Los Alamos
NATIONAL LABORATORY
EST. 1943

memorandum

TRU WASTE PROJECT SUPPORT
WDP-TWPS

To/MS: Mark Shepard, WDP-DO, J595
Paul Newberry, WDP-HMWO, J598
Sean French, WDP-LLWD, J970
Andrew Montoya, WES-WA, J971
Thru/MS: Jason Apperson, ES-EWMO, J910
From/MS: J. Veilleux, WS-TWPS, 599
Phone/Fax: 7-7434/Fax 5-8346
Symbol: WDP-DO-09-0233
Date: *December 15, 2009*

SUBJECT: SOFTWARE QA FOR NUCDATAR02B

Objectives

The objective of this software documentation is to standardize the nuclear constants being used for the transuranic (TRU), low level waste (LLW), and mixed low level waste (MLLW) to the values being used by the Department of Energy (DOE). The values selected are based on the CH-TRAMPAC, DOE/EH-0071, DOE 5633.5, and CCP-AK-LANL-006 and, where the data is not available, then from the Federal Guidance Report # 11; LANL technical report, TD-SWO-006; and from Browne and Firestone. In a number of cases, the nuclear data had to be derived from physics principals.

Software Information:

1. Name: NucDataR02B.xls, version 02B, for the storage of the nuclear constants for isotopes and material types. The requirements and design documentation is included in enclosure 1.
2. Scope of Computation. All of the cell values are constants or simple calculations within select cells.
3. Data entry. Not applicable.
4. Change Documentation: Dose rates were updated, version 3 of the CH-TRAMPAC was incorporated, and mixed fission products and mixed activation product sources were updated. The changes are documented in enclosure 2.
5. Testing. Testing was conducted as noted in enclosure 3 and the results independently verified.

Conclusion

The nuclear constants were successfully validated.

Enclosures

1. Nuclear Data Constants for the TRU and CHEMLL Databases, Requirements and Design Documentation for NucData, dated Jan 16, 2009 as revised December 11, 2009
2. Change Documentation for NucDataR02B.xls, December 11, 2009
3. NucDataR02B.xls Test Plan and Test Report, October 23, 2009 with independent technical review completed on 12/10/2009 and final implementation on 12/11/2009

Distribution: Sean French, WDP-DO, J970
Randy Lucero, WDP-LLWD, MS J595
Kathleen M. Gruetzmacher, WDP-LLWD, MS J595

January 16, 2009
Revised: December 11, 2009

Nuclear Data Constants for the TRU and CHEMLL Databases

Requirements and Design Documentation for NucData

1. Introduction

Starting in 2004, the DOE began standardizing the nuclear constants for use in shipping waste to WIPP as documented in the CH-TRAMPAC[1], the WIPP waste acceptance criteria[2], and PECI documentation[3]. Independently of these efforts, LANL undertook a study in 1997, updated in 2003, to standardize the nuclear constants for waste[4]. These values were generally implemented in the nuclear constants table for the transuranic (TRUDB) and low level waste (CHEMLL) databases. Most of the nuclear data are the same in both the DOE and LANL listings, but some differences exist, usually less than 5% although for less common isotopes the differences can be much larger[5]. Beginning with NucDataR02B, another source for dose calculation was added, Federal Guidance Report #11[6] and this will supplement DOE/EH-0071 when the data is lacking in the latter document.

Many of the isotopes in the database have very short half-lives and should be evaluated for inclusion in waste. However, they cannot be arbitrarily deleted without first evaluating if the isotope is in equilibrium with a parent and daughter isotope (i.e., if the isotope is being pumped it could represent a significant component of the total activity). There was no attempt in this evaluation to remove an isotope; if the isotope is either in the TRAMPAC or was formerly in either the TRUDB or the CHEMLL database, it remains in the database.

Several LANL software utilities have been developed which utilize the DOE standard values and these utilities have been quality checked and documented. The first validation occurred for the utility ActivityPu239_R0.xls[7] which verified all the nuclear constants then in use except for the PECi and associated weighting functions. The PECi values and weighting factors (plus a few more isotopes) were quality checked and documented for the utility SNAPR01A.xls[8]. These two utilities combined to provide the nuclear constants for all the isotopes listed in the DOE references plus other selected isotopes that were listed in the waste database, and were initially consolidated in NucData_R01.xls.

The nuclear data were selected from the following documents, listed in order of priority:

- CH-TRAMPAC + DOE/EH-0071 + FGR#11
- TD-SWO-006 (the LANL document)
- Browne and Firestone[9]
- First principals when data was not otherwise available, as documented in this paper

The nuclear constants workbook is labeled NucDataRmnp, where mn is the revision number and p is the minor change letter (e.g., NucDataR02B.xls), and contains four worksheets as shown in Table 1. The worksheets contain the nuclear data for the isotopes, the material type activity fractions, the material type nuclear data (FGE, specific activity, dose, etc.), and a change history.

Table 1. Worksheets in NucData Repository

Worksheet	*Contents*
Isotope	Contains nuclear data for the isotopes, global variables, and material type mass fractions for plutonium, mixed fission products, and mixed activation products all based on DOE standardized values
MaterialType	Contains nuclear constants for the material types based on DOE

	standardized values (specific activities, FGE, PECi, etc.)
MT ActivityFractions	Activity fractions for all material types
Change	Change summary

2. Isotopic Data

The "Isotope" worksheet contains all the isotopes listed in the DOE documentation plus any additional isotopes that were listed in the TRUDB and CHEMLL DB; the isotopic data is tabulated in Appendix A. The field descriptions are shown in Table 2. There are other fields associated with fission rates, but these data have not been quality checked and are therefore not included as part of this quality document.

Table 2. Field Descriptions

Field	*Description or Reference*
Atomic number	See for example http://periodic.lanl.gov/list1.html or any chemistry text
Atomic Weight	The number associated with the isotope (the atomic mass)
FGE (g isotope/g Pu239)	Fissile Gram Equivalent
Decay Heat (W/g)	
Specific Activity (Ci/g), S_j^A	In the expression, j is the isotope
Half Life (years)	Browne and Firestone, 1986
TRU Nuclide, δ_j^T	The value is 1 under the following situations (else 0): 1) The atomic number is > 92 2) The half-life is > 20 years 3) The isotope decays with probability > 0 by alpha particle emission.
PECi Nuclide, δ_j^P	The value is 1 under the following situations (else 0): 1) The atomic number is > 92 2) U233
Alpha Ratio, R_j	Browne and Firestone, 1986
Dose (rem/uCi), D_j	The 50-year effective whole-body dose commitment due to inhalation. The highest of the daily, weekly, or yearly CEDE is used.

The calculated fields are shown in Table 3.

Table 3. Calculated Fields

Field	*Description*	*Equation #*
Alpha Specific Activity, S_j^α	$S_j^\alpha = R_j S_j^A$	(1)
Dose Weighting Factor, WF_j	$WF_j = \frac{510}{D_j}$, where 510 is the Pu239 dose per uCi.	(2)
Pu239 Equivalent Ci (Ci/g), MAR_j	$MAR_j = \frac{S_j^A}{WF_j}$, i.e., every isotope contributes to dose	(3)

PECI (Ci/g), $PECI_j$	$PECI_j = \frac{S_j^A}{WF_j}\delta_j^P$, i.e., only the PECI isotopes contribute to dose	(4)

The calculation of PECi and TRU activity was most easily implemented by introducing two functions, δ_j^T and δ_j^P, that describe a TRU isotope and a PECi isotope, respectively. Each function is 1 if it meets the definition, otherwise 0. The definitions are summarized in Table 4.

Table 4. Definitions for a TRU and PECi Isotope[2]

Definition	*TRU Isotope*	*PECi Isotope*
Atomic Number > 92	Yes	Yes
Decays with probability > 0 by alpha emission	Yes	Yes
Only Isotopes with Half-life > 20 years?	Yes	No
Includes U233	No	Yes

Many of the isotopes from this set are not available in the CH-TRAMPAC. Consequently, the nuclear constants for the missing isotopes were determined by applying in order of preference TD-SWO-006, Browne and Firestone, or first principals (see paragraph 2 equations in TD-SWO-006).

There are 21 isotopes for which the decay heat had not been calculated in TD-SWO-066 (e.g., V52, Se72, Y87m, Nb91, Nb91m, Nb92, Nb92m, Nb93, Rh97, Ba133m, Nd144, Ho163, Lu172m, Hf178n, Re183, Pt193, Au196, Po208, Np242, Rh106m and Pu233) and these have to be calculated from the average photon, particle energies, and internal conversion energies given in Browne and Firestone. The decay heat (DH) in watts per gram for isotope j is given by the specific activity and sum of the average energies, ε_k of the emitted photons, particles, and internal conversions k (see Equation **(5)**). The applied conversion factors are:

- 1E-3, keV to MeV
- 3.7E10, Ci to Bq
- 1.6022E-13, MeV to Joule

$$DH_j = S_j^A \sum_k \varepsilon_k \quad (5)$$

The calculation of the decay heat is straightforward except for two isotopes, Np242 and Pu233, where the average energy is not available from Browne and Firestone. In these two cases, the average energy must be calculated from the individual gamma energy multiplied by the relative intensity and the results normalized by summing the relative intensity weights. Pu233 must additionally be normalized to account for the 0.12% alpha emission. Equation **(6)** describes the relationship for this situation.

$$DH_j = S_j^A \frac{\sum_k \varepsilon_k w_k}{\sum_k w_k} \quad (6)$$

The FGE of six isotopes (Am239, Am240, Np235, Np242, Pu233 and Pu234) are reported as "Null" in TD-SWO-006 (paragraph 9). For all isotopes except Np235, the half-life is much less than 1 day, there are no associated parent nuclides to pump the isotope[10], and so the FGE can be set to zero since these isotopes will not be present in waste. Np235 has an even number of neutrons and therefore is unlikely to become critical[11]. The atomic weight for Rh106m is too small to fission. Therefore the FGE of these isotopes has been set to zero rather than "Null".

There are 51 isotopes for which the dose value is not available (Table 5) in either DOE/EH-0071 or in FGR #11. For these isotopes, the dose was set to null and the PECi and MAR set to zero.

Table 5. Missing Dose Values

Isotope	Isotope	Isotope	Isotope
Ag108	Kr85	Po214	Se72
Ag109m	Lu172m	Po215	
Ag110	Nb91m	Po216	
At217	Nb92	Po218	
Au196	Nb92m	Pr144m	Tl207
Ba137	Nb93	Pu233	Tl208
Ba137m	Nd144	Rb82	Tl209
Bi211	Np240m	Re183	Tm168
Ce142	Pa234m	Rh106	V52
Es252	Po208	Rh97	Xe133
Fr221	Po209	Rn219	Y87m
Hf178n	Po211	Rn220	Zr90
Ho163	Po212	Rn222	Zr90m
In114	Po213		

These nuclear constants are intended to replace the existing set in the RAD_CODE table. Table 6 cross references the naming convention for the RAD_CODE table and these nuclear constants.

Table 6. Naming Conventions

RAD_CODE Table	*NucDataR02A, Worksheet Isotope and MaterialType*
A_CONVERSION	Alpha specific activity (Ci/g), S_j^{α}
T_CONVERSION	Specific Activity (Ci/g), S_j^{A}
FISS_FRACT	FGE (g isotope/g Pu239)
DECAY_HEAT	DH_j (Watts/g)
PECI_WGTFACT	Dose Weighting Factor, WF_j (for material types, if value is 0, set PECi = 0)
HALF_LIFE	Half Life (Yrs) (not applicable for Material Types)
TRUFLAG	TRU Nuclide, δ_j^T (not applicable for Material Types)
TBD (zero non-PECi isotopes or new field)	PECi TRU Nuclide, δ_j^P (not applicable for Material Types)

3. Material Type

Many of the legacy drums in the inventory are specified in terms of a material type which typically consists of one or more isotopes with a specified activity fraction. The inventory of these material types is significant, representing several thousand Curies of activity. The "MaterialType" worksheet contains all the plutonium material types listed in the DOE documentation plus any additional

material types listed in the TRUDB and CHEMLL DB with the exception of certain types which are undefined; these are summarized below.

The material type activity fractions are shown in Appendix B and the nuclear constants in Appendix C. The activity fractions are included in worksheet "MTActivityFractions" and the nuclear constants in worksheet "MaterialType".

3.1. Material Type Activity Fractions except MFP and MAP

The plutonium material types are currently defined in the Central Characterization Project acceptable knowledge documentation, such as CCP-AK-LANL-006[12] and these differ from the current material type descriptions in the TRUDB and CHEMLL DB. The plutonium material types added contributions from Am241, U234, U235, Cs137, and Sr90. The Sr90 activity[13] is based on a correlation with Cs137. The Oracle database requires activity fractions rather than mass fractions.

Letting f_j^A and f_j^m represent the activity and mass fractions of isotope j respectively, m_{Pu} the plutonium mass, and A_j the activity, then for each gram of plutonium in a given material type one can express the activity fractions for each isotope as shown below.

$\sum_{j=1}^{PuOnly} f_j^m = 1$	(7)
$m_j = f_j^m m_{Pu}$	(8)
$A_j = m_j S_j^A$	(9)
$A = \sum_{j=1}^{All} A_j$ (the sum is over all isotopes in the material type)	(10)
$f_j^A = \frac{A_j}{A}$	(11)

The uranium, americium, curium, berkelium, californium, and neptunium material types are defined in DOE5633.5[14] in terms of ranges of enrichment; a review of the nuclear constants in the RAD_CODE table indicates that the current values remain appropriate. With the exception of the plutonium material types, the activity fractions are the same as the original Oracle values.

There are other material types which cannot be defined at this time, including ASBES, CHEM, GAMMA, GRALPH, GRBETA, NONRAD, PCB, TRU, and UNID. These remain undefined.

3.2. Mixed Fission Products (MFP) and Mixed Activation Products (MAP)

An excellent review of the Area G waste at TA54 addresses the mixed fission products (MFP) and mixed activation products (MAP)[15], identifying the isotopic distributions as a function of aging (1, 2, 5, and 10 years). Since material type distributions have not been accepted into Area G since approximately 1987, it is assumed that MFP/MAP waste in Area G is at least 10 years old.

The mass and activity averaged percent distributions are shown in Table 7 for MFP waste and in Table 8 for MAP waste.

3.2.1. MFP Waste

In this implementation, fast neutron waste generation was disregarded since the majority of interactions will be with thermal neutrons. It was further assumed that 30% of the waste will be generated by Pu239 fissions (w_{Pu239}) with the remainder coming from U235 fissions (w_{U235}) and the activity fractions (f_j^A) from Pu239 or U235 averaged with these weights. The mass is then calculated from the specific activity (S_j^A) of each isotope j. In both the activity and mass fractions, the sum must add to 1. The activity and mass fractions are those that would exist after 10 years, so there is no additional decay correction needed. The following equations were applied and the results are tabulated in Table 7.

$\langle f_j^A \rangle = w_{Pu239} f_j^{A(Pu239)} + w_{U235} f_j^{A(U235)}$	(12)
$\sum_j \langle f_j^A \rangle = 1$	(13)
$\langle f_j^m \rangle = \frac{\langle f_j^A \rangle}{S_j^A}$	(14)
$\sum_j \langle f_j^m \rangle = 1$	(15)

Table 7. Average MFP Activity and Mass Percentages Aged 10 Years

Isotopes	Mass Weight %	Activity %
Ce144	0.0%	0.1%
Cs137	55.7%	47.2%
Eu154	0.0%	0.0%
Eu155	0.0%	0.0%
Kr85	4.9%	18.8%
Ru106	0.0%	0.5%
Sb125	0.0%	0.0%
Sm151	0.0%	0.0%
Sn121m	0.0%	0.0%
Sn126	14.3%	0.0%
Sr90	25.0%	33.3%

3.2.2. MAP Waste

The MAP waste distribution was presented at the age of the waste when it was shipped for disposal. Consequently, these mass and activity fractions must be decay corrected 10 years. The following equations apply, where $f_j^m(0)$ is the initial mass fraction, t_j is the half-life of isotope j, and T is the amount of decay correction to be applied. The distribution for MAP is tabulated in Table 8.

$f_j^m = f_j^m(0)e^{-TLn(2)/t_j}$	(16)
$f_j^A = f_j^m S_j^A$	(17)
$\sum_j f_j^m = 1$	(18)
$\sum_j f_j^A = 1$	(19)

Table 8. MAP Activity Percentages Aged 10 Years

Isotopes	Mass Weight %	Activity %
Be7	0.0%	0.0%
Co57	0.0%	0.1%
Co60	94.4%	75.1%
Mn54	0.0%	0.2%
Na22	5.6%	24.6%
Zn65	0.0%	0.0%

3.3. Material Type Nuclear Constants

The material type nuclear constants for FGE, decay heat, alpha specific activity, total specific activity, Pu239 Equivalent activity (MAR) and PECi may be calculated using the mass fraction distributions for each material type. In the expressions to follow, the nuclear constants are specified per unit mass of a given material type and the results tabulated in Appendix C.

3.3.1. Discussion

For the plutonium material types, PU42 through PU83, the mass fractions of each nuclide were selected based on the values stipulated by CCP[12]. An additional MT was encountered, PU41, which is similar to PU42 except that it has Pu242 enrichment[14] between 20 to 60%; an average value of 40% was selected with the remaining nuclides allocated proportionately the same as PU42 using the relationship shown below, where the value 0.8984 is the average Pu242 enrichment in PU42. The weight percent for Cs137 will remain a constant as for other plutonium material types and include the contribution from production reactors (0.5 ng/g Pu) and spontaneous fission (0.4 pg/g Pu), or 5.004E-6 weight %.

$f_j^{PU41} = \left(\frac{1-0.4}{1-0.8984}\right) f_j^{PU42}$, j ≠Pu242	(20)
$f_{Pu242}^{PU41} = 0.4$	(21)

The uranium material types (U10-U70), as well as the natural and depleted uranium applied the values already in the TRUDB. The values for D38 and depleted uranium are identical. To confirm the activity ratios, the mass fractions were calculated and the U235 enrichment (or depletion) was in agreement with DOE 5633.5. Consequently, the values in the Oracle database were retained.

The U72 material type was added. DOE 5633.5 detailed computer listings identify this material type as being enriched in U233 between 97 and 99%. The value selected was 98% enrichment and the remaining isotopic distributions were selected based on natural uranium using the same procedure described earlier for PU41.

AM44 is equivalent to Am241, AM45 to Am243, and NP82 to Np237 as described in DOE 5633.5. However, for BK47, CF48, and CM46, DOE5633.5 just relates them to the atomic number; consequently, the selection already applied in the TRUDB was retained. Thus BK47 is equivalent to Bk249, CF48 to Cf242 and CM46 to Cm246.

3.3.2. Nuclear Constants

The nuclear constants for each material type (specific activity, FGE, PECI, etc) are to be specified per unit of material type as a function of the activity fractions. The following relationships are needed where MT represents the material type and the the variables have been previously defined. Note that the constraint on the plutonium mass represented by equation *(7)* no longer applies.

$$m_{MT} = \sum_{j}^{All} m_j \,,\; A_{MT} = \sum_{j}^{All} A_j \,,\; A_j = m_j S_j^A \text{, and } f_j^A = \frac{A_j}{A_{MT}} \qquad (22)$$

This leads to the following relationship for the relative mass:

$$\frac{m_j}{m_{MT}} = \left(\frac{f_j^A}{S_j^A}\right)\left(\frac{1}{\sum_{j}^{All}\frac{f_j^A}{S_j^A}}\right) \qquad (23)$$

For each material type, the specific FGE (S_{MT}^{FGE}), specific decay heat (S_{MT}^{DH}), alpha specific activity (S_{MT}^{α}), total specific activity (S_{MT}^{A}), specific MAR activity (S_{MT}^{MAR}), and specific PECI activity (S_{MT}^{PECI}) were calculated using the relationships shown in equations (**24)** through (**29)** assuming one gram of material type. These units are per gram of material type. The PECi weighting factor WF_{MT}^{PECi} is calculated as shown in equation **(30).**[1]

$$S_{MT}^{FGE} = \sum_{j}^{All} \frac{m_j}{m_{MT}} S_j^{FGE} \qquad (24)$$

$$S_{MT}^{DH} = \sum_{j}^{All} \frac{m_j}{m_{MT}} S_j^{DH} \qquad (25)$$

$$S_{MT}^{\alpha} = \sum_{j}^{All} \frac{m_j}{m_{MT}} S_j^{\alpha} \qquad (26)$$

$$S_{MT}^{A} = \sum_{j}^{All} \frac{m_j}{m_{MT}} S_j^{A} \qquad (27)$$

$$S_{MT}^{MAR} = \sum_{j}^{All} \frac{m_j}{m_{MT}} S_j^{MAR} \qquad (28)$$

$$S_{MT}^{PECI} = \sum_{j}^{All} \frac{m_j}{m_{MT}} S_j^{PECI} \qquad (29)$$

[1] The weighting factor, WF, is set to 1E15, an arbitrarily large number, to represent the value of infinity.

