hazard categorization threshold quantity (for the dominant isotope), that the presence of small amounts of Am-241 will vary with time as Pu-241 decays and can cause a time-dependent change of the threshold values. This reduction with age for the Category 2 threshold values is particularly significant only for mixtures that are 20 or more years old. Additionally, the Am-241 content data for the mixtures may be lacking. If the Am-241 content data are available, ESH-3 can calculate, as needed, the reduced threshold values caused by aging. However, through methodology and parameter choices, DOE has built considerable conservatism into their threshold values. Therefore, calculating time-dependent threshold values is probably unnecessary.