$WF_{MT}^{PECi} = \frac{S_{MT}^{A}}{S_{MT}^{PECi}}$, with $WF_{MT}^{PECi} = \infty$ if $S_{MT}^{PECi} = 0$ (Note: 1E15 is used to represent infinity)	(30)

4. Conclusions

Implementation of the nuclear constants will provide a consistent set of data that represents a consistent set of values representing accepted DOE values for waste shipment and disposal. The nuclear constants will undergo a software quality assurance validation providing assurance the the values used are defensible.

5. Appendices

A. Isotope Nuclear Constants
B. Material Type Activity Fractions
C. Material Type Nuclear Constants

REFERENCES

[1] CH-TRAMPAC, Contact-Handled Transuranic Waste Authorized Methods for Payload Control, US Department of Energy Carlsbad Field Office (www.wipp.energy.gov/library/CHsar/Documents), Revision 3, February 2009
[2] DOE/WIPP-02-3122, Transuranic Waste Acceptance Criteria for the Waste Isolation Pilot Plant, US Department of Energy Carlsbad Field Office, Rev. 6.3, February 5, 2009
[3] DOE/EH-0071, Dose Conversion Factors for Calculation of Dose to the Public, US Department of Energy, July 1988
[4] TD-SWO-006, Rad_Code Table Input Data, Los Alamos National Laboratory, Rev. 2, September 23, 2003
[5] WS-TWPS2007-0015, Software Quality Assurance Verification and Validation Testing for the Facility Radioactive Inventory Spreadsheet V4.4.1, Los Alamos Memorandum, April 11, 2007
[6] Federal Guidance Report No. 11, Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion, US EPA report EPA-520/1-88-020, Sep 1988
[7] WDP-TWPS2008-0054, Software Quality Assurance Documentation: ActivityPu239_R0.xls, Los Alamos Memorandum, April 7, 2008.
[8] WDP-TWPS2008-0060, Software Quality Assurance Documentation and Testing of the SNAPR01A.xls Software, Los Alamos Memorandum, July 8, 2008
[9] Browne, E. and R.B. Firestone, Table of Radioactive Isotopes, Lawrence Berkeley Laboratory, Wiley & Sons, NY, 1986
[10] Walker, FW, J Parrington, and F Feiner, Nuclides and Isotopes, 14th Edition, 1989, General Electric Company, San Jose, California
[11] American National Standards Institute/American Nuclear Society, Nuclear Criticality Control of Special Actinide Elements, ANSI/ANS-8.15-1981, Washington, DC
[12] CCP-AK-LANL-006, Los Alamos National Laboratory TA-55 Mixed Transuranic Waste, Central Characterization Project (CCP), Revision 8, March 12, 2008
[13] Memorandum, *^{234}U and ^{90}Sr Calculations for NDA Reporting*, TWCP-12684, Los Alamos National Laboratory, April 7, 2003
[14] DOE 5633.5, Figure VI-1, Nuclear Material Type Codes, May 22, 1987
[15] Shuman, R., Radioactive Waste Inventory for Los Alamos National Laboratory Technical Area 54, Area G, 2008 (draft of an LAUR report)

Appendix A

Isotope Nuclear Constants

Isotopic Data

Isotopes: 358

FGE, Decay Heat, Specific Activity and Half-Life selected in following order of priority: CH Transpac, TD-SWO-006, Browns & Firestone, Requirements & Design document. Dose selected in order: DOE/EH-0071, FGR11.

0	1	2	3	4	5	6	7	13	14	15	16	17	18	19	20	21			References (End of Table)					
Sel	Isotope	FGE (g isotope/g Pu238)	Decay Heat (W/g)	Alpha specific Activity (Ci/g)	Specific Activity (Ci/g)	Pu238 Eq. Ci (Ci/g) (NAR)	PECI (Ci/g)	Half Life (Yrs)	TRU Nuclide	PECI TRU Nuclide	Atomic Weight	Atomic Number	Alpha Ratio	Dose (rem/uCi)	Dose Weighting Factor, WF	Comments	Version	Dose Comment	Specific Activity (Ci/g)	FGE (g/g)	Decay Heat (W/g)	Dose (rem/uCi)	Alpha Ratio	Half-Life (yrs)
	Ac225	0.00E+00	1.95E-03	5.80E+04	5.80E+04	1.14E-03	0.00E+00	2.74E-02	0	0	225	89	1.00E+00	1.00E+01	5.10E-01				1	1	1	4	3	3
	Ac227	0.00E+00	3.68E-02	1.01E+00	7.32E+01	9.62E+02	0.00E+00	2.18E+01	0	0	227	89	1.38E-02	6.70E-03	7.61E-02				1	1	1	4	3	3
	Ac228	0.00E+00	1.80E+04	1.33E-01	2.24E-06	1.27E-03	0.00E+00	6.99E-04	0	0	228	89	5.50E-01	2.90E-01	1.76E-03				1	1	1	4	3	3
	Ag105	0.00E+00	9.73E+01	0.00E+00	3.01E+04	2.78E-01	0.00E+00	1.13E-01	0	0	105	47	0.00E+00	4.70E-03	1.09E-05		R03A		1	2	2	4	3	3
	Ag106m	0.00E+00	2.45E-03	0.00E+00	1.46E+05	2.01E+00	0.00E+00	2.32E-02	0	0	106	47	0.00E+00	7.10E-03	7.18E-04		R07A		2	2	2	4	3	3
2	Ag110t	4.84E-01	2.74E+06	0.00E+00	7.35E+08	0.00E+00	0.00E+00	4.51E+00	0	0	108	47	0.00E+00			Transpac v3	R02B	per in 0071, FGR11	1	1	1	5	3	3
2	Ag108m	0.00E+00	2.53E-01	0.00E+00	2.61E+01	1.02E-02	0.00E+00	1.27E-02	0	0	108	47	0.00E+00	2.00E-01	2.55E-03	Transpac v3	R07B		1	1	1	4	3	3
	Ag109m	0.00E+00	1.32E+06	0.00E+00	2.41E+09	0.00E+00	0.00E+00	1.25E-06	0	0	109	47	0.00E+00					per in 0071, FGR11	1	1	1	5	3	3
	Ag110	0.00E+00	3.01E+07	0.00E+00	4.17E+09	0.00E+00	0.00E+00	7.80E-07	0	0	110	47	0.00E+00					not in 0071, FGR11	1	1	1	5	3	3
	Ag110m	0.00E+00	7.99E+01	0.00E+00	4.86E+03	4.99E-01	0.00E+00	6.84E-01	0	0	110	47	0.00E+00	5.30E-02	9.62E-03				1	1	1	4	3	3
	Ag111	0.00E+00	3.56E+02	0.00E+00	1.55E+05	1.83E+00	0.00E+00	2.04E-02	0	0	111	47	0.00E+00	5.90E-03	8.84E-04		R02A		2	2	2	4	3	3
	Al26	0.00E+00	3.53E-04	0.00E+00	1.91E-02	2.96E-06	0.00E+00	7.20E+05	0	0	26	13	0.00E+00	7.90E-02	6.46E-03		R02A		2	2	2	4	3	1
	Am239	0.00E+00	2.67E-03	1.10E+02	1.10E+06	8.64E-01	8.64E-01	1.36E-03	0	1	239	95	1.00E-04	4.00E-04	1.28E+06		R01A		2	5	1	4	3	3
	Am240	0.00E+00	1.69E-03	4.88E-01	2.57E+05	9.07E-01	9.07E-01	5.10E-03	0	1	240	95	1.90E-06	1.80E-03	2.83E+05				1	5	2	4	3	3
	Am241	1.87E-02	1.16E-01	3.47E+00	3.47E+00	3.54E+00	3.54E+00	4.33E+02	1	1	241	95	1.00E+00	5.20E+02	9.81E+01				1	1	1	4	3	3
	Am242	0.00E+00	9.38E-02	0.00E+00	8.08E+03	9.66E+01	9.66E+01	1.83E-01	0	1	242	95	0.00E+00	6.10E-02	8.56E-03				1	1	1	4	3	3
	Am242m	3.44E-01	4.32E-03	4.42E-02	9.83E+00	9.83E+00	9.83E+00	1.41E-02	1	1	242	95	4.50E-03	5.10E+02	1.00E+00				1	1	1	4	3	3
	Am243	1.39E-02	6.49E-03	2.02E-01	2.02E-01	7.06E-01	2.06E-01	7.38E+03	1	1	243	95	1.00E+00	5.20E+02	9.81E+01				1	1	1	4	3	3
	Am245	0.00E+00	2.12E+04	0.00E+00	6.34E+06	8.01E-01	8.03E-01	2.34E-04	0	1	245	95	0.00E+00	6.60E-05	7.73E+06				1	1	1	4	3	3
	As71	0.00E+00	2.80E+03	0.00E+00	6.11E+05	1.47E+00	0.00E+00	7.39E-01	0	0	71	33	0.00E+00	1.10E-03	4.64E+05		R01A		2	2	2	4	3	3
	As72	0.00E+00	2.80E+04	0.00E+00	1.87E+06	1.15E+01	0.00E+00	2.97E-03	0	0	72	33	0.00E+00	3.50E-03	1.46E+05		R02A		2	2	2	4	3	3
	As73	0.00E+00	1.02E+01	0.00E+00	2.23E+04	1.37E-01	0.00E+00	2.20E-01	0	0	73	33	0.00E+00	3.10E-03	1.65E+05				1	1	1	4	3	1
	As74	0.00E+00	6.01E+02	0.00E+00	9.92E+04	1.26E+00	0.00E+00	4.87E-02	0	0	74	33	0.00E+00	6.50E-03	7.85E+04		R02A		2	2	2	4	3	3
	At211	0.00E+00	3.05E+04	8.59E+03	2.06E+08	3.76E+02	0.00E+00	8.21E+04	0	0	211	85	4.17E-01	9.30E+02	5.41E+03				1	1	1	4	3	3
	At217	0.00E+00	6.74E+10	1.61E+12	1.61E+12	0.00E+00	0.00E+00	1.02E+09	0	0	217	85	1.00E+00					not in 0071, FGR11	1	1	1	5	3	3
	Au194	0.00E+00	2.68E+03	0.00E+00	4.09E+05	1.04E+00	0.00E+00	4.51E-03	0	0	194	79	0.00E+00	1.30E-03	3.91E-05		R02A		2	2	2	5	3	3
	Au195	0.00E+00	2.68E+08	0.00E+00	3.68E+03	8.47E-02	0.00E+00	5.10E-01	0	0	195	79	0.00E+00	1.20E-02	4.23E-04		R02A		2	2	2	4	3	3
1	Au196	0.00E+00	3.25E+02	0.00E+00	1.01E+05	0.00E+00	0.00E+00	1.69E-02	0	0	196	79	0.00E+00				R02B	not in 0071, FGR11	1	2	5	5	3	3
	Au198	0.00E+00	1.51E+03	0.00E+00	2.43E+05	1.39E+00	0.00E+00	7.37E-03	0	0	198	79	0.00E+00	3.90E-03	1.76E+05				1	1	1	4	3	3
	Ba133	0.00E+00	6.82E-01	0.00E+00	2.33E+02	3.42E-01	0.00E+00	1.05E+01	0	0	133	56	0.00E+00	6.90E-03	7.39E+04				1	1	1	4	3	3
	Ba133m	0.00E+00	1.61E+03	0.00E+00	6.06E+05	6.65E-01	0.00E+00	4.44E-03	0	0	133	56	0.00E+00	5.80E-04	9.11E-03		R01A		2	5	5	4	3	3
2	Ba137	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+20	0	0	137	56	0.00E+00			Transpac v3; stable isotope (set half-life to 1E20 yr)	R02B	not in 0071, FGR11	1	1	1	5	3	3
	Ba137m	0.00E+00	2.12E-06	0.00E+00	5.38E-04	0.00E+00	0.00E+00	4.85E-06	0	0	137	56	0.00E+00					not in 0071, FGR11	1	1	1	3	3	3
	Ba139	0.00E+00	8.92E-04	0.00E+00	1.60E+07	3.01E+00	0.00E+00	1.61E-04	0	0	139	56	0.00E+00	1.60E-04	3.19E-06		R01A		2	2	2	4	3	3
	Ba140	0.00E+00	2.15QE-02	0.00E+00	7.31E+04	5.16E-01	0.00E+00	3.49E-02	0	0	140	56	0.00E+00	3.60E-03	1.42E+05				2	2	2	4	3	3
2	Be10	0.00E+00	2.68E-05	0.00E+00	2.24E-02	1.54E-05	0.00E+00	1.60E+06	0	0	10	4	0.00E+00	3.50E-01	1.46E+03	Transpac v3	R02B		1	1	1	4	3	3
	Be7	0.00E+00	1.020E-02	0.00E+00	3.500E+05	1.85E-01	0.00E+00	1.46E-01	0	0	7	4	0.00E+00	2.70E-04	1.89E+06				2	2	2	4	3	3
	Bi207	0.00E+00	5.34E-01	0.00E+00	5.48E+01	1.50E-03	0.00E+00	3.22E+01	0	0	207	83	0.00E+00	1.40E-02	3.64E+04				1	1	1	4	3	3
	Bi210	0.00E+00	2.86E+02	1.64E-01	1.24E+05	6.62E-01	0.00E+00	1.37E-02	0	0	210	83	1.32E-06	1.90E-01	2.68E-03	I think Transpac should have used the 3E6 year isomer			1	1	1	4	3	3
	Bi211	0.00E+00	1.64E+07	6.17E-03	6.18E+06	0.00E+00	0.00E+00	4.07E-06	0	0	211	83	9.97E-01					not in 0071, FGR11	1	1	1	5	3	3
	Bi212	0.00E+00	2.42E-03	5.28E-06	1.47E-07	6.03E+02	0.00E+00	1.15E-04	0	0	212	83	3.59E-01	2.10E-02	2.43E-04				1	1	1	4	3	3
	Bi213	0.00E+00	7.64E-04	4.17E-05	1.93E-07	8.43E+02	0.00E+00	8.67E-05	0	0	213	83	2.16E-02	1.70E-02	3.00E-04				1	1	1	4	3	3
	Bi214	0.00E+00	7.25E+03	9.26E+03	6.41E-03	5.43E+01	0.00E+00	3.79E-05	0	0	214	83	2.10E-04	6.10E-03	8.10E-04				1	1	1	4	3	3
	Bk247	0.00E+00	3.69E-02	1.06E+00	1.04E+06	1.14E+00	1.14E+00	1.38E+03	1	1	247	97	1.00E+00	5.10E-02	9.27E-01				1	1	1	4	3	3
	Bk249	0.00E+00	3.24E-01	2.41E-02	1.66E+03	4.23E+00	4.23E+00	8.78E-01	0	1	249	97	1.45E-05	1.1	3.92E-02				1	1	1	4	3	3
	Bk250	0.00E+00	3.34E+04	0.00E+00	3.90E-04	5.21E-01	5.21E-01	3.87E-04	0	1	250	97	0.00E+00	6.90E-05	7.39E-04				1	1	1	4	3	3
	Br76	0.00E+00	5.03E+04	0.00E+00	2.55E-06	6.00E+00	0.00E+00	1.83E-03	0	0	76	35	0.00E+00	1.20E-03	4.25E+05		R02A		2	2	2	4	3	3
	Br77	0.00E+00	1.39E+03	0.00E+00	7.14E+05	3.64E-01	0.00E+00	6.51E-03	0	0	77	35	0.00E+00	2.60E-04	1.96E+06		R02A		2	1	2	4	3	3
	Br82	0.00E+00	1.79E+04	0.00E+00	1.08E-06	2.76E+00	0.00E+00	4.03E-03	0	0	82	35	0.00E+00	1.30E-03	3.92E+05		R07A		2	2	2	4	3	3
	C14	0.00E+00	1.32E-03	0.00E+00	4.51E+00	1.86E-05	0.00E+00	5.73E+03	0	0	14	6	0.00E+00	2.10E-03	2.43E-05				1	1	1	4	3	3
	Ca41	0.00E+00	1.39E-06	0.00E+00	8.50E-02	2.17E-07	0.00E+00	1.03E+05	0	0	41	20	0.00E+00	1.30E-03	3.92E-05		R01A		2	2	2	4	3	3
2	Ca45	0.00E+00	8.12E+00	0.00E+00	1.78E+04	2.13E-01	0.00E+00	4.48E-01	0	0	45	20	0.00E+00	6.10E-03	8.36E+04	Transpac v3	R02B		1	1	1	4	3	3
	Cd109	0.00E+00	1.68E+00	0.00E+00	2.61E+03	5.12E-01	0.00E+00	1.27E+00	0	0	109	48	0.00E+00	1.80E-01	5.10E-03				1	1	1	4	3	3
	Cd113m	0.00E+00	2.34E-01	0.00E+00	2.17E+02	3.96E-01	0.00E+00	1.37E+01	0	0	113	48	0.00E+00	1.4	3.64E-02				1	1	1	4	3	3
	Cd115	0.00E+00	1.62E+03	0.00E+00	5.10E+05	3.80E+00	0.00E+00	6.10E-03	0	0	115	48	0.00E+00	3.80E-01	1.34E+05		R07A		2	2	2	4	3	3
2	Cd115m	0.00E+00	9.56E+01	0.00E+00	2.55E+04	1.23E+00	0.00E+00	1.22E-01	0	0	115	48	0.00E+00	6.50E-03	7.85E+03	Transpac v3	R02B		1	1	1	4	3	3
	Ce137	0.00E+00	7.87E+02	0.00E+00	2.54E+06	1.94E-01	0.00E+00	1.03E-03	0	0	137	58	0.00E+00	3.90E-05	1.31E+07		R02A		2	2	2	4	3	3
1	Ce139	0.00E+00	7.89E+00	0.00E+00	6.82E+03	1.00E-01	0.00E+00	3.77E-01	0	0	139	58	0.00E+00	7.70E-01	6.80E-04		R02B		2	2	2	4	3	3
	Ce141	0.00E+00	4.19E+01	0.00E+00	2.88E+04	4.80E-01	0.00E+00	8.90E-02	0	0	141	58	0.00E+00	8.50E-03	6.00E-04				1	1	1	4	3	3
2	Ce142	0.00E+00	0.00E+00	0.00E+00	2.40E-08	0.00E+00	0.00E+00	5.00E+16	0	0	142	58	0.00E+00			Transpac v3; Half-life is > value shown	R02B	not in 0071, FGR11	1	1	1	5	3	3
	Ce144	0.00E+00	2.14E+00	0.00E+00	1.22E+03	2.21E+00	8.00E-01	7.80E-01	0	0	144	58	0.00E+00	3.50E-01	1.46E+03				1	1	1	4	3	3
	Cf248	0.00E+00	98.649	1.58E+03	1.58E+03	3.33E+02	1.33E+02	9.14E-01	0	1	248	98	1.00E+00	4.30E+01	1.19E-01	isotope is TRUDB. Decay heat calculated from particle energy	R01		3	5	5	4	3	3
	Cf249	4.50E+01	1.54E-01	4.14E+00	4.14E+00	4.46E+00	4.46E+00	3.51E+02	1	1	249	98	1.00E+00	5.50E-02	9.27E-01				1	1	1	4	3	3
	Cf250	0.00E+00	4.13E+00	1.11E+02	1.11E+02	4.79E+01	4.79E+01	1.31E+01	0	1	250	98	9.99E-01	2.20E-02	2.32E-06				1	1	1	4	3	3
	Cf251	9.00E+01	5.89E-02	1.60E+00	1.60E+00	1.76E+00	1.76E+00	8.98E+02	1	1	251	98	1.00E+00	5.60E+02	9.11E-01				1	1	1	4	3	3
	Cf252	0.00E+00	4.04E+01	5.27E+02	5.44E+02	1.39E+02	1.39E+02	2.45E+00	0	1	252	98	9.69E-01	1.30E+02	3.92E+00				1	1	1	4	3	3
	Cf254	0.00E+00	9.10E-01	2.64E+01	8.10E+03	4.67E+03	4.67E+03	1.66E-01	0	1	254	98	3.10E-03	2.80E+02	1.82E+00				1	1	1	4	3	3
	Cl36	0.00E+00	5.36QE-05	0.00E+00	3.29QE-02	1.29E-06	0.00E+00	3.01E+05	0	0	36	17	0.00E+00	2.00E-02	2.55E-04				1	1	1	4	3	3
	Cm240	0.00E+00	7.46E-02	2.01E+04	2.01E+04	3.27E+02	3.27E+02	7.39E-02	0	1	240	96	1.00E+00	8.3	6.14E+01				1	1	1	4	3	3
	Cm242	0.00E+00	1.23E+02	3.35E+03	3.35E+03	1.12E+03	1.12E+02	4.46E-01	0	1	242	96	1.00E+00	1.70E-01	3.00E-01				1	1	1	4	3	3
1	Cm243	5.00E+00	1.90E+00	5.21E+01	5.22E+01	3.58E+01	3.58E+01	2.85E+01	1	1	243	96	9.74E-01	3.50E+02	1.46E+00		R02B		1	1	1	4	3	3
	Cm244	9.00E-02	2.86E+00	8.18E+01	8.18E+01	4.33E+01	4.33E+01	1.81E+01	0	1	244	96	1.00E+00	2.70E+02	1.89E+00				1	1	1	4	3	3
	Cm245	1.50E+01	5.77E-03	1.74E-01	1.74E-01	1.84E-01	1.84E-01	8.50E+03	1	1	245	96	1.00E+00	5.40E+02	9.44E-01				2	1	1	4	3	3
	Cm246	0.00E+00	1.02E-02	3.11E-01	3.11E-01	3.29E-01	3.29E-01	4.73E+03	1	1	246	96	1.00E+00	5.40E+02	9.44E-01				1	1	1	4	3	3
	Cm247	5.00E-01	2.95E-06	9.38E-05	9.01E-05	9.01E-05	9.01E-05	1.56E+07	1	1	247	96	1.00E+00	4.90E-02	1.04E+00				1	1	1	4	3	3
	Cm248	9.00E+00	5.53E-04	3.94E-03	4.30E-03	1.60E-02	1.60E-02	3.40E+05	1	1	248	96	9.17E-01	1.90E-03	2.68E-01				1	1	1	4	3	3
1	Cm250	0.00E+00	1.59E-01	0.00E+00	2.10E-01	3.87E+00	3.87E+00	1.13E+04	1	1	250	96	0.00E+00	4.70E	5.43E-02		R02H		1	1	1	4	3	3
	Co55	0.00E+00	4.68E+04	0.00E+00	1.25E+06	1.21E+01	8.00E-00	2.00E-01	0	0	55	27	0.00E+00	1.90E-03	2.61E-05		R07A		2	2	2	4	3	3
	Co56	0.00E+00	6.39E+02	0.00E+00	3.00E+04	1.53E+00	0.00E+00	2.13E-01	0	0	56	27	0.00E+00	2.60E-02	1.96E+04	isotope is TRUDB	R01		2	2	2	4	3	3
	Co57	0.00E+00	7.29E+00	8.00E-00	8.55E+03	1.26E+01	8.00E-00	7.44E-01	0	0	57	27	0.00E+00	7.50E-03	6.80E-04				1	1	1	4	3	3
	Co58	0.00E+00	1.91E-02	0.00E+00	3.18E+04	4.43E-01	9.00E-00	1.94E-01	0	0	58	27	0.00E+00	7.10E-03	7.18E-04				1	1	1	4	3	3

Set	Isotope	FGE (g isotope/g Pu238)	Decay Heat (W/g)	Alpha specific Activity (Ci/g)	Specific Activity (Ci/g)	Pu238 Eq. Ci (Ci/g) (MAR)	PECI (Ci/g)	Half Life (Yrs)	TRU Nuclide	PECI TRU Nuclide	Atomic Weight	Atomic Number	Alpha Ratio	Dose (rem/uCi)	Dose Weighting Factor, WF	Comments	Version	Dose Comment	Specific Activity (Ci/g)	FGE (g/g)	Decay Heat (W/g)	Dose (rem/uCi)	Alpha Ratio	Half-Life (yrs)
	Cu60	3.00E+00	1.76E+01	0.00E+00	1.14E+03	3.35E-01	0.00E-00	5.27E-00	0	0	60	27	0.00E+00	1.50E-01	3.40E-03				1	1	1	4	3	3
	Cr48	3.00E+00	7.93E+03	0.00E-00	3.01E+04	4.22E+00	0.00E-00	2.46E-03	0	0	48	24	0.00E-00	7.10E-04	7.18E+05		R02A		2	2	2	4	3	3
	Cr51	0.00E+00	1.95E-01	0.00E-00	9.24E+04	4.71E-02	0.00E+00	7.58E-02	0	0	51	24	0.00E-00	2.60E-04	1.96E+06				1	1	1	4	3	3
	Cs134	0.00E+00	1.33E+01	0.00E-00	1.31E+03	1.21E-01	0.00E+00	2.06E+00	0	0	134	55	0.00E+00	4.70E-02	1.09E+04				1	1	1	4	3	3
	Cs135	0.00E+00	3.82E-07	0.00E-00	1.15E-03	1.01E-01	0.00E-00	3.00E+06	0	0	135	55	0.00E+00	4.50E-03	1.13E+05				1	1	1	4	3	3
	Cs136	0.00E+00	9.96E-02	0.00E+00	7.30E+04	1.07E-00	0.00E+00	3.60E-02	0	0	136	55	0.00E+00	7.50E-03	8.30E+04		R02A		2	2	2	4	3	3
	Cs137	0.00E+00	9.74E-02	0.00E+00	8.82E+01	5.32E-03	0.00E+00	3.00E-01	0	0	137	55	0.00E+00	3.20E-02	1.59E+04				1	1	1	4	3	3
	Cu64	0.00E+00	7.21E+03	0.00E-00	5.89E+06	1.75E+00	0.00E+00	1.43E-03	0	0	64	29	0.00E+00	2.30E-04	2.22E+06				1	1	1	4	3	3
	Cu67	0.00E+00	1.21E+03	0.00E+00	7.55E+05	1.63E+00	0.00E+00	7.06E-03	0	0	67	29	0.00E+00	1.10E-03	4.84E+05		R02A		2	2	2	4	3	3
	Dy159	0.00E+00	1.95E+00	0.00E+00	5.69E+03	2.34E-01	0.00E+00	3.95E-01	0	0	159	66	0.00E+00	2.10E-03	2.43E+05		R02A		2	2	2	4	3	3
	Es252	0.00E+00	4.37E+01	8.44E+02	1.11E+03	0.00E+00	0.00E+00	1.29E-00	0	1	252	99	7.60E-01			no alpha per Nuc Navigator, yes per B&F		not in 0071, FGR11	1	1	1	5	3	3
	Es253	0.00E+00	9.91E+02	2.52E+04	2.52E+04	1.63E+02	1.63E+02	5.59E-02	0	1	253	99	1.00E+00	3.3	1.55E+02				1	1	1	5	3	3
	Es254	0.00E+00	7.35E+01	1.83E+03	1.83E+03	1.33E+02	1.33E-02	7.55E-01	0	1	254	99	1.00E+00	3.60E+01	1.42E+01				1	1	1	4	3	3
	Es254m	0.00E+00	1.69E-03	1.04E+03	3.14E+05	2.19E+02	2.19E+02	4.44E-03	0	1	254	99	3.30E-01	4.70E-01	1.09E+03				1	1	1	6	3	3
	Eu149	0.00E+00	4.17E+00	0.00E+00	9.41E+03	2.95E-02	0.00E+00	2.55E-01	0	0	149	63	0.00E+00	1.60E-03	3.19E+03		R02A		2	2	2	8	3	3
	Eu150	0.00E+00	5.95E-01	0.00E+00	6.46E+01	1.42E-02	0.00E+00	3.58E-01	0	0	150	63	0.00E+00	2.70E-03	1.89E+03				1	1	1	6	3	3
	Eu152	0.00E+00	1.35E+00	0.00E+00	1.78E+02	7.68E-02	0.00E+00	1.33E-01	0	0	152	63	0.00E+00	2.20E-01	2.32E-03				1	1	1	4	3	3
	Eu154	0.00E+00	2.39E+00	0.00E+00	2.67E+02	1.36E-01	0.00E+00	8.80E+00	0	0	154	63	0.00E+00	2.60E-01	1.96E-03				1	1	1	4	3	3
	Eu155	0.00E+00	3.42E-01	0.00E+00	4.70E+02	3.59E-02	0.00E+00	4.96E+00	0	0	155	63	0.00E+00	3.90E-02	1.31E+04				1	1	1	4	3	3
	Eu156	0.00E+00	5.71E+02	0.00E+00	5.51E+04	1.19E+00	0.00E+00	4.16E-02	0	0	156	63	0.00E+00	1.10E-02	4.64E+04		R02A		2	2	2	4	3	3
	Eu158	0.00E+00	3.09E-05	0.00E+00	2.59E+07	4.24E+00	0.00E+00	8.75E-05	0	0	158	63	0.00E+00	8.40E-05	6.07E+06		R02A		2	2	2	4	3	3
	Fe55	0.00E+00	8.49E-02	0.00E+00	2.44E+03	1.24E-03	0.00E+00	2.73E+00	0	0	55	26	0.00E+00	2.50E-03	1.96E+03				1	1	1	4	3	3
	Fe59	0.00E+00	3.30E+02	0.00E+00	4.92E+04	9.55E-01	0.00E+00	1.22E-01	0	0	59	26	0.00E+00	9.90E-03	5.15E+04				1	1	1	4	3	3
	Fr221	0.00E+00	6.71E+06	1.77E-08	1.77E+08	0.00E+00	0.00E+00	9.32E-06	0	0	221	87	1.00E+00					not in 0071, FGR11	1	1	1	5	3	3
1	Fr223	0.00E+00	1.10E-05	2.32E+03	3.87E+07	4.61E+02	0.00E+00	4.14E-05	0	0	223	87	6.00E-03	6.10E+05	8.36E+04		R02B		1	1	1	4	3	3
	Ga66	0.00E+00	1.02E-05	0.00E+00	5.00E+06	1.67E+01	0.00E+00	1.03E-03	0	0	66	31	0.00E+00	1.70E-03	3.00E+05		R02A		2	2	2	4	3	3
	Ga67	0.00E+00	6.84E+02	0.00E+00	5.98E+05	5.62E-01	0.00E+00	8.93E-03	0	0	67	31	0.00E+00	4.80E-04	1.06E+06		R02A		2	2	2	4	3	3
	Ga68	0.00E+00	4.07E-05	0.00E+00	4.06E+07	9.55E+00	0.00E+00	1.29E-04	0	0	68	31	0.00E+00	1.20E-04	4.25E+06		R02A		2	2	2	4	3	3
	Ga72	0.00E+00	5.88E+04	0.00E+00	3.09E+06	1.03E+01	0.00E+00	1.61E-03	0	0	72	31	0.00E+00	1.70E-03	3.00E+05		R02A		2	2	2	4	3	3
	Gd146	0.00E+00	4.17E-01	0.00E+00	1.85E+04	1.38E+00	0.00E+00	3.32E-01	0	0	146	64	0.00E+00	3.80E-02	1.34E+04		R02A		2	2	2	4	3	3
	Gd148	0.00E+00	6.22E-01	3.24E+01	3.24E+01	2.10E+01	0.00E+00	7.50E+01	0	0	148	64	1.00E+00	3.30E+02	1.55E+00		R02A		2	2	2	4	3	3
	Gd151	0.00E+00	4.17E+00	5.76E-05	7.21E+03	1.12E-01	0.00E+00	3.29E-01	0	0	151	64	8.00E-09	7.90E-03	6.46E+04		R02A		2	2	2	4	3	3
	Gd152	0.00E+00	2.77E-13	0.00E+00	2.18E-11	1.03E-11	0.00E+00	1.08E+14	0	0	152	64	0.00E+00	2.40E+02	2.13E+00				1	1	1	4	3	3
	Gd153	0.00E+00	2.96E+00	0.00E+00	3.53E+03	1.45E+01	0.00E+00	6.61E+01	0	0	153	64	0.00E+00	2.10E-02	2.43E+04				1	1	1	4	3	3
	Ge68	0.00E+00	3.80E-01	0.00E+00	7.09E+03	6.31E-01	0.00E+00	7.41E-01	0	0	68	32	0.00E+00	4.90E-02	1.04E+04				2	2	2	4	3	3
	Ge69	0.00E+00	7.27E-03	0.00E+00	1.16E+06	1.41E+00	0.00E+00	4.45E-03	0	0	69	32	0.00E+00	6.10E-04	8.23E+05		R02A		2	2	2	4	3	3
	Ge71	0.00E+00	8.47E+00	0.00E+00	1.65E+05	3.84E-02	0.00E+00	3.05E-02	0	0	71	32	0.00E+00	1.20E-04	4.25E+06		R02A		2	2	2	4	3	3
1	H3	0.00E+00	3.28E-01	0.00E+00	9.76E+03	1.21E-03	0.00E+00	1.23E+01	0	0	3	1	0.00E+00	0.30E-05	8.10E+06		R02B	vapor form	1	1	1	4	3	3
	Hf172	0.00E+00	1.37E+00	0.00E+00	1.12E+03	5.95E-01	0.00E+00	1.87E+00	0	0	172	72	0.00E+00	2.70E-01	1.89E+03		R02A		2	2	2	4	3	3
	Hf175	0.00E+00	2.63E+01	0.00E+00	1.07E+04	1.03E+01	0.00E+00	1.92E-01	0	0	175	72	0.00E+00	4.90E-03	1.04E+05		R02A		2	2	2	4	3	3
	Hf178m	0.00E+00	1.02E+00	0.00E+00	6.48E+01	2.54E-01	0.00E+00	3.10E+01	0	0	178	72	0.00E+00	2.80E+00	2.55E+02	Hf178 is stable	R02A		2	2	2	4	3	3
1	Hf178n	0.00E+00	9.89E-07	0.00E+00	1.45E+10	0.00E+00	0.00E+00	1.27E+07	0	0	178	72	0.00E+00			Hf178 is stable	R02B	not in 0071, FGR11	5	5	5	5	3	3
	Hf181	0.00E+00	7.650E+01	0.00E+00	1.70E+04	4.34E-01	0.00E+00	1.16E-01	0	0	181	72	0.00E+00	1.30E-02	3.92E+04				3	1	2	4	3	3
	Hg194	0.00E+00	2.03E-04	0.00E+00	3.54E+00	8.33E-04	0.00E+00	5.20E+02	0	0	194	80	0.00E+00	1.20E-01	4.25E+03		R02A	soluble	2	2	2	5	3	3
	Hg203	0.00E+00	2.76GE+01	0.00E+00	1.34GE+04	1.76E+01	0.00E+00	1.28E-01	0	0	203	80	0.00E+00	6.50E-03	7.85E+04				3	2	2	4	3	3
1	Ho163	0.00E+00	0.00E+00	0.00E+00	6.60E-01	0.00E+00	0.00E+00	3.30E+01	0	0	163	67	0.00E+00				R02B	not in 0071, FGR11	3	2	5	5	3	3
	Ho166	0.00E+00	3.01GE+03	0.00E+00	7.04E+05	3.87E+00	0.00E+00	3.06E-03	0	0	166	67	0.00E+00	2.80E-03	1.82E+05				2	2	2	4	3	3
2	Ho166m	0.00E+00	1.99E-02	0.00E+00	1.80E+00	2.34E-03	0.00E+00	1.20E+03	0	0	166	67	0.00E+00	7.20E-01	7.04E+02	Transpec v3	R02B		1	1	1	4	3	3
	I125	0.00E+00	6.38E-00	0.00E+00	1.76E+04	8.28E-01	0.00E+00	1.65E-01	0	0	125	53	0.00E+00	2.40E-02	2.15E+04				1	1	1	4	3	3
	I126	0.00E+00	2.89E-02	0.00E+00	7.96E+04	6.71E+00	0.00E+00	3.57E-02	0	0	126	53	0.00E+00	4.30E-02	1.19E+04		R02A		2	2	2	4	3	3
	I129	0.00E+00	9.34E-08	0.00E+00	1.79E+04	6.32E-08	0.00E+00	1.57E+07	0	0	129	53	0.00E+00	1.10E-01	2.83E+03				1	1	1	4	3	3
	I131	0.00E+00	4.23E+02	0.00E+00	1.25E+05	7.14E+00	0.00E+00	7.20E-02	0	0	131	53	0.00E+00	3.20E-02	1.99E+04				1	1	1	4	3	3
	I133	0.00E+00	6.83E-03	0.00E+00	1.13E+06	1.20E+01	0.00E+00	2.37E-03	0	0	133	53	0.00E+00	5.40E-03	9.44E+04		R02A		2	2	2	4	3	3
	In111	0.00E+00	1.09E+03	0.00E+00	4.19E+05	6.33E+01	0.00E+00	7.69E-03	0	0	111	49	0.00E+00	7.70E-04	6.62E+05		R02A		2	2	2	4	3	3
	In113m	0.00E+00	3.88E-04	0.00E+00	1.67E+07	1.12E+00	0.00E+00	1.89E-04	0	0	113	49	0.00E+00	3.40E-05	1.50E+07		R02A		2	2	2	4	3	3
2	In114	0.00E+00	6.32E+06	0.00E+00	1.38E+09	0.00E+00	0.00E+00	2.26E-06	0	0	114	49	0.00E+00			Transpec v3	R02B	not in 0071, FGR11	1	1	1	5	3	3
2	In114m	0.00E+00	3.23E+01	0.00E+00	2.31E+04	3.53E+00	0.00E+00	1.36E-01	0	0	114	49	0.00E+00	7.80E-02	6.54E+03	Transpec v3	R02B		1	1	1	4	3	3
2	In115m	0.00E+00	1.20E+04	0.00E+00	6.34E+06	1.49E+00	0.00E+00	5.12E-04	0	0	115	49	0.00E+00	1.20E-04	4.25E+06	Transpec v3	R02B		1	1	1	4	3	3
	Ir192	0.00E+00	5.63GE+01	0.00E+00	9.31E+03	4.15E+01	0.00E+00	2.02E-01	0	0	192	77	0.00E+00	2.30E-02	2.32E+04				3	2	2	4	3	3
	Ir194	0.00E+00	4.50E+03	0.00E+00	8.44E+05	4.47E+00	0.00E+00	2.19E-03	0	0	194	77	0.00E+00	2.70E-03	1.89E+05		R02A		2	2	2	4	3	3
	K40	0.00E+00	2.27GE-08	0.00E+00	5.65GE-06	1.31E-10	0.00E+00	1.28E+09	0	0	40	19	0.00E+00	1.20E-02	4.25E+04				2	1	2	4	3	3
	K43	0.00E+00	2.48E+04	0.00E+00	3.27E+06	3.59E+00	0.00E+00	2.55E-03	0	0	43	19	0.00E+00	5.60E-04	9.11E+05		R02A		2	2	2	4	3	3
	Kr85	0.00E+00	5.94E-01	0.00E+00	3.97E+02	0.00E+00	0.00E+00	1.07E+01	0	0	85	36	0.00E+00					not in 0071, FGR11	1	1	1	5	3	3
	La140	0.00E+00	9.40E+03	0.00E+00	5.56E+05	4.80E+00	0.00E+00	4.59E-03	0	0	140	57	0.00E+00	4.40E-03	1.16E+05		R02A		2	2	2	4	3	3
	Lu171	0.00E+00	4.30E-02	0.00E+00	9.27E+04	4.73E-01	0.00E+00	2.26E-02	0	0	171	71	0.00E+00	2.60E-03	1.96E+05		R02A		2	2	2	4	3	3
	Lu172	0.00E+00	1.35E+03	0.00E+00	1.13E+05	9.77E-01	0.00E+00	1.83E-02	0	0	172	71	0.00E+00	4.40E-03	1.16E+05		R02A		2	2	2	4	3	3
1	Lu172m	0.00E+00	6.95E+04	0.00E+00	2.90E+08	0.00E+00	0.00E+00	7.04E-06	0	0	172	71	0.00E+00				R02B	not in 0071, FGR11	3	2	5	5	3	3
	Lu173	0.00E+00	1.49E+00	0.00E+00	1.31E+03	5.62E-02	0.00E+00	1.37E+00	0	0	173	71	0.00E+00	1.90E-02	2.63E+04		R02A		2	2	2	4	3	3
	Lu174	0.00E+00	6.19E-01	0.00E+00	6.31E+03	1.90E-02	0.00E+00	3.31E+00	0	0	174	71	0.00E+00	3.20E-02	1.59E+04		R02A		2	2	2	4	3	3
	Lu176	0.00E+00	2.29E-04	0.00E+00	4.90E+06	6.05E+03	0.00E+00	3.59E+10	0	0	176	71	0.00E+00	6.30E-01	8.10E+02		R02A		2	2	2	4	3	3
	Lu177	0.00E+00	1.19E-02	0.00E+00	1.10E+05	4.96E-01	0.00E+00	1.84E-02	0	0	177	71	0.00E+00	2.10E-03	2.22E+05		R02A		2	2	2	4	3	3
	Mn52	0.00E+00	9.41GE+03	0.00E+00	4.49E+05	4.93E+00	0.00E+00	1.53E-02	0	0	52	25	0.00E+00	5.60E-03	9.11E+04				3	2	2	4	3	3
	Mn52m	0.00E+00	3.60E-06	0.00E+00	1.71E+02	1.15E+01	0.00E+00	4.01E-05	0	0	52	25	0.00E+00	5.50E-05	9.27E+06		R02A		2	2	2	4	3	3
	Mn54	0.00E+00	3.88E-01	0.00E+00	7.82E+03	9.81E+02	0.00E+00	8.55E-01	0	0	54	25	0.00E+00	6.40E-03	7.97E+04				1	1	1	4	3	3
	Mn56	0.00E+00	3.29E+05	0.00E+00	2.47E+07	1.40E+01	0.00E+00	2.94E-04	0	0	56	25	0.00E+00	3.30E-04	1.55E+06	isotope in TRUDB	R01		3	2	2	4	3	3
	Mo93	0.00E+00	1.04E-04	0.00E+00	1.10E+00	6.04E-05	0.00E+00	3.50E+03	0	0	93	42	0.00E+00	2.80E-02	1.82E+04		R02A		2	2	2	4	3	3
	Mo99	0.00E+00	1.54GE+01	0.00E+00	4.60GE+05	3.39E+00	0.00E+00	7.52E-03	0	0	99	42	0.00E+00	3.60E-03	1.42E+05				3	2	2	4	3	3
	Na22	0.00E+00	8.94E-01	0.00E+00	6.32E+03	9.91E+02	0.00E+00	2.60E+00	0	0	22	11	0.00E+00	8.90E-03	6.38E+04				1	1	1	4	3	3
	Na24	0.00E+00	2.47GE-05	0.00E+00	8.90TE-06	1.66E+01	0.00E+00	1.67E-03	0	0	24	11	0.00E+00	9.50E-04	5.37E+05				3	2	2	4	3	3
	Nb91	0.00E+00	5.43E-04	0.00E+00	5.80E+00	2.39E-05	0.00E+00	6.80E+02	0	0	91	41	0.00E+00	2.10E-03	2.43E+05		R02A		3	2	5	4	3	3
1	Nb91m	0.00E+00	1.92E-01	0.00E+00	2.30E+04	0.00E+00	0.00E+00	1.70E-01	0	0	91	41	0.00E+00				R02B	not in 0071, FGR11	3	2	5	5	3	3
1	Nb92	0.00E+00	9.69E-07	0.00E+00	1.03E+04	0.00E+00	0.00E+00	3.60E+07	0	0	92	41	0.00E+00				R02B	not in 0071, FGR11	3	2	5	5	3	3
1	Nb92m	0.00E+00	3.07E-02	0.00E+00	1.40E+05	0.00E+00	0.00E+00	2.78E-02	0	0	92	41	0.00E+00				R02B	not in 0071, FGR11	3	2	5	5	3	3
1	Nb93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+20	0	0	93	41	0.00E+00			stable isotope (not half-life to 1E20 yr)	R02B	not in 0071, FGR11	3	5	5	5	3	3
2	Nb93m	0.00E+00	5.01E-02	0.00E+00	2.83E+02	1.55E-02	0.00E+00	1.16E+01	0	0	93	41	0.00E+00	2.80E-02	1.82E+04	Transpec v3	R02B		1	1	1	4	3	3
2	Nb94	0.00E+00	1.91E-05	0.00E+00	1.07E-01	1.21E-04	0.00E+00	2.03E+04	0	0	94	41	0.00E+00	3.30E-01	1.55E+03	Transpec v3	R02B		1	1	1	4	3	3
	Nb95	0.00E+00	1.87E-02	0.00E+00	3.91E+04	3.45E-01	0.00E+00	9.57E-02	0	0	95	41	0.00E+00	4.50E-03	1.13E+05				1	1	1	4	3	3
	Nb95m	0.00E+00	6.11E-02	0.00E+00	3.31E+05	1.64E+00	0.00E+00	9.88E-03	0	0	95	41	0.00E+00	2.30E-03	2.32E+05				1	1	1	4	3	3
1	Nd144	0.00E+00	1.18E-14	1.18E-12	1.18E-12	0.00E+00	0.00E+00	2.10E+15	0	0	144	60	1.00E+00				R02B	not in 0071, FGR11	3	5	5	5	3	3
1	Nd147	0.00E+00	1.97E-02	0.00E+00	8.09E-04	9.83E-01	0.00E+00	3.01E+02	0	0	147	60	0.00E+00	6.20E-05	8.33E+04		R02B		2	2	2	4	3	3
1	Ni56	0.00E+00	3.93E-03	0.00E+00	3.82E+05	2.85E+00	0.00E+00	1.67E-02	0	0	56	28	0.00E+00	3.80E-03	1.34E+05		R02B	isotopic	2	2	2	4	3	3

Nuclear Data Constants

Version R02B, 10/23/2009

Set	Isotope	FGE (g isotope/g Pu239)	Decay Heat (W/g)	Alpha specific Activity (Ci/g)	Specific Activity (Ci/g)	Pu239 Eq. Cl (Ci/g) (MAR)	PECI (Ci/g)	Half Life (Yrs)	TRU Nuclide	PECI TRU Nuclide	Atomic Weight	Atomic Number	Alpha Ratio	Dose (rem/uCi)	Dose Weighting Factor, WF	Comments	Version	Dose Comment	Specific Activity (Ci/g)	FGE (g/g)	Decay Heat (W/g)	Dose (rem/uCi)	Alpha Ratio	Half-Life (yrs)
	Ni61	0.00E+00	1.87E-04	0.00E+00	1.51E+06	3.08E+00	0.00E+00	4.12E-05	0	0	57	28	0.00E+00	1.70E-03	1.00E-05		R02A	Inorganic	2	1	1	1	4	3	3
	Ni59	0.00E+00	3.22E-06	0.00E+00	8.08E-02	2.06E-07	0.00E+00	7.50E+04	0	0	59	28	0.00E+00	1.30E-03	3.92E-05			Inorganic	1	1	1	1	4	3	3
	Ni63	0.00E+00	6.05E-03	0.00E+00	5.98E+01	3.52E-04	0.00E+00	1.00E+02	0	0	63	28	0.00E+00	3.00E-03	1.70E-05			Inorganic	1	1	1	1	4	3	3
1	Ni65	0.00E+00	1.34E-05	0.00E+00	1.91E+07	7.88E-00	0.00E+00	2.83E-04	0	0	65	28	0.00E+00	2.10E-04	2.43E-06		R02B	Inorganic	2	2	2	1	4	3	3
	Np233	0.00E+00	1.47E-01	1.96E-02	1.40E+03	1.04E-02	1.04E-02	1.09E+00	0	1	235	93	1.48E-05	3.80E-03	1.34E-05		R02A		2	5	2	1	4	3	3
	Np237	1.50E-02	2.09E-03	7.13E-04	7.13E-04	6.85E-04	6.85E-04	2.14E+06	1	1	237	93	1.00E+00	4.90E+02	1.04E+00				1	1	1	1	4	3	3
	Np238	0.00E+00	1.49E-03	0.00E+00	2.59E+05	1.57E-01	1.57E-01	5.80E-03	0	1	238	93	0.00E+00	3.10E-02	1.65E-04				1	1	1	1	4	3	3
	Np239	0.00E+00	5.87E-02	0.00E+00	2.12E+03	1.00E-00	1.00E-00	6.45E-03	0	1	239	93	0.00E+00	3.20E-03	2.32E-05				1	1	1	1	4	3	3
1	Np240	0.00E+00	8.52E+04	0.00E+00	1.27E+07	1.57E+00	1.57E+00	3.18E-04	0	1	240	93	0.00E+00	9.30E+05	8.10E-06		R02B		1	1	1	1	4	3	3
	Np240m	0.00E+00	9.98E+05	0.00E+00	1.08E+08	0.00E+00	0.00E+00	1.37E-05	0	1	240	93	0.00E+00					not in 0071, FGR11	1	1	1	1	5	3	3
	Np242	0.00E+00	5.77E+05	0.00E+00	1.41E+03	1.74E+00	1.74E+00	1.05E-03	0	1	242	93	0.00E+00	6.30E-06	8.10E-07		R02A		3	5	3	4	3	3	3
	Os185	0.00E+00	3.30E+01	0.00E+00	7.54E+03	1.48E-01	0.00E+00	2.56E-01	0	0	185	76	0.00E+00	1.00E-02	5.10E-04		R02A		2	2	2	4	3	3	3
	Os194	0.00E+00	6.26E-02	0.00E+00	3.07E-02	4.01E-01	0.00E+00	6.00E+00	0	0	194	76	0.00E+00	6.70E-01	7.61E-02		R02A		2	3	2	4	3	3	3
	P32	0.00E+00	1.19E+03	0.00E+00	2.89E+05	7.37E-00	0.00E+00	3.91E-02	0	0	32	15	0.00E+00	1.30E-02	3.92E-04				1	1	1	1	4	3	3
2	P33	0.00E+00	2.33E+02	0.00E+00	1.58E+05	5.89E-01	0.00E+00	6.94E-02	0	0	33	15	0.00E+00	1.90E-03	7.84E-05	Trampec v3	R02B		1	1	1	1	4	3	3
	Pa231	0.00E+00	1.46E-03	4.78E-02	4.78E-02	1.22E-01	0.00E+00	3.28E-04	0	0	231	91	1.00E+00	1.30E+03	3.92E-01				1	1	1	1	4	3	3
	Pa233	0.00E+00	4.90E-01	0.00E+00	2.03E+04	1.51E-01	0.00E+00	7.39E-02	0	0	233	91	0.00E+00	8.60E-03	5.93E-04				1	1	1	1	4	3	3
	Pa234	0.00E+00	2.40E+04	0.00E+00	2.00E+06	2.90E+00	0.00E+00	7.64E-04	0	0	234	91	0.00E+00	7.40E-04	6.89E-05				1	1	1	1	4	3	3
	Pa234m	0.00E+00	3.40E-06	0.00E+00	6.87E+08	0.00E+00	0.00E+00	2.22E-06	0	0	234	91	0.00E+00					not in 0071, FGR11	1	1	1	1	5	3	3
1	Pb202	0.00E+00	1.73E-06	0.00E+00	3.37E-02	6.54E-06	0.00E+00	5.30E+04	0	0	202	82	0.00E+00	4.90E-02	3.15E-03		R02B		2	2	1	4	3	3	3
1	Pb203	0.00E+00	1.81E+07	0.00E+00	2.97E+05	3.02E-01	0.00E+00	5.94E-03	0	0	203	82	0.00E+00	5.20E-04	9.81E-05		R02B		2	2	1	1	3	3	3
	Pb209	0.00E+00	5.32E+03	0.00E+00	4.54E+06	1.01E-01	0.00E+00	3.71E-04	0	0	209	82	0.00E+00	9.00E-05	5.67E-06				1	1	1	1	4	3	3
	Pb210	0.00E+00	1.96E-02	1.70E-06	7.72E+01	1.97E-00	0.00E+00	2.23E+01	0	0	210	82	2.20E-08	1.30E+01	1.92E+01				1	1	1	1	4	3	3
	Pb211	0.00E+00	7.61E+04	0.00E+00	2.47E+07	3.87E-02	0.00E+00	6.86E-05	0	0	211	82	0.00E+00	8.00E-03	6.38E-04				1	1	1	1	4	3	3
	Pb212	0.00E+00	2.44E+03	0.00E+00	1.39E+06	4.36E+02	0.00E+00	1.21E-03	0	0	212	82	0.00E+00	1.60E-01	3.19E-03				1	1	1	1	4	3	3
1	Pb214	0.00E+00	1.49E+05	0.00E+00	3.28E+07	4.31E+02	0.00E+00	5.10E-05	0	0	214	82	0.00E+00	6.70E-01	7.61E-04		R02B		1	1	1	1	4	3	3
	Pd107	0.00E+00	2.83E-08	0.00E+00	5.14E-04	1.31E-08	0.00E+00	6.50E+06	0	0	107	46	0.00E+00	1.30E-02	3.92E-04				1	1	1	1	4	3	3
	Pm143	0.00E+00	6.61E+00	0.00E+00	3.45E+03	5.61E-02	0.00E+00	7.26E-01	0	0	143	61	0.00E+00	1.30E-03	6.14E-04		R02A		2	2	2	4	3	3	3
	Pm144	0.00E+00	2.15E+01	0.00E+00	2.30E+03	2.14E-01	0.00E+00	9.94E-01	0	0	144	61	0.00E+00	6.40E-02	3.16E-04		R02A		2	2	2	4	3	3	3
	Pm145	0.00E+00	3.72E-02	3.87E-07	1.39E-02	7.34E-03	0.00E+00	1.77E-01	0	0	145	61	2.80E-09	2.70E-02	1.89E-04				2	2	2	4	3	3	3
	Pm146	0.00E+00	2.22E+00	0.00E+00	4.43E-02	9.35E-02	0.00E+00	5.53E+00	0	0	146	61	0.00E+00	1.10E-01	4.64E-03				1	1	1	1	4	3	3
	Pm147	0.00E+00	3.44E-01	0.00E+00	9.38E-02	6.25E-02	0.00E+00	2.62E+00	0	0	147	61	0.00E+00	3.40E-02	1.50E-04				1	1	1	1	4	3	3
2	Pm148	0.00E+00	1.26E-03	0.00E+00	1.66E+05	3.22E+00	0.00E+00	1.47E-02	0	0	148	m1	0.00E+00	1.90E-02	5.10E-04	Trampec v3	R02B		1	1	1	1	4	3	3
2	Pm148m	0.00E+00	2.73E+02	0.00E+00	2.14E+04	7.13E-01	0.00E+00	1.13E-01	0	0	148	m1	0.00E+00	1.70E-02	3.00E-04	Trampec v3	R02B		1	1	1	4	3	3	3
	Pm149	0.00E+00	1.58E-02	0.00E+00	3.96E+05	2.18E+00	0.00E+00	6.06E-03	0	0	149	61	0.00E+00	2.80E-03	1.82E-05		R02A		2	2	2	4	3	3	3
	Pm151	0.00E+00	2.72E-03	0.00E+00	7.31E+05	2.29E+00	0.00E+00	3.24E-01	0	0	151	61	0.00E+00	1.60E-03	3.19E-05		R02A		2	2	2	4	3	3	3
1	Po208	0.00E+00	1.80E+01	5.93E+02	5.93E+02	0.00E+00	0.00E+00	2.90E+00	0	0	208	84	1.00E+00				R02B	not in 0071, FGR11	3	3	3	3	3	3	3
	Po209	0.00E+00	4.94E+00	1.61E-01	1.61E+01	0.00E+00	0.00E+00	1.02E+02	0	0	209	84	9.97E-01					not in 0071, FGR11	1	1	1	1	5	3	3
	Po210	0.00E+00	1.45E+03	4.54E+03	4.54E+03	7.21E+01	0.00E+00	3.79E-01	0	0	210	84	1.00E+00	8.1	6.30E+01				1	1	1	1	4	3	3
	Po211	0.00E+00	4.58E+09	1.04E+11	1.04E+11	0.00E+00	0.00E+00	1.64E-08	0	0	211	84	1.00E+00					not in 0071, FGR11	1	1	1	1	5	3	3
	Po212	0.00E+00	9.24E+15	1.77E+17	1.77E+17	0.00E+00	0.00E+00	9.44E-09	0	0	212	84	1.00E+00					not in 0071, FGR11	1	1	1	1	5	3	3
	Po213	0.00E+00	6.26E+14	1.26E+16	1.26E+16	0.00E+00	0.00E+00	1.33E-13	0	0	213	84	1.00E+00					not in 0071, FGR11	1	1	1	1	5	3	3
	Po214	0.00E+00	1.46E+13	3.21E+14	3.21E+14	0.00E+00	0.00E+00	5.19E-12	0	0	214	84	1.00E+00					not in 0071, FGR11	1	1	1	1	5	3	3
	Po215	0.00E+00	1.79E+12	2.95E+13	2.95E+13	0.00E+00	0.00E+00	5.64E-11	0	0	215	84	1.00E+00					not in 0071, FGR11	1	1	1	1	5	3	3
	Po216	0.00E+00	1.40E+10	3.48E+11	3.48E+11	0.00E+00	0.00E+00	4.75E-09	0	0	216	84	1.00E+00					not in 0071, FGR11	1	1	1	1	5	3	3
	Po218	0.00E+00	9.90E-06	2.78E-08	2.78E+08	0.00E+00	0.00E+00	5.91E-06	0	0	218	84	1.00E+00					not in 0071, FGR11	1	1	1	1	5	3	3
2	Pr143	0.00E+00	1.20E+02	0.00E+00	6.73E+04	9.63E-01	0.00E+00	3.72E-02	0	0	143	59	0.00E+00	7.10E-03	6.99E-04	Trampec v3	R02B		1	1	1	4	3	3	3
1	Pr144	0.00E+00	5.54E+05	0.00E+00	7.56E+07	6.23E+00	0.00E+00	3.29E-05	0	0	144	59	0.00E+00	1.20E-05	1.21E+07		R02B		1	1	1	1	5	3	3
	Pr144m	0.00E+00	6.22E-04	0.00E+00	3.81E-08	0.00E+00	0.00E+00	1.37E-03	0	0	144	59	0.00E+00					not in 0071, FGR11	1	1	1	1	5	3	1
	Pt188	0.00E+00	1.14E+02	1.77E-02	6.81E-04	4.14E-01	0.00E+00	2.79E-02	0	0	188	78	2.60E-07	3.10E-03	1.65E-05		R02A		2	2	2	4	3	3	3
	Pt193	0.00E+00	4.61E-04	0.00E+00	3.70E-01	1.52E-05	0.00E+00	5.00E+01	0	0	193	78	0.00E+00	2.10E-04	2.43E-06		R02A		3	5	3	4	3	3	3
1	Pu233	0.00E+00	1.27E-05	4.63E+04	3.86E+07	0.00E+00	0.00E+00	3.97E-03	0	1	233	94	1.20E-03				R02B	not in 0071, FGR11	3	5	3	5	3	3	3
	Pu234	0.00E+00	4.11E-03	9.11E-04	1.52E+06	8.04E+01	8.04E+01	1.00E-03	0	1	234	94	6.00E-02	3.70E-02	1.89E+04		R02A		3	5	2	4	3	3	3
	Pu236	0.00E+00	1.87E-01	5.37E-02	5.37E+02	1.61E+02	1.68E+02	2.85E+00	0	1	236	94	1.00E+00	1.60E+02	3.19E+00				1	1	1	4	3	3	3
	Pu238	1.13E-01	5.75E-01	1.73E-01	1.73E+01	1.56E-01	1.56E+01	8.77E-01	1	1	238	94	1.00E+00	4.60E-02	1.11E+00				1	1	1	4	3	3	3
	Pu239	1.00E+00	1.95E-03	6.29E-02	6.29E+02	6.29E-02	6.39E-01	2.41E+04	1	1	239	94	1.00E+00	5.10E+02	1.00E+00				1	1	1	4	3	3	3
	Pu240	2.25E-02	7.16E-03	2.30E-01	2.30E+01	2.30E-01	7.30E-01	6.56E+03	1	1	240	94	1.00E+00	5.10E+02	1.00E+00				1	1	1	4	3	3	3
	Pu241	2.25E+00	3.31E-03	2.51E-03	1.04E+02	2.04E+00	2.04E+00	1.44E-01	0	1	241	94	2.41E-05	1.00E+01	5.10E+01				1	1	1	4	3	3	3
	Pu242	7.50E-01	7.17E-04	3.97E-03	3.97E-03	3.74E-01	3.74E-01	3.76E+05	1	1	242	94	1.00E+00	4.80E+02	1.06E+00				1	1	1	4	3	3	3
	Pu243	0.00E+00	5.38E-03	0.00E+00	2.60E+06	7.65E-01	7.65E-01	5.63E-04	0	1	243	94	0.00E+00	1.50E-04	3.40E-06				1	1	1	4	3	3	3
	Pu244	0.00E+00	5.22E-07	1.79E-05	1.79E-05	1.68E-05	1.68E-05	8.26E-07	1	1	244	94	9.99E-01	4.80E+02	1.06E+00				1	1	1	4	3	3	3
	Ra223	0.00E+00	1.83E+01	5.11E+04	5.11E+04	9.61E+01	0.00E+00	5.11E-02	0	0	223	88	1.00E+00	7.5	6.80E-01				1	1	1	3	3	3	3
	Ra224	0.00E+00	5.37E+01	1.59E+05	1.59E+05	9.04E+02	0.00E+00	1.00E+00	0	0	224	88	1.00E+00	2.9	1.76E-02				1	1	1	4	3	3	3
	Ra225	0.00E+00	2.78E-01	0.00E+00	3.92E+04	5.76E-02	0.00E+00	4.05E-02	0	0	225	88	0.00E+00	7.5	6.80E-01				1	1	1	4	3	3	3
	Ra226	0.00E+00	2.88E-02	1.00E+00	1.00E+00	1.55E-02	0.00E+00	1.60E+03	0	0	226	88	1.00E+00	7.9	6.46E-01				3	1	1	4	3	3	3
	Ra228	0.00E+00	2.76E-01	0.00E+00	2.76E+02	2.27E-00	0.00E+00	5.75E+00	0	0	228	88	0.00E+00	4.2	1.21E-02				1	1	1	4	3	3	3
1	Rb82	0.00E+00	2.65E+07	0.00E+00	1.79E+09	0.00E+00	0.00E+00	2.42E-06	0	0	82	37	0.00E+00				R02B	not in 0071, FGR11	2	2	2	5	3	3	3
	Rb83	0.00E+00	5.61E+01	0.00E+00	1.83E+04	1.73E-01	0.00E+00	2.34E-01	0	0	83	37	0.00E+00	4.90E-03	1.04E+05		R02A		2	2	2	4	3	3	3
	Rb84	0.00E+00	1.00E+02	0.00E+00	4.73E+04	6.03E-01	0.00E+00	9.00E-02	0	0	84	37	0.00E+00	6.50E-03	7.85E-04		R02A		2	2	2	4	3	3	3
	Rb86	0.00E+00	3.71E+02	0.00E+00	8.22E+04	1.06E+00	0.00E+00	5.11E-02	0	0	86	37	0.00E+00	6.60E-03	7.73E-04				1	1	1	4	3	3	3
2	Rn87	0.00E+00	7.32E-11	0.00E+00	8.75E-05	5.66E-13	0.00E+00	4.80E-10	0	0	87	37	0.00E+00	3.30E+03	1.55E+05	Trampec v3	R02B		1	1	1	4	3	3	3
1	Ru103	0.00E+00	1.54E+01	0.00E+00	1.02E+04	0.00E+00	0.00E+00	1.92E-01	0	0	103	45	0.00E+00				R02B	not in 0071, FGR11	3	2	5	5	3	3	3
	Ru104	0.00E+00	1.05E+02	0.00E+00	1.87E+04	1.32E-01	0.00E+00	1.04E-01	0	0	104	75	0.00E+00	3.60E-03	1.42E-05		R02A		3	2	2	4	3	3	3
	Re184m	0.00E+00	1.35E+01	0.00E+00	4.30E+03	1.01E-01	0.00E+00	4.52E-01	0	0	184	75	0.00E+00	1.20E-02	4.35E-04		R02A		3	2	2	4	3	3	3
	Re188	0.00E+00	4.88E+03	0.00E+00	9.82E+05	3.46E+00	0.00E+00	1.94E-03	0	0	188	75	0.00E+00	1.80E-03	2.83E-05		R02A		2	2	2	4	3	3	3
	Rh101	0.00E+00	1.91E+00	0.00E+00	1.07E+03	6.73E-02	0.00E+00	3.30E+00	0	0	101	45	0.00E+00	3.20E-02	1.59E-04		R02A		3	2	2	4	3	3	3
1	Rh101m	0.00E+00	5.77E+03	0.00E+00	2.98E+05	3.91E-01	0.00E+00	1.19E-03	0	0	101	45	0.00E+00	6.70E-04	7.61E-05		R02B		2	2	2	4	3	3	3
	Rh102	0.00E+00	1.55E+01	0.00E+00	1.21E-03	2.06E-01	0.00E+00	2.90E+00	0	0	102	45	0.00E+00	8.70E-02	5.86E-03		R02A		2	2	2	4	3	3	3
	Rh102m	0.00E+00	2.40E+01	0.00E+00	6.18E+03	5.09E-01	0.00E+00	5.67E-01	0	0	102	45	0.00E+00	4.20E-02	1.21E-04		R02A		2	2	2	4	3	3	3
	Rh103m	0.00E+00	7.55E+01	0.00E+00	3.25E+07	2.93E-01	0.00E+00	1.07E-04	0	0	103	45	0.00E+00	4.60E-06	1.11E+08				1	1	1	4	3	3	3
	Rh106	0.00E+00	6.74E+07	0.00E+00	5.56E+09	0.00E+00	0.00E+00	9.44E-07	0	0	106	45	0.00E+00					not in 0071, FGR11	1	1	1	4	3	3	3
1	Sb126m	0.00E+00	2.35E+02	0.00E+00	1.36E+07	5.35E+00	0.00E+00	2.43E-04	0	0	126	51	0.00E+00	2.70E-04	2.35E+06	Added isomer, decay heat from sum of average energies from	R02B		3	5	5	4	3	3	3
1	Rh97	0.00E+00	2.78E+05	0.00E+00	6.31E+07	0.00E+00	0.00E+00	5.84E-05	0	0	97	45	0.00E+00				R02B	not in 0071, FGR11	3	2	5	5	3	3	3
	Ru99	0.00E+00	3.16E+02	0.00E+00	8.20E+04	4.18E-01	0.00E+00	4.38E-02	0	0	99	45	0.00E+00	2.60E-03	1.96E-05		R02A		2	2	2	4	3	3	3
	Ra219	0.00E+00	5.30E+08	1.30E-10	1.30E+10	0.00E+00	0.00E+00	1.25E-07	0	0	219	86	1.00E+00					not in 0071, FGR11	1	1	1	1	5	3	3
	Ra220	0.00E+00	3.44E-07	9.22E+04	9.22E+01	0.00E+00	0.00E+00	1.76E-06	0	0	220	86	1.00E+00					not in 0071, FGR11	1	1	1	1	5	3	3
	Ra222	0.00E+00	5.01E-03	1.34E-05	1.34E+05	0.00E+00	0.00E+00	1.05E-02	0	0	222	86	1.00E+00					not in 0071, FGR11	1	1	1	1	5	3	3
	Ru103	0.00E+00	1.05E+02	0.00E+00	3.26E+04	4.95E-01	0.00E+00	1.07E-01	0	0	103	44	0.00E+00	7.30E-03	6.34E-04				1	1	1	4	3	3	3
	Ru106	0.00E+00	2.09E+01	0.00E+00	3.31E+01	2.91E+00	0.00E+00	1.02E+00	0	0	106	44	0.00E+00	4.40E-01	1.16E-03				1	1	1	4	3	3	3
2	S35	0.00E+00	1.73E-01	0.00E+00	4.26E+04	1.92E-01	0.00E+00	2.40E-01	0	0	35	16	0.00E+00	3.30E-01	2.22E-05	Trampec v3	R02B		1	1	1	4	3	3	3
2	Sb134	0.00E+00	2.32E+02	0.00E+00	1.75E+04	7.21E-01	0.00E+00	1.65E-01	0	0	134	51	0.00E+00	2.10E-02	2.43E-04	Trampec v3	R02B		1	1	1	4	3	3	3

Nuclear Data Constants

Version R02B, 10/23/2009

Sel	Isotope	FGE (g isotope/g Pu239)	Decay Heat (W/g)	Alpha specific Activity (Ci/g)	Specific Activity (Ci/g)	PU239 Eq. Ci (Ci/g) (MAR)	PECI (Ci/g)	Half Life (Yrs)	TRU Nuclide	PECI TRU Nuclide	Atomic Weight	Atomic Number	Alpha Ratio	Dose (rem/uCi)	Dose Weighting Factor, Wf	Comments	Version	Dose Comment	Specific Activity (Ci/g)	FGE (g/g)	Decay Heat (W/g)	Dose (rem/uCi)	Alpha Ratio	Half-Life (yrs)
	Sb125	0.00E+00	3.27E+00	0.00E+00	1.84E-01	2.90E-02	0.00E+00	2.73E+00	0	0	125	51	0.00E+00	9.80E-03	5.20E-04				1	1	1	4	3	3
	Sb126	0.00E+00	1.54E+03	0.00E+00	8.36E+04	1.64E+00	0.00E+00	3.39E-02	0	0	126	51	0.00E+00	1.04E-02	5.10E-06				1	1	1	4	3	3
	Sb126m	0.00E+00	1.01E+06	0.00E+00	7.85E+07	4.31E+00	0.00E+00	3.61E-05	0	0	126	51	0.00E+00	2.60E-05	1.32E-07				1	1	1	4	3	3
	Sc43	0.00E+00	1.57E+05	0.00E+00	1.87E+07	8.08E+00	0.00E+00	6.44E-04	0	0	43	21	0.00E+00	2.20E-04	2.32E-06		R02A		2	2	2	1	3	3
	Sc44	0.00E+00	2.94E+03	0.00E+00	1.81E+07	1.49E+01	0.00E+00	6.44E-04	0	0	44	21	0.00E+00	4.20E-04	1.21E-06		R01A		2	2	2	4	3	3
	Sc44m	0.00E+00	2.25E+03	0.00E+00	1.22E+06	1.59E+01	0.00E+00	6.69E-03	0	0	44	21	0.00E+00	7.10E-03	7.11E-04		R02A		2	2	3	4	3	3
2	Sc46	0.00E+00	4.25E+02	0.00E+00	3.38E+04	1.33E+00	0.00E+00	2.30E-01	0	0	46	21	0.00E+00	2.00E-02	2.55E-04	Transpec v3	R01B		1	1	1	4	3	3
	Sc47	0.00E+00	1.34E+03	0.00E+00	8.32E+05	2.77E+00	0.00E+00	9.15E-03	0	0	47	21	0.00E+00	1.70E-03	3.00E-05		R02A		2	2	2	4	3	3
	Sc48	0.00E+00	3.17E+06	0.00E+00	1.49E+06	1.05E+01	0.00E+00	4.99E-03	0	0	48	21	0.00E+00	3.60E-03	1.42E-05		R02A		2	2	2	4	3	3
1	Se72	0.00E+00	7.19E-01	0.00E+00	2.16E+05	0.00E+00	0.00E+00	2.30E-02	0	0	72	34	0.00E+00				R02B	not in 0071, FGR11	3	2	5	5	3	3
	Se73	0.00E+00	5.22E+04	0.00E+00	6.00E+06	4.47E+00	0.00E+00	8.16E-04	0	0	73	34	0.00E+00	3.80E-04	1.34E+06		R02A		2	2	2	4	3	3
	Se75	0.00E+00	3.52OE-01	0.00E+00	1.45E+04	2.34E-01	0.00E+00	3.28E-01	0	0	75	34	0.00E+00	8.20E-03	6.22E-04				3	2	2	4	3	3
	Se79	0.00E+00	3.18E+05	0.00E+00	6.97E-02	1.22E+06	0.00E+00	6.50E+04	0	0	79	34	0.00E+00	1.90E-03	5.73E-04				1	1	1	4	3	3
	Sr32	0.00E+00	4.10E-02	0.00E+00	1.07E+02	2.10E-01	0.00E+00	1.04E-02	0	0	32	14	0.00E+00	1.00E+00	5.10E-02		R02A		2	2	2	4	3	3
	Sm145	0.00E+00	1.53E+00	0.00E+00	2.63E+03	5.19E-02	0.00E+00	9.31E-01	0	0	145	62	0.00E+00	1.00E-02	5.10E-04		R02A		2	2	2	4	3	3
	Sm146	0.00E+00	3.47E-07	0.00E+00	2.38E-05	3.64E-06	0.00E+00	1.03E+08	0	0	146	62	0.00E+00	7.80E-01	6.54E-00				1	1	1	4	3	3
	Sm147	0.00E+00	3.04E-10	0.00E+00	2.30E-08	3.20E-09	0.00E+00	1.06E+11	0	0	147	62	0.00E+00	7.10E+01	7.11E+00				1	1	1	4	3	3
	Sm151	0.00E+00	3.10E-03	0.00E+00	2.66E+01	1.51E-03	0.00E+00	9.00E-01	0	0	151	62	0.00E+00	2.90E-02	1.76E-04				1	1	1	4	3	3
	Sm153	0.00E+00	5.70E+02	0.00E+00	4.39E+05	1.46E+00	0.00E+00	5.33E-03	0	0	153	62	0.00E+00	1.70E-03	3.00E-05		R02A		2	2	2	4	3	3
	Sn113	0.00E+00	1.74OE+00	0.00E+00	1.00E+04	1.75E-01	0.00E+00	3.15E-01	0	0	113	50	0.00E+00	8.90E-03	5.71E-04				2	2	2	4	3	3
	Sn119m	0.00E+00	3.33E+00	0.00E+00	4.48E-01	4.66E-02	0.00E+00	8.02E-01	0	0	119	50	0.00E+00	5.30E-03	9.62E+04				1	1	1	4	3	3
	Sn121	0.00E+00	6.47E+02	0.00E+00	9.57E+05	8.12E-01	0.00E+00	3.09E-03	0	0	121	50	0.00E+00	4.70E-04	1.09E+06		R02A		2	2	2	4	3	3
	Sn121m	0.00E+00	1.44E+02	0.00E+00	5.91E+01	1.03E-03	0.00E+00	5.50E+01	0	0	121	50	0.00E+00	8.90E-03	5.71E-04				1	1	1	4	3	3
	Sn123	0.00E+00	2.53E+01	0.00E+00	8.22E+03	4.84E-01	0.00E+00	3.54E-01	0	0	123	50	0.00E+00	3.00E-02	1.70E+04				1	1	1	4	3	3
	Sn126	0.00E+00	3.06E-05	0.00E+00	2.84E-02	4.79E-06	0.00E+00	1.00E+05	0	0	126	50	0.00E+00	8.60E-02	5.93E-03				1	1	1	6	3	3
1	Sr32	0.00E+00	4.91E+00	0.00E+00	6.23E+04	7.50E+00	0.00E+00	7.00E-02	0	0	82	38	0.00E+00	6.14E-02	8.30E-03		R02B		2	2	2	6	3	3
	Sr85	0.00E+00	7.31E+01	0.00E+00	2.37E+04	1.49E-01	0.00E+00	1.78E-01	0	0	85	38	0.00E+00	3.20E-03	1.39E+05		R02A		2	2	2	4	3	3
	Sr89	0.00E+00	1.01E-02	0.00E+00	2.94E+04	2.13E-00	0.00E+00	1.15E-01	0	0	89	38	0.00E+00	3.70E-02	1.35E+04				1	1	1	4	3	3
	Sr90	0.00E+00	1.60E-01	0.00E+00	1.38E-02	3.52E-01	0.00E+00	2.85E+01	0	0	90	38	0.00E+00	1.3	3.93E-02				1	1	1	4	3	3
	Te179	0.00E+00	2.68E-01	0.00E+00	1.12E-03	1.27E-02	0.00E+00	1.79E-03	0	0	179	73	0.00E+00	5.80E-03	8.79E+04		R02A		2	2	2	4	3	3
	Te182	0.00E+00	5.60E-01	0.00E+00	6.31E-03	4.58E-01	0.00E+00	3.15E-01	0	0	182	73	0.00E+00	3.70E-02	1.31E-04				1	1	1	4	3	3
	Te183	0.00E+00	5.30E-02	0.00E+00	1.40E-05	1.32E+00	0.00E+00	1.40E-02	0	0	183	73	0.00E+00	4.80E-03	1.06E-05		R02A		2	2	2	4	3	3
	Tb157	0.00E+00	7.81E-04	0.00E+00	1.50E+01	2.65E-04	0.00E+00	1.50E+02	0	0	157	65	0.00E+00	9.00E-03	5.67E-04		R02A		2	2	2	4	3	3
2	Tb160	0.00E+00	9.24E+01	0.00E+00	1.13E+04	4.87E-01	0.00E+00	1.99E-01	0	0	160	65	0.00E+00	2.20E-02	2.32E-04	Transpec v3	R01B		1	1	1	4	3	3
	Tb161	0.00E+00	1.62E+02	0.00E+00	1.17E+05	7.14E-01	0.00E+00	1.89E-02	0	0	161	65	0.00E+00	3.10E-03	1.65E-03		R02A		2	2	2	4	3	3
1	Tc95	0.00E+00	7.86E-03	0.00E+00	1.65E+06	8.09E-01	0.00E+00	2.28E-03	0	0	95	43	0.00E+00	2.50E-04	2.04E+06		R01B		2	2	2	4	3	3
1	Tc95m	0.00E+00	9.21E+01	0.00E+00	2.25E+04	1.31E-01	0.00E+00	1.67E-01	0	0	95	43	0.00E+00	3.30E-03	1.31E-03		R02B		2	2	2	6	3	3
	Tc97	0.00E+00	1.42E-07	0.00E+00	1.42E-03	2.48E-09	0.00E+00	2.60E+06	0	0	97	43	0.00E+00	8.90E-04	5.73E-05		R02A		2	2	2	4	3	3
	Tc99	0.00E+00	8.49E-06	0.00E+00	1.70E-02	2.50E-07	0.00E+00	2.13E+05	0	0	99	43	0.00E+00	7.50E-03	6.30E-04				1	1	1	4	3	3
1	Tc99m	0.00E+00	4.31E+03	0.00E+00	5.27E+06	3.31E-01	0.00E+00	6.85E-04	0	0	99	43	0.00E+00	3.30E-05	1.59E+07		R02B		1	1	1	4	3	3
	Te123	0.00E+00	6.50E-17	0.00E+00	4.35E-13	1.05E-16	0.00E+00	1.30E+13	0	0	123	52	0.00E+00	1.10E-02	6.64E-04				1	1	1	4	3	3
	Te123m	0.00E+00	1.31E+01	0.00E+00	8.87E+01	1.65E-01	0.00E+00	3.33E-01	0	0	123	52	0.00E+00	9.50E-03	5.37E-04				1	1	1	4	3	3
	Te125m	0.00E+00	1.57E-01	0.00E+00	1.80E+04	2.34E-01	0.00E+00	1.59E-01	0	0	125	52	0.00E+00	6.70E-03	7.61E-04				1	1	1	4	3	3
	Te127	0.00E+00	3.59E-03	0.00E+00	2.64E+06	1.50E+00	0.00E+00	1.07E-03	0	0	127	52	0.00E+00	2.90E-04	1.76E+06				1	1	1	4	3	3
	Te127m	0.00E+00	5.21E-06	0.00E+00	9.43E+03	3.51E-01	0.00E+00	2.93E-01	0	0	127	52	0.00E+00	1.90E-02	2.44E+04				1	1	1	4	3	3
2	Te129	0.00E+00	7.48E+04	0.00E+00	2.08E-07	3.16E+00	0.00E+00	1.42E+03	0	0	129	52	0.00E+00	7.30E-05	6.42E+06	Transpec v3	R02B		1	1	1	4	3	3
2	Te129m	0.00E+00	5.42E+01	0.00E+00	3.01E+04	1.18E+00	0.00E+00	9.20E-02	0	0	129	52	0.00E+00	2.00E-02	2.55E+04	Transpec v3	R02B		1	1	1	4	3	3
	Te132	0.00E+00	6.05E+02	0.00E+00	3.04E+05	4.59E+00	0.00E+00	8.93E-03	0	0	132	52	0.00E+00	7.70E-03	6.42E+04		R02A		2	2	2	4	3	3
	Th227	0.00E+00	1.11E-03	3.07E+04	3.07E+04	9.63E-02	0.00E+00	5.12E-02	0	0	227	90	1.00E+00	1.60E+01	3.19E-01				1	1	1	4	3	3
	Th228	0.00E+00	2.71E+01	8.29E+02	8.29E+02	5.04E+02	0.00E+00	1.91E+00	0	0	228	90	1.00E+00	3.10E-02	1.45E-00				1	1	1	4	3	3
	Th229	0.00E+00	6.17E-03	2.13E-01	2.13E-01	8.35E-01	0.00E+00	7.34E+03	0	0	229	90	1.00E+00	2.00E+01	2.55E-01				1	1	1	4	3	3
	Th230	0.00E+00	5.75E-04	2.04E-02	2.04E-02	1.28E-02	0.00E+00	7.54E+04	0	0	230	90	1.00E+00	3.20E+01	1.59E-00				1	1	1	4	3	3
	Th231	0.00E+00	6.43E+02	0.00E+00	5.32E+05	8.45E-01	0.00E+00	2.91E-03	0	0	231	90	0.00E+00	8.10E-04	6.30E+05				1	1	1	4	3	3
	Th232	0.00E+00	2.68E-09	1.11E-07	1.11E-07	3.48E-07	0.00E+00	1.41E+10	0	0	232	90	1.00E+00	1.60E+03	3.19E-01				1	1	1	4	3	3
	Th234	0.00E+00	3.45E+00	0.00E+00	2.32E+04	1.50E+00	0.00E+00	6.60E-02	0	0	234	90	0.00E+00	3.30E-02	1.55E-04				1	1	1	4	3	3
	Tl44	0.00E+00	1.51OE+01	0.00E+00	1.72OE+02	3.00E-01	0.00E+00	4.73E-01	0	0	44	22	0.00E+00	8.90E-01	5.71E-02				2	2	2	4	3	3
	Tl202	0.00E+00	1.54E-02	0.00E+00	5.29E+04	1.02E-01	0.00E+00	3.35E-02	0	0	202	81	0.00E+00	9.80E-04	5.20E-05		R02A		2	2	2	4	3	3
	Tl204	0.00E+00	6.57E-01	0.00E+00	4.64E-02	3.09E-03	0.00E+00	3.78E+00	0	0	204	81	0.00E+00	2.30E-03	2.22E-05		R02A		2	2	2	4	3	3
	Tl207	0.00E+00	1.53E-05	0.00E+00	1.90E+01	0.00E+00	0.00E+00	9.07E-06	0	0	207	81	0.00E+00					not in 0071, FGR11	1	1	1	5	3	3
	Tl208	0.00E+00	6.93E+06	0.00E+00	2.95E-08	0.00E+00	0.00E+00	5.80E-06	0	0	208	81	0.00E+00					not in 0071, FGR11	1	1	1	5	3	3
	Tl209	0.00E+00	1.53E-06	0.00E+00	4.16E+06	0.00E+00	0.00E+00	4.18E-06	0	0	209	81	0.00E+00					not in 0071, FGR11	1	1	1	5	3	3
	Tm168	0.00E+00	8.39E+01	0.00E+00	8.44E+03	0.00E+00	0.00E+00	2.53E-01	0	0	168	69	0.00E+00					not in 0071, FGR11	1	1	1	5	3	3
	Tm170	0.00E+00	1.190E-01	0.00E+00	3.97E-03	3.69E-01	0.00E+00	3.52E-01	0	0	170	69	8.00E+00	2.30E-02	2.22E-04				2	2	2	4	3	3
	Tm171	0.00E+00	1.69OE-01	0.00E+00	1.08E-03	1.84E-01	0.00E+00	1.92E+00	0	0	171	69	0.00E+00	8.60E-03	5.93E-04	isotope in TRUDB	R01		3	2	2	4	3	3
	U232	0.00E+00	6.93E-01	2.16E+01	2.16E+01	2.84E-01	0.00E+00	6.89E+01	0	0	232	92	1.00E+00	6.70E-02	7.61E-01				1	1	1	4	3	3
	U233	9.00E-01	2.84E-04	9.76E-03	9.76E-03	2.49E-03	2.49E-03	1.59E+05	0	1	233	92	1.00E+00	1.30E+02	3.92E+00				1	1	1	4	3	3
	U234	0.00E+00	1.82E-04	6.32E-03	6.32E-03	1.61E-03	0.00E+00	2.45E+05	0	0	234	92	1.00E+00	1.30E+02	3.91E+00				1	1	1	4	3	3
	U235	6.43E-01	6.04E-08	2.19E-06	2.19E-06	5.15E-07	0.00E+00	7.04E+08	0	0	235	92	1.00E+00	1.20E+02	4.25E+00				1	1	1	4	3	3
	U236	0.00E+00	1.78E-04	6.34E-03	6.34E-03	1.54E-03	0.00E+00	2.34E+07	0	0	236	92	1.00E+00	1.20E+02	4.25E+00				1	1	1	4	3	3
	U237	0.00E+00	1.64E-02	0.00E+00	8.25E+04	5.34E-01	0.00E+00	1.85E-02	0	0	237	92	0.00E+00	3.30E-03	1.55E+03				1	1	1	4	3	3
	U238	0.00E+00	8.62E-09	1.40E-07	1.40E-07	8.00E-08	0.00E+00	6.47E+09	0	0	238	92	1.00E+00	1.20E+02	4.25E+00				1	1	1	4	3	3
	U239	0.00E+00	1.69E-05	0.00E+00	3.33E+07	2.17E+00	0.00E+00	4.46E-03	0	0	239	92	0.00E+00	3.30E-05	1.55E+07				1	1	1	4	3	3
	U240	0.00E+00	1.17E-03	0.00E+00	9.26E+05	3.81E+00	0.00E+00	1.61E-03	0	0	240	92	0.00E+00	2.10E-03	2.43E-05				1	1	1	4	3	3
	V48	0.00E+00	3.09OE-01	0.00E+00	1.79OE+03	2.67E-00	0.00E+00	4.37E-02	0	0	48	23	0.00E+00	8.00E-03	6.38E+04				3	2	2	4	3	3
2	V49	0.00E+00	2.06E-01	0.00E+00	8.08E+03	4.44E-03	0.00E+00	9.04E-01	0	0	49	23	0.00E+00	2.80E-04	1.87E+06	Transpec v3	R02B		1	1	1	4	3	3
1	V52	0.00E+00	1.44E+07	0.00E+00	9.63E+08	0.00E+00	0.00E+00	7.13E-06	0	0	52	23	0.00E+00				R02B	not in 0071, FGR11	3	2	5	5	3	3
	W181	0.00E+00	1.81E+00	0.00E+00	5.93E+03	1.75E-03	0.00E+00	3.32E-01	0	0	181	74	0.00E+00	1.50E-04	3.40E+06		R02A		2	2	2	4	3	3
	W185	0.00E+00	7.08E+00	0.00E+00	9.40E+03	3.38E-02	0.00E+00	2.06E-01	0	0	185	74	0.00E+00	7.50E-04	6.60E-05		R02A		2	2	2	4	3	3
	W187	0.00E+00	3.29E+01	0.00E+00	7.01E-05	7.28E-01	0.00E+00	2.73E-03	0	0	187	74	0.00E+00	5.10E-04	9.62E+05		R02A		2	2	2	4	3	3
	W188	0.00E+00	6.01E-00	0.00E+00	1.00E+04	8.05E-02	0.00E+00	1.90E-01	0	0	188	74	0.00E+00	4.10E-03	1.24E-05		R02A		2	2	2	4	3	3
	Xe133	0.00E+00	2.81OE-02	0.00E+00	1.87E-05	0.00E+00	0.00E+00	1.44E-02	0	0	133	54	0.00E+00					not in 0071, FGR11	3	2	2	5	3	3
1	Y87m	0.00E+00	6.26E-03	0.00E+00	2.79E+06	0.00E+00	0.00E+00	1.47E-03	0	0	87	39	0.00E+00				R02B	not in 0071, FGR11	3	2	5	5	3	3
	Y88	0.00E+00	2.24E+01	0.00E+00	1.41E+04	5.81E-01	0.00E+00	2.92E-01	0	0	88	39	0.00E+00	2.10E-02	2.43E+04				1	1	1	4	3	3
	Y90	0.00E+00	3.01E+03	0.00E+00	5.44E+05	8.75E-00	0.00E+00	7.31E-03	0	0	90	39	0.00E+00	8.20E-03	6.22E+04				1	1	1	4	3	3
	Y90m	0.00E+00	4.40E-04	0.00E+00	1.09E+07	9.40E+00	0.00E+00	3.64E-04	0	0	90	39	0.00E+00	4.40E-04	1.16E+06				1	1	1	4	3	3
	Y91	0.00E+00	8.83E-01	0.00E+00	2.45E+04	2.11E+00	0.00E+00	1.60E-01	0	0	91	39	0.00E+00	4.40E-02	1.16E+04				1	1	1	4	3	3
	Yb169	0.00E+00	6.22E-01	0.00E+00	2.41E+04	3.31E-01	0.00E+00	8.77E-02	0	0	169	70	0.00E+00	7.00E-03	7.29E-04		R02A		2	2	2	4	3	3
	Zn65	0.00E+00	2.89E+01	0.00E+00	8.24E+03	2.91E-01	0.00E+00	6.68E-01	0	0	65	30	0.00E+00	1.60E-02	2.83E-04				1	1	1	4	3	3
	Zn69m	0.00E+00	8.60E-03	0.00E+00	3.18E+06	4.47E+00	0.00E+00	1.57E-03	0	0	69	30	0.00E+00	6.90E-04	7.39E-05		R02B		2	2	2	4	3	3
	Zr72	0.00E+00	1.41E+03	0.00E+00	9.36E+05	7.71E+00	0.00E+00	5.31E-03	0	0	72	30	0.00E+00	4.20E-03	1.21E-05		R02A		2	2	2	4	3	3
	Zr88	0.00E+00	4.44E+01	0.00E+00	1.80E+04	7.76E-01	0.00E+00	2.28E-01	0	0	88	40	0.00E+00	2.10E-02	3.32E-04				1	1	1	4	3	3

Nuclear Data Constants

Version R02B, 10/23/2009

Set	Isotope	FGE (g isotope/g PU239)	Decay Heat (W/g)	Alpha specific Activity (Ci/g)	Specific Activity (Ci/g)	PU239 Eq. CI (Ci/g) (NAR)	PECI (Ci/g)	Half Life (Yrs)	TRU Nuclide	PECI TRU Nuclide	Atomic Weight	Atomic Number	Alpha Ratio	Dose (rem/uCi)	Dose Weighting Factor, WF	Comments	Version	Dose Comment	Specific Activity (Ci/g)	FGE (g/g)	Decay Heat (W/g)	Dose (rem/uCi)	Alpha Ratio	Half-Life (yrs)
1	Zr90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	[illegible]	0	0	90	40	0.00E+00			Trumpet v3; stable isotope (set half-life to 1E20 yr)	R02B	not in 0071, FOR11	1	1	1	5	5	5
	Zr90m	0.00E+00	2.13E-09	0.00E+00	1.55E+11	0.00E+00	0.00E+00	2.56E-08	0	0	90	40	0.00E+00					not in 0071, FOR11	1	1	1	5	5	3
	Zr91	0.00E+00	7.29E-07	0.00E+00	1.51E-03	1.57E-06	0.00E+00	1.53E-06	0	0	91	40	0.00E+00	3.20E-01	1.59E-03				1	1	1	4	3	3
	Zr95	0.00E+00	1.10E-02	0.00E+00	2.17E+04	8.08E-01	0.00E+00	1.71E-01	0	0	95	40	0.00E+00	1.90E-02	3.68E-04				1	1	1	4	3	3

References

1	CH-TRAMPAC, Carlsbad Field Office, Rev. 2, , May 2005, Carlsbad, NM
2	TD-SWO-006, R.2, Rad_Code Table Input Data, Los Alamos National Laboratory, FWO-Solid Waste Management, Los Alamos, NM 87545
3	Browne, E and R Firestone, Table of Radioactive Isotopes, J Wiley & Sons, New York, 1986
4	DOE/EH-0071, Internal Dose Conversion Factors for Calculation of Dose to the Public, US DOE, Washington, DC, July 1988
5	Requirements and Design for the NucData Repository, NucDataRmm.xls
6	Federal Guidance Report No. 11, US EPA, Washington, DC, 1988
7	Shuman, R., Radioactive Waste Inventory for Los Alamos National Laboratory Technical Area 54, Area G, 2008 (draft of an LAUR report)

Appendix B

Material Type Activity Fraction

Material Type Activity Fractions

MT	Isotope	Activity Fraction
AM44	AM241	1
AM45	AM243	1
BK47	BK249	1
CF48	CF252	1
CM46	CM246	1
D38	U234	0.294
D38	U235	0.013
D38	U238	0.693
NP82	NP237	1
PU41	Am241	4.536E-02
PU41	Cs137	3.252E-07
PU41	Pu238	5.503E-02
PU41	Pu239	2.905E-04
PU41	Pu240	6.414E-03
PU41	Pu241	8.928E-01
PU41	Pu242	1.173E-04
PU41	Sr90	3.252E-07
PU41	U234	8.262E-06
PU41	U235	8.589E-12
PU42	Am241	4.530E-02
PU42	Cs137	1.916E-06
PU42	Pu238	5.495E-02
PU42	Pu239	2.901E-04
PU42	Pu240	6.405E-03
PU42	Pu241	8.915E-01
PU42	Pu242	1.552E-03
PU42	PU244	0.000E+00
PU42	Sr90	1.916E-06
PU42	U234	8.250E-06
PU42	U235	8.576E-12
PU51	Am241	1.386E-02
PU51	Cs137	2.931E-05
PU51	Pu238	6.909E-03
PU51	Pu239	4.051E-01
PU51	Pu240	4.792E-02
PU51	Pu241	5.261E-01
PU51	Pu242	4.756E-06
PU51	Sr90	2.931E-05
PU51	U234	4.207E-07
PU51	U235	1.458E-08
PU52	Am241	2.398E-02
PU52	Cs137	1.521E-05
PU52	Pu238	5.976E-03
PU52	Pu239	2.038E-01
PU52	Pu240	4.767E-02
PU52	Pu241	7.186E-01
PU52	Pu242	2.743E-06
PU52	Sr90	1.521E-05
PU52	U234	4.367E-07
PU52	U235	7.566E-09
PU53	Am241	2.201E-02
PU53	Cs137	9.310E-06
PU53	Pu238	1.097E-02
PU53	Pu239	1.211E-01
PU53	Pu240	4.109E-02
PU53	Pu241	8.048E-01
PU53	Pu242	5.959E-06
PU53	Sr90	9.310E-06
PU53	U234	9.354E-07

MT	Isotope	Activity Fraction
PU53	U235	4.167E-09
PU54	Am241	2.541E-02
PU54	Cs137	4.606E-06
PU54	Pu238	8.323E-03
PU54	Pu239	5.751E-02
PU54	Pu240	2.766E-02
PU54	Pu241	8.811E-01
PU54	Pu242	9.135E-06
PU54	Sr90	4.606E-06
PU54	U234	6.610E-07
PU54	U235	2.061E-09
PU55	Am241	2.604E-02
PU55	Cs137	3.671E-06
PU55	Pu238	8.654E-03
PU55	Pu239	4.399E-02
PU55	Pu240	2.824E-02
PU55	Pu241	8.931E-01
PU55	Pu242	1.006E-05
PU55	Sr90	3.671E-06
PU55	U234	1.054E-06
PU55	U235	1.643E-09
PU56	Am241	2.548E-02
PU56	Cs137	3.233E-06
PU56	Pu238	7.748E-03
PU56	Pu239	3.782E-02
PU56	Pu240	2.788E-02
PU56	Pu241	9.011E-01
PU56	Pu242	1.035E-05
PU56	Sr90	3.233E-06
PU56	U234	9.281E-07
PU56	U235	1.447E-09
PU57	Am241	2.401E-02
PU57	Cs137	1.523E-06
PU57	Pu238	2.591E-02
PU57	Pu239	1.624E-02
PU57	Pu240	1.647E-02
PU57	Pu241	9.173E-01
PU57	Pu242	2.321E-05
PU57	Sr90	1.523E-06
PU57	U234	2.186E-06
PU57	U235	6.060E-10
PU83	Am241	1.061E-03
PU83	Cs137	3.205E-07
PU83	Pu238	9.934E-01
PU83	Pu239	8.423E-04
PU83	Pu240	4.185E-04
PU83	Pu241	4.163E-03
PU83	Pu242	4.334E-07
PU83	Sr90	3.205E-07
PU83	U234	1.522E-04
PU83	U235	3.188E-11
TH88	TH232	1
U(DEP)	U234	0.294
U(DEP)	U235	0.013
U(DEP)	U238	0.693
U(NAT)	U234	0.505
U(NAT)	U235	0.022
U(NAT)	U238	0.473
U10	U238	1
U11	U234	0.222
U11	U235	0.005

MT	Isotope	Activity Fraction
U11	U238	0.773
U12	U234	0.268
U12	U235	0.010
U12	U238	0.722
U13	U234	0.276
U13	U235	0.012
U13	U238	0.713
U14	U234	0.284
U14	U235	0.012
U14	U238	0.703
U15	U234	0.294
U15	U235	0.013
U15	U238	0.693
U16	U234	0.333
U16	U235	0.017
U16	U238	0.650
U17	U234	0.382
U17	U235	0.021
U17	U238	0.597
U18	U234	0.413
U18	U235	0.024
U18	U238	0.563
U21	U234	0.455
U21	U235	0.027
U21	U238	0.518
U22	U234	0.505
U22	U235	0.031
U22	U236	0.002
U22	U238	0.462
U23	U234	0.570
U23	U235	0.035
U23	U236	0.004
U23	U238	0.391
U24	U234	0.630
U24	U235	0.038
U24	U236	0.006
U24	U238	0.326
U25	U234	0.681
U25	U235	0.041
U25	U236	0.008
U25	U238	0.270
U26	U234	0.717
U26	U235	0.042
U26	U236	0.009
U26	U238	0.233
U27	U234	0.733
U27	U235	0.043
U27	U236	0.009
U27	U238	0.215
U28	U234	0.748
U28	U235	0.043
U28	U236	0.009
U28	U238	0.200
U29	U234	0.768
U29	U235	0.044
U29	U236	0.010
U29	U238	0.179
U30	U234	0.782
U30	U235	0.044
U30	U236	0.010
U30	U238	0.164

MT	Isotope	Activity Fraction
U31	U234	0.801
U31	U235	0.044
U31	U236	0.010
U31	U238	0.145
U32	U234	0.862
U32	U235	0.044
U32	U236	0.010
U32	U238	0.084
U33	U234	0.914
U33	U235	0.041
U33	U236	0.009
U33	U238	0.036
U34	U234	0.940
U34	U235	0.037
U34	U236	0.007
U34	U238	0.015
U35	U234	0.950
U35	U235	0.035
U35	U236	0.006
U35	U238	0.008
U36	U234	0.959
U36	U235	0.033
U36	U236	0.005
U36	U238	0.003
U37	U234	0.964
U37	U235	0.031
U37	U236	0.004
U37	U238	0.000703
U38	U234	0.965
U38	U235	0.030
U38	U236	0.004
U38	U238	0.000281
U39	U234	0.966
U39	U235	0.030
U39	U236	0.004
U39	U238	0.0000717
U70	U233	1
U81	U234	0.505
U81	U235	0.022
U81	U238	0.473
MFP	Ce144	1.23E-03
MFP	Cs137	4.72E-01
MFP	Eu154	2.37E-05
MFP	Eu155	1.64E-04
MFP	Kr85	1.88E-01
MFP	Ru106	5.35E-03
MFP	Sb125	1.48E-04
MFP	Sm151	6.93E-06
MFP	Sn121m	2.37E-04
MFP	Sn126	3.90E-05
MFP	Sr90	3.33E-01
MAP	Be7	1.365E-19
MAP	Co57	5.152E-04
MAP	Co60	7.513E-01
MAP	Mn54	2.362E-03
MAP	Na22	2.457E-01
MAP	Zn65	1.871E-04

Appendix C

MaterialType Nuclear Constants

Material Type Data

Number of Material Types 62

Table is protected but not password protected

Primary sources are listed in note 2.

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
Sel	Isotope	FGE (g)	Decay Heat (W/g)	Alpha specific Activity (Ci/g)	Specific Activity (Ci/g)	PU239 Eq. Ci (Ci/g) (MAR)	PECI (Ci/g)	PU240 Eq. SF (g)	1st Moment Neutron Distribution	2nd Moment Neutron Distribution	Fission Rate (Fissions/ g/s)	Pu240 Eff SF (uCi)	Half Life (Yrs)	TRU Nuclide	PECI TRU Nuclide	Atomic Weight	Atomic Number	Alpha Ratio	DOE/EH-0071 Dose (rem/uCi)	Dose Weighting Factor, WF	Comments	Version
	AM44	1.87E-02	1.16E-01	3.47E+00	3.47E+00	3.54E+00	3.54E+00													1.0	MT: Same as Am241 per DOE 5633.5	
	AM45	1.29E-02	6.49E-03	2.02E-01	2.02E-01	2.06E-01	2.06E-01													1.0	MT: Same as Am243 per DOE 5633.5	
	BK47	0.00E+00	3.24E-01	2.41E-02	1.66E+03	4.23E+00	4.23E+00													392.3	MT: Note 3	
	CF48	0.00E+00	4.06E+01	5.27E+02	5.44E+02	1.39E+02	1.39E-02													3.9	MT: Note 3	
	CM46	0.00E+00	1.02E-02	3.11E-01	3.11E-01	3.29E-01	3.29E-01													0.9	MT: Note 3	
	D38	1.90E-03	1.29E-08	4.89E-07	4.89E-07	1.18E-07	0.00E+00													1E15	MT: Note 3	
	NP82	1.50E-02	2.09E-05	7.13E-04	7.13E-04	6.85E-04	6.85E-04													1.0	MT: Note 3	
	PU41	2.88E-01	4.06E-02	1.22E+00	1.13E+01	1.36E+00	1.36E+00													8.3	Enriched in Pu242 between 20 and 60%, used 40% average (DOE 5633.5)	
	PU42	6.24E-02	8.05E-03	2.41E-01	2.22E+00	2.70E-01	2.70E-01													8.2	MT: TRAMPAC and Note 4	
	PU51	9.69E-01	2.21E-03	7.11E-02	1.50E-01	7.26E-02	7.26E-02													2.1	MT: TRAMPAC and Note 4	
	PU52	9.41E-01	2.55E-03	8.12E-02	2.89E-01	8.52E-02	8.52E-02													3.4	MT: TRAMPAC and Note 4	
	PU53	9.18E-01	2.90E-03	9.20E-02	4.71E-01	9.91E-02	9.91E-02													4.8	MT: TRAMPAC and Note 4	
	PU54	8.89E-01	3.60E-03	1.13E-01	9.49E-01	1.29E-01	1.29E-01													7.4	MT: TRAMPAC and Note 4	
	PU55	8.57E-01	4.07E-03	1.27E-01	1.19E+00	1.47E-01	1.47E-01													8.1	MT: TRAMPAC and Note 4	
	PU56	8.41E-01	4.28E-03	1.33E-01	1.35E+00	1.57E-01	1.57E-01													8.6	MT: TRAMPAC and Note 4	
	PU57	7.93E-01	7.66E-03	2.34E-01	2.83E+00	2.79E-01	2.79E-01													10.1	MT: TRAMPAC and Note 4	
	PU83	2.06E-01	3.39E-01	1.02E+01	1.03E+01	9.24E+00	9.24E+00													1.1	MT: TRAMPAC and Note 4	
	TH88	0.00E+00	2.68E-09	1.11E-07	1.11E-07	3.48E-07	0.00E+00													1E15	MT: Note 3	
	U(DEP)	1.90E-03	1.29E-08	4.89E-07	4.89E-07	1.18E-07	0.00E+00													1E15	MT: Note 3	
	U(NAT)	4.61E-03	1.94E-08	7.14E-07	7.14E-07	1.75E-07	0.00E+00													1E15	MT: Note 3	
	U10	0.00E+00	8.62E-09	3.40E-07	3.40E-07	8.00E-08	0.00E+00													1E15	MT: Note 3	
	U11	6.72E-04	1.15E-08	4.39E-07	4.39E-07	1.05E-07	0.00E+00													1E15	MT: Note 3	
	U12	1.43E-03	1.24E-08	4.70E-07	4.70E-07	1.13E-07	0.00E+00													1E15	MT: Note 3	
	U13	1.61E-03	1.25E-08	4.76E-07	4.76E-07	1.15E-07	0.00E+00													1E15	MT: Note 3	
	U14	1.73E-03	1.27E-08	4.82E-07	4.82E-07	1.16E-07	0.00E+00													1E15	MT: Note 3	
	U15	1.90E-03	1.29E-08	4.89E-07	4.89E-07	1.18E-07	0.00E+00													1E15	MT: Note 3	
	U16	2.60E-03	1.38E-08	5.21E-07	5.21E-07	1.26E-07	0.00E+00													1E15	MT: Note 3	
	U17	3.53E-03	1.51E-08	5.66E-07	5.66E-07	1.38E-07	0.00E+00													1E15	MT: Note 3	
	U18	4.19E-03	1.61E-08	6.00E-07	6.00E-07	1.46E-07	0.00E+00													1E15	MT: Note 3	
	U21	5.16E-03	1.76E-08	6.51E-07	6.51E-07	1.59E-07	0.00E+00													1E15	MT: Note 3	
	U22	6.57E-03	1.98E-08	7.28E-07	7.28E-07	1.78E-07	0.00E+00													1E15	MT: Note 3	
	U23	8.81E-03	2.35E-08	8.58E-07	8.58E-07	2.11E-07	0.00E+00													1E15	MT: Note 3	
	U24	1.15E-02	2.83E-08	1.02E-06	1.02E-06	2.54E-07	0.00E+00													1E15	MT: Note 3	
	U25	1.48E-02	3.42E-08	1.23E-06	1.23E-06	3.06E-07	0.00E+00													1E15	MT: Note 3	
	U26	1.76E-02	3.97E-08	1.42E-06	1.42E-06	3.54E-07	0.00E+00													1E15	MT: Note 3	
	U27	1.92E-02	4.29E-08	1.53E-06	1.53E-06	3.83E-07	0.00E+00													1E15	MT: Note 3	
	U28	2.08E-02	4.61E-08	1.64E-06	1.64E-06	4.11E-07	0.00E+00													1E15	MT: Note 3	
	U29	2.34E-02	5.14E-08	1.83E-06	1.83E-06	4.58E-07	0.00E+00													1E15	MT: Note 3	
	U30	2.56E-02	5.60E-08	1.99E-06	1.99E-06	4.98E-07	0.00E+00													1E15	MT: Note 3	
	U31	2.91E-02	6.32E-08	2.24E-06	2.24E-06	5.62E-07	0.00E+00													1E15	MT: Note 3	
	U32	4.80E-02	1.06E-07	3.74E-06	3.74E-06	9.42E-07	0.00E+00													1E15	MT: Note 3	
	U33	9.62E-02	2.29E-07	8.01E-06	8.01E-06	2.03E-06	0.00E+00													1E15	MT: Note 3	
	U34	1.76E-01	4.60E-07	1.60E-05	1.60E-05	4.07E-06	0.00E+00													1E15	MT: Note 3	
	U35	2.56E-01	7.13E-07	2.48E-05	2.48E-05	6.30E-06	0.00E+00													1E15	MT: Note 3	
	U36	4.01E-01	1.21E-06	4.20E-05	4.20E-05	1.07E-05	0.00E+00													1E15	MT: Note 3	
	U37	5.53E-01	1.76E-06	6.13E-05	6.13E-05	1.56E-05	0.00E+00													1E15	MT: Note 3	
	U38	5.98E-01	1.94E-06	6.74E-05	6.74E-05	1.71E-05	0.00E+00													1E15	MT: Note 3	
	U39	6.24E-01	2.04E-06	7.08E-05	7.08E-05	1.80E-05	0.00E+00													1E15	MT: Note 3	
	U70	9.00E-01	2.84E-04	9.76E-03	9.76E-03	2.50E-03	2.50E-03													3.9	MT: Note 3	
	U72	8.82E-01	2.78E-04	9.56E-03	9.56E-03	2.44E-03	2.44E-03													3.9	Enriched in U233 between 97 and 99 %, used 98% (DOE 5633.5)	
	U81	4.61E-03	1.94E-08	7.14E-07	7.14E-07	1.75E-07	0.00E+00													1E15	MT: Note 3	
	ASBES																					
	CHEM																					
	GAMMA																					
	ORALPH																					
	ORBETA																					
	MAP	0.00E+00	1.84E+01	0.00E+00	1.20E+03	3.33E+01	0.00E+00															R02B
	MFP	0.00E+00	1.24E+01	0.00E+00	1.94E+02	9.47E+02	0.00E+00															R02B
	NONRAD																					
	PCB																					
	TRU																					

Sel	Isotope	FGE (g)	Decay Heat (W/g)	Alpha specific Activity (Ci/g)	Specific Activity (Ci/g)	PU239 Eq. Ci (Ci/g) (MAR)	PECI (Ci/g)	PU240 Eq. SF (g)	1st Moment Neutron Distribution	2nd Moment Neutron Distribution	Fission Rate (Fissions/g/s)	Pu240 Eff SF (uCi)	Half Life (Yrs)	TRU Nuclide	PECI TRU Nuclide	Atomic Weight	Atomic Number	Alpha Ratio	DOE/EH-0071 Dose (rem/uCi)	Dose Weighting Factor, WF	Comments	Version
	UNLD																					

Notes

1 An "m" in the atomic weight indicates a metastable state.

2 Nuclear Data Source Summary

FGE	CH-TRAMPAC, Rev. 2, May 2005; When not available, TD-SWO-008, Rev 2, 9/23/2003, as annotated in Comments field.
Decay Heat (W/g)	CH-TRAMPAC, Rev. 2, May 2005; When not available, TD-SWO-008, Rev 2, 9/23/2003, as annotated in Comments field.
Alpha Specific Activity (Ci/g)	Browns & Firestone, Table of Radioactive Isotopes for ratios (alpha to total) times Total Specific Activity
Total Specific Activity (Ci/g)	CH-TRAMPAC, Rev. 2, May 2005; When not available, Browns and Firestone 1988, as annotated in Comments field
PU239 Eq. Curies (1/WF)	DOE/MPP-02-3122, Rev. 3.0, Apr 25, 2005 and DOE/EH-0071, Jul 88
PU240 Eq. SF	LA-13422-M
Fission Rate (Fissions/g/s)	Browns and Firestone, 1988
Half-lives (yr)	Browns and Firestone, 1986

3 Source of data is from the Oracle TRUP.Isotope_Activity table as of 4/18/2008.

4 CCP-AK-LANL-008, for material type (MT) isotopic breakout

Change Documentation for NucDataR02B.xls

December 11, 2009

1. Objective

This document provides a detailed accounting of the changes made to NucDataR02A[1]. The changes were promulgated to reach agreement between the TRU and LLW/MLLW applications. The changes incorporate several recommendations proposed by the LLW/MLLW group[2].

2. Dose rates, PECi and MAR

In this review, 37 isotopes previously tabulated in NucDataR02A are reviewed for dose rates and the calculation of PECi and MAR. The isotopes in question are tabulated in Table 1. The following paragraphs summarize those changes.

The Federal Guidance Report No. 11[3] has been applied in determining the dose rates when the dose is missing from DOE/EH-0071. FGR#11 provided dose for four additional isotopes: Cm250, Sr82, Tc95, and Tc95m.

The chemical form for H3 was changed from elemental to vapor and the form of the Ni isotopes were changed to consistently reflect the inorganic form (Ni56 and Ni65 only were affected).

There were several isotopes in which the dose is defined in neither DOE/EH-0071 nor FGR11. In those cases, the dose was set to "null" and the PECi and MAR set to zero. The formula for MAR was changed such that when the weighting factor is null, the MAR and PECi are set to zero rather than to null. Most of these isotopes have an atomic number less than 92 and by definition, their PECi values (but not the MAR value) will be zero. There were two isotopes that are PECi isotopes by definition: Es252 and Np240m and PECi and MAR will become zero by the revised definition.

There were several isotopes for which the available copy of DOE/EH-0071 was not always legible. A more legible copy was obtained, the rates reviewed, and the dose rates corrected when appropriate.

Isotope Rh106m was added. The decay heat was calculated for the average particle and photon energies The remaining nuclear constants were obtained from Browne & Firestone (specific activity, half-life, alpha ratio) while FGE was set to zero based on the atomic weight.

The changes are listed in Table 1. The values were adjusted for one of the following reasons:

- The data were available from another source (e.g., FGR#11),
- The data were corrected because a more legible copy of DOE/EH-0071 was available,
- NucDataR02A estimated the dose based on a "like" isotope and these were changed to "null".
- A new isotope was added (Rh106m)
- The chemical form of the isotope used in calculating dose was changed

---

[1] WDP-TWPS2009-0007, Software Quality Assurance Validation of Nuclear Data Constants for the TRU and CHEMLL Oracle Databases, Los Alamos Memorandum, Feb 26, 2009

[2] Rob Shuman, Comparison of Nuclear Constants and Waste Allocation Factors Found in NucDataR02A.xls and the Area G Dataset, June 16, 2009 (unpublished)

[3] EPA-520/1-88-020, Federal Guidance Report No. 11, Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion, US EPA, Sep 1988

Table 1. 37 Isotopes Reviewed for Dose

Isotope	NucDataR02A	NucDataR02B	Reason for Change
Au196	1.20E-02		Value not available, set to null
Ce139	7.60E-03	7.50E-03	Correct value, legible copy
Cm243	3.60E+02	3.50E+02	Correct value, legible copy
Cm250		9398	Use FRG#11
Fr223	8.10E-03	6.10E-03	Correct value, legible copy
H3	4.40E-09	6.30E-05	Changed from elemental to vapor form
Hf178n	2.00E+00		Value not available, set to null
Ho163	2.10E-06		Value not available, set to null
Lu172m	4.40E-03		Value not available, set to null
Nb91m	2.80E-03		Value not available, set to null
Nb92	2.80E-02		Value not available, set to null
Nb92m	2.80E-02		Value not available, set to null
Nb93	2.80E-03		Value not available, set to null
Nd144	6.30E-03		Value not available, set to null
Nd147	6.30E-03	6.20E-03	Correct value, legible copy
Ni56	4.20E-03	3.80E-03	Changed to inorganic form
Ni65	3.00E-04	2.10E-04	Changed to inorganic form
Np240	6.30E-06	6.30E-05	Correct value, legible copy
Pb202	7.90E-04	9.90E-02	Correct value, legible copy
Pb203	7.90E-04	5.30E-04	Correct value, legible copy
Pb214	8.70E-03	6.70E-03	Correct value, legible copy
Po208	2.00E-04		Value not available, set to null
Pr144	3.90E-05	4.20E-05	Correct value, legible copy
Pu233	2.70E-02		Value not available, set to null
Rb82	2.80E-04		Value not available, set to null
Re183	4.00E-04		Value not available, set to null
Rh101m	8.10E-04	6.10E-04	Correct value, legible copy
Rh106m		2.00E-04	New isomer added
Rh97	2.60E-03		Value not available, set to null
Se72	1.30E-04		Value not available, set to null
Sr82	1.40E-03	6.14E-2	Use FGR#11
Tc95	2.40E-03	2.50E-4	Use FRG#11
Tc95m	2.40E-03	3.89E-3	Use FRG#11
Tc99m	3.20E-06	3.20E-05	Correct value, legible copy
V52	2.80E-04		Value not available, set to null
Y87m	1.60E-03		Value not available, set to null
Zn69m	8.90E-04	6.90E-04	Correct value, legible copy

Equations for MAR and PECi calculation were changed as noted in Table 2.

Table 2. Cell Formula Changes

Parameter	NucDataR02A	NucDataR02B
PECi	If WF is null, PECi is null, Else PECi is specific activity times PECi function divided by WF	If WF is null, PECi is 0, Else PECi is specific activity times PECi function divided by WF
MAR	If WF is null, MAR is null, Else MAR is specific activity divided by WF	If WF is null, MAR is 0, Else MAR is specific activity divided by WF

3. Update of CH-TRAMPAC from Version 2 to Version 3[4]

The CH-TRAMPAC changes in version 3 resulted in 26 isotopes being affected, seven of which were new isotopes (Table 7). Changes are highlighted in gray. Dose rates for 5 isotopes (Zr90, Ag108, In114, Ba137, and Ce142) were not available in either DOE/EH-0071 or FGR#11 and the PECi for these isotopes will be reported as zero.

4. Mixed Fission Products (MFP) and Mixed Activation Products (MAP)

An excellent review of the Area G waste at TA54 addresses the mixed fission products (MFP) and mixed activation products (MAP)[5], identifying the isotopic distributions as a function of aging (1, 2, 5, and 10 years). Since material type distributions have not been accepted into Area G since approximately 1987, it is assumed that MFP/MAP waste in Area G is at least 10 years old.

The mass and activity averaged percent distributions are shown in

Table 3 for MFP waste and in Table 4 for MAP waste.

4.1. MFP Waste

In this implementation, fast neutron waste generation was disregarded since the majority of interactions will be with thermal neutrons. It was further assumed that 30% of the waste will be generated by Pu239 fissions (w_{Pu239}) with the remainder coming from U235 fissions (w_{U235}) and the activity fractions (f_j^A) from Pu239 or U235 averaged with these weights. The mass fractions are then calculated as the ratio of the activity fraction to the specific activity (S_j^A). In both the activity and mass fractions, the sum must add to 1. The activity and mass fractions are those that would exist after 10 years, so there is no decay correction needed. The following equations were applied and the results are tabulated in

Table 3.

$$\left\langle f_j^A \right\rangle = w_{Pu239} f_j^{A(Pu239)} + w_{U235} f_j^{A(U235)} \qquad (1)$$

[4] CH-TRAMPAC, Contact-Handled Transuranic Waste Authorized Methods for Payload Control, US Department of Energy Carlsbad Field Office (www.wipp.energy.gov/library/CHsar/Documents), Revision 3, February 2009

[5] Shuman, R., Radioactive Waste Inventory for Los Alamos National Laboratory Technical Area 54, Area G, 2008 (draft of an LAUR report)

$\sum_j \langle f_j^A \rangle = 1$	(2)
$\langle f_j^m \rangle = \frac{\langle f_j^A \rangle}{S_j^A}$	(3)
$\sum_j \langle f_j^m \rangle = 1$	(4)

Table 3. Average MFP Activity and Mass Percentages Aged 10 Years

Isotopes	Mass Weight %	Activity %
Ce144	0.0%	0.1%
Cs137	55.7%	47.2%
Eu154	0.0%	0.0%
Eu155	0.0%	0.0%
Kr85	4.9%	18.8%
Ru106	0.0%	0.5%
Sb125	0.0%	0.0%
Sm151	0.0%	0.0%
Sn121m	0.0%	0.0%
Sn126	14.3%	0.0%
Sr90	25.0%	33.3%

4.2. MAP Waste

The MAP waste distribution was presented at the age of the waste when it was shipped for disposal. Consequently, these mass and activity fractions must be decay corrected 10 years. The following equations apply, where $f_j^m(0)$ is the initial mass fraction, t_j is the half-life of isotope j, and T is the amount of decay correction to be applied. The distribution for MAP is tabulated in Table 4.

$f_j^m = f_j^m(0) e^{-T Ln(2)/t_j}$	(5)
$f_j^A = f_j^m S_j^A$	(6)
$\sum_j f_j^m = 1$	(7)
$\sum_j f_j^A = 1$	(8)

Table 4. MAP Activity Percentages Aged 10 Years

Isotopes	Mass Weight %	Activity %
Be7	0.0%	0.0%
Co57	0.0%	0.1%
Co60	94.4%	75.1%
Mn54	0.0%	0.2%
Na22	5.6%	24.6%

Zn65	0.0%	0.0%

5. Material Type Activity Fractions

The MT activity fractions were presented in Appendix B of the SQA for NucDataR02A. In this version, the data is added as a separate worksheet.

6. Conclusion

A total of 63 isotopes and 2 material types were modified and/or added in this version of NucData and an activity fractions worksheet added. Corrections were made to PECi dose rates and an additional isotope, Rh106m, was added for consistency between the TRU and LLW applications. Tritium was changed to reflect the vapor form and all Ni isotopes were changed to reflect the inorganic form of the chemical. Changes to the CH-TRAMPAC were incorporated. The MFP and MAP material types were changed to reflect the 10 year decay values.

Table 5. Nuclear Constants for MFP. For the isotopes, the nuclear constants are multiplied by the relative mass of the isotope which, when summed, leads to the nuclear constant per unit mass of the material type

MT	ISOTOPE _CD	Activity FRACTION	FGE	Decay Heat	Alpha Specific Activity	Specific Activity	Dose Rate (MAR)	PECi	Comments
MFP	Ce144	1.228E-03	0.00E+00	8.47E-05	0.00E+00	1.27E-01	8.75E-05	0.00E+00	10 yr decay
MFP	Cs137	4.724E-01	0.00E+00	5.43E-02	0.00E+00	4.90E+01	3.08E-03	0.00E+00	10 yr decay
MFP	Eu154	2.374E-05	0.00E+00	2.21E-05	0.00E+00	2.46E-03	1.26E-06	0.00E+00	10 yr decay
MFP	Eu155	1.643E-04	0.00E+00	1.24E-05	0.00E+00	1.71E-02	1.30E-06	0.00E+00	10 yr decay
MFP	Kr85	1.877E-01	0.00E+00	2.91E-02	0.00E+00	1.95E+01	0.00E+00	0.00E+00	10 yr decay
MFP	Ru106	5.348E-03	0.00E+00	3.29E-05	0.00E+00	5.55E-01	4.79E-04	0.00E+00	10 yr decay
MFP	Sb125	1.476E-04	0.00E+00	4.82E-05	0.00E+00	1.53E-02	2.94E-07	0.00E+00	10 yr decay
MFP	Sm151	6.932E-06	0.00E+00	8.39E-08	0.00E+00	7.20E-04	4.09E-08	0.00E+00	10 yr decay
MFP	Sn121m	2.367E-04	0.00E+00	5.99E-06	0.00E+00	2.46E-02	4.29E-07	0.00E+00	10 yr decay
MFP	Sn126	3.902E-05	0.00E+00	4.36E-06	0.00E+00	4.05E-03	6.83E-07	0.00E+00	10 yr decay
MFP	Sr90	3.328E-01	0.00E+00	4.01E-02	0.00E+00	3.45E+01	8.81E-02	0.00E+00	10 yr decay
TOTAL		1.000E+00	0.00E+00	1.24E-01	0.00E+00	1.04E+02	9.17E-02	0.00E+00	

Table 6. Nuclear Constants for MAP. For the isotopes, the nuclear constants are multiplied by the relative mass of the isotope which, when summed, leads to the nuclear constant per unit mass of the material type

MT	ISOTOPE _CD	Activity FRACTION	FGE	Decay Heat	Alpha Specific Activity	Specific Activity	Dose Rate (MAR)	PECi	Comments
MAP	Be7	5.585E-22	0.00E+00	1.95E-22	0.00E+00	6.67E-19	3.53E-25	0.00E+00	10 yr decay
MAP	Co57	8.629E-05	0.00E+00	8.79E-05	0.00E+00	1.03E-01	1.52E-06	0.00E+00	10 yr decay
MAP	Co60	9.438E-01	0.00E+00	1.74E+01	0.00E+00	1.13E+03	3.32E-01	0.00E+00	10 yr decay
MAP	Mn54	4.325E-04	0.00E+00	2.56E-03	0.00E+00	5.17E-01	6.49E-06	0.00E+00	10 yr decay
MAP	Na22	5.567E-02	0.00E+00	9.41E-01	0.00E+00	6.65E+01	1.04E-03	0.00E+00	10 yr decay
MAP	Zn65	3.252E-05	0.00E+00	1.36E-04	0.00E+00	3.89E-02	1.37E-06	0.00E+00	10 yr decay
TOTAL		1.000E+00	0.00E+00	1.84E+01	0.00E+00	1.20E+03	3.33E-01		

Table 7. CH-TRAMPAC Version 3 Changes

Changes in nuclear constants are highlighted

Sel	Isotope	FGE (g Isotope/g Pu239)	Decay Heat (W/g)	Specific Activity (Ci/g)	Half Life (Yrs)	TRU Nuclide	PECI TRU Nuclide	Atomic Weight	Atomic Number	Alpha Ratio	Dose (rem/uCi)	Dose Comment
1	Be10	0.00E+00			1.60E+06	0	0	10	4	0.00E+00	3.50E-01	
1	P33	0.00E+00			6.94E-02	0	0	33	15	0.00E+00	1.90E-03	
1	S35	0.00E+00			2.40E-01	0	0	35	16	0.00E+00	2.30E-03	
1	Ca45	0.00E+00			4.48E-01	0	0	45	20	0.00E+00	6.10E-03	
1	Sc46	0.00E+00			2.30E-01	0	0	46	21	0.00E+00	2.00E-02	
1	V49	0.00E+00			9.04E-01	0	0	49	23	0.00E+00	2.80E-04	
1	[illegible]											
1	Zr90	0.00E+00				0	0	90	40	0.00E+00		not in 0071, FGR11
1	Nb93m	0.00E+00			1.36E+01	0	0	93	41	0.00E+00	2.80E-02	
1	Nb94	0.00E+00			2.03E+04	0	0	94	41	0.00E+00	3.30E-01	
1	[illegible]											not in 0071, FGR11
1	Ag108m	0.00E+00			1.27E+02	0	0	108	47	0.00E+00	2.00E-01	
1	Cd115m	0.00E+00			1.22E-01	0	0	115	48	0.00E+00	6.50E-02	
1	[illegible]											not in 0071, FGR11
1	In114m	0.00E+00			1.36E-01	0	0	114	49	0.00E+00	7.80E-02	
1	In115m	0.00E+00			5.12E-04	0	0	115	49	0.00E+00	1.20E-04	
1	Sb124	0.00E+00			1.65E-01	0	0	124	51	0.00E+00	2.10E-02	
1	[illegible]											
1	Te129m	0.00E+00			9.20E-02	0	0	129	52	0.00E+00	2.00E-02	
1	Ba137	0.00E+00			[illegible]	0	0	137	56	0.00E+00		not in 0071, FGR11
1	[illegible]											not in 0071, FGR11
1	Pr143	0.00E+00			3.72E-02	0	0	143	59	0.00E+00	7.30E-03	
1	[illegible]											
1	[illegible]											
1	Tb160	0.00E+00			1.98E-01	0	0	160	65	0.00E+00	2.20E-02	
1	Ho166m	0.00E+00			1.20E+03	0	0	166	67	0.00E+00	7.20E-01	

References (End of Table)

Specific Activity (Ci/g)	FGE (g/g)	Decay Heat (W/g)	Dose (rem/uCi)	Alpha Ratio	Half-Life (yrs)
1	1	1	4	3	3
1	1	1	4	3	3
1	1	1	4	3	3
1	1	1	4	3	3
1	1	1	4	3	3
1	1	1	4	3	3
1	1	1	4	3	3
1	1	1	5	3	5
1	1	1	4	3	3
1	1	1	4	3	3
1	1	1	5	3	3
1	1	1	4	3	3
1	1	1	4	3	3
1	1	1	5	3	3
1	1	1	4	3	3
1	1	1	4	3	3
1	1	1	4	3	3
1	1	1	4	3	3
1	1	1	5	3	3
1	1	1	5	3	3
1	1	1	4	3	3
1	1	1	4	3	3
1	1	1	4	3	3
1	1	1	4	3	3
1	1	1	4	3	3

References

1. CH-TRAMPAC, Carlsbad Field Office, Rev. 2, , May 2005, Carlsbad, NM
2. TD-SWO-006, R.2, Rad_Code Table Input Data, Los Alamos National Laboratory, FWO-Solid Waste Management, Los Alamos, NM 87545
3. Browne, E and R Firestone, Table of Radioactive Isotopes, J Wiley & Sons, New York, 1986
4. DOE/EH-0071, Internal Dose Conversion Factors for Calculation of Dose to the Public, US DOE, Washington, DC, July 1988
5. Requirements and Design for the NucData Repository, NucDataRmn.xls
6. Federal Guidance Report No. 11, US EPA, Washington, DC, 1988
7. Shuman, R., Radioactive Waste Inventory for Los Alamos National Laboratory Technical Area 54, Area G, 2008 (draft of an LAUR report)

NucDataR02B.xls Test Plan and Test Report

1. Introduction

This plan is designed to test and independently verify the nuclear data added during the implementation of NucDataR02B. This test plan also serves as the test report. Test report evidence is to be included in the appendices.

2. Approach

The changes described in the change document for migrating from version NucDataR02A and NucDataR02B will be quality checked. These changes are identified by the keyword "R02B" in the version column (column W) of the Isotope and MaterialType worksheets. In addition, the MTActivityFractions worksheet was added to document the activity fractions. With the exception of material types MFP and MAP, the activity fractions of all remaining material types were quality checked in NucDataR02A and will not be repeated here. Equations for calculating the MAR and PECi from the dose and weighting factors were modified and this will also be quality checked.

Obtain the following documents for reference:

- DOE/EH-0071 July 1988
- Federal Guidance Report #11
- Browne and Firestone 1986
- CH-TRAMPAC version 3
- Shuman, R., Radioactive Waste Inventory for Los Alamos National Laboratory Technical Area 54, Area G, 2008 (draft of an LAUR report)
- Nuclear Data Constants for the TRU and CHEMLL Databases, Requirements and Design Documentation for NucData
- Change Documentation for NucDataR02B.xls, October 30, 2009

Obtain the following utilities

- NucDataR02B.xls
- Calculator MaterialType_NucDataR02B.xls

NOTE: All response must be "YES" to successfully pass the test.

3. Software Evaluation

3.1. Worksheet Isotope, NucDataR02B.xls

Open the NucDataR02B workbook, save it as NucDataR02B_Test, and then select the "Isotope" worksheet. Select the header row (row 8) and select the filter (Data/Filter/Autofilter). In the Version column (W), select "R02B". This will provide the complete list of the 63 isotopes that have been modified. Next, sort the list by atomic number.

Then, in the comments field (column V), click on the filter, select "custom", in the comments field select "**contains**" and type "Trampac v3". This selects just the isotopes that were changed or added in CH-TRAMPAC version 3. There should be 26 isotopes in the table. The isotopic values that were changed are color coded red; only those need to be confirmed. These values are to be compared to Table 3.1-2 of the CH-TRAMPAC version 3 for FGE, decay heat, specific activity, and atomic

number. The half-lives and alpha ratios are to be verified using Browne and Firestone. The TRU and PECi nuclides are to be verified using the definition (see comments note in the header row). The dose is to be compared to DOE/EH-0071 and, if not available, with FGR#11.

a.	Confirm that there are 26 isotopes. Since all isotopes have a low atomic weight (well below 235 AMU[1] of U233, for example), the FGE will be zero. Confirm with the CH-TRAMPAC that the FGE of all 26 isotopes is zero.	YES	NO
b.	Confirm with the CH-TRAMPAC that the decay heats are correct	YES	NO
c.	Confirm with the CH-TRAMPAC that the specific activities are correct	YES	NO
d.	Confirm with Browne and Firestone that the half-lives and the alpha ratio are correct	YES	NO
e.	Confirm that the TRU Nuclide function agrees with the definition of a TRU nuclide	YES	NO
f.	Confirm that the PECi TRU Nuclide function agrees with the definition of a PECi nuclide	YES	NO
g.	Confirm that the atomic weight is correct (i.e., same as the isotope number suffix)	YES	NO
h.	Confirm that the atomic number agrees with the CH-TRAMPAC	YES	NO
i.	Confirm that the dose agrees with DOE/EH-0071 (where available) and, otherwise, the cell is blank.	YES	NO
j.	Where the dose is null, confirm that the dose is not available neither in DOE/EH-0071 nor FGR#11 (for internal inhalation)	YES	NO
k.	The alpha specific activity (column E), MAR (column G), PECi (column H), and Dose Weighting factor formulae reflect the requirements table 3 of the requirement document for one arbitrary isotope.	YES	NO

[1] Atomic mass units (AMU)

Change the filter in the comments column by selecting "Does Not Contain" "Trampac v3". This will provide a listing of the 37 isotopes that were reviewed for dose. The changed data is indicated in red.

l.	Confirm that there are 37 isotopes listed	YES	NO
m.	For Tc95, Tc95m, and Cm250, verify the conversion from Sv/Bq (in FGR#11) to Rem/μCi and Sr-82 added 12/11/09 JW	YES	NO
n.	Confirm that the dose for the remaining isotopes agrees with DOE/EH-0071 (where available) otherwise the cell is blank. Includes ES252 and Np240m in parenthesis added 12/11/09 JW	YES	NO
o.	For Rh106m (an added isomer), verify the alpha ratio, specific activity, and half-life with Browne and Firestone. Verify the FGE based on physics principals (atomic weight << atomic weight of Th232—e.g., see Lamarsh[2] table 3.3). Verify the decay heat with the physics method of TD-SWO-006 (page 5) using decay mode energies from Browne and Firestone. Verify atomic number from chemistry textbook.	YES	NO
p.	For all isotopes with a "null" value in the dose cell, confirm that the isotope is NOT listed in either DOE/EH-0071 nor in FGR#11 (inhalation)	YES	NO

3.2. MFP and MAP Verification

In this section, the Plutonium Activity Fraction Calculator (Calculator MaterialType_NucDataR02B.xls) is used to provide a listing of the distributions for MAP and MFP. This calculator was verified during the V&V of NucDataR02A and implements the equations described in the Requirements and Design document for Material Types (section 3.1). It also implements the MAP and MFP material types which are quality checked in this document.

In this first series of tests, the methodology for generating the weighted average fission, mass and activity fractions are confirmed. Open the Excel Worksheet, "Calculator Material_Type_NucDataR02B.xls" and select worksheet MAP_MFP. The equations that determine the weight % and Activity% will be validated.

a.	Compare Table I-3 (Shuman's paper) with table for MFP in the MAP_MFP worksheet. Are the isotopes and activity fractions from U235 and Pu239 fissions the same?	YES	NO
b.	For Kr85 within MFP table in the MAP_MFP worksheet, manually verify the wt% and activity%. Are the values in agreement.	YES	NO
c.	Compare Table I-4 (Shuman's paper) with table for MAP in the MAP_MFP worksheet for the isotope and mass %. Are they in	YES	NO

[2] Lamarsh, J.R., Introduction to Nuclear Engineering, Addison-Wesley, Menlo Park, CA, 2nd Edition, 1983

	agreement? (Note—the activity fractions may not be identical due to the use of different nuclear constants).		
d.	For Co60 within MAP table of the MAP_MFP worksheet, manually verify the decay corrected mass, activity, wt%, and Activity%	YES	NO

Open the following Excel workbooks. In NucDataR02B, select Window/New Window. This will provide two separate windows for NucDatar02B and one for "Calculator Material_Type_NucDataR02B.xls"

- WB1: "Calculator Material_Type_NucDataR02B.xls", worksheet "MTNucConstants', filter on MT = MFP
- WB2: NucDataR02B, worksheet "MTActivityFractions", filter on MT = MFP
- WB3: NucDataR02B, worksheet "Material Type", filter on Isotope = MFP

Perform the following tests of the MFP material type

e.	Compare WB1 and WB2. Confirm that the list of isotopes and the activity fractions for the MFP material type agree with the NucDataR02B, MTActivityFractions worksheet	YES	NO
f.	Compare WB1 and WB3. Confirm that the Total values for FGE, Decay Heat, Alpha specific activity, Dose Rate for MAR, and PECi agree with the material type values in NucDataR02B, MaterialType worksheet	YES	NO

Next, select the filter "MAP" in all three workbooks and perform the following tests of the MAP material type.

g.	Compare WB1 and WB2. Confirm that the list of isotopes and activity fractions for MAP material type agree.	YES	NO
h.	Compare WB1 and WB3. Confirm that the Total values for FGE, Decay Heat, Alpha specific activity, Dose Rate for MAR, and PECi agree	YES	NO

I certify that the tests were completed on November 9, 2009 with the results as indicated in the above tables. Evidence of the successful completion is included in the appendices.

John M. Veilleux, Ph.D.
Waste Services, TRU Waste Project Support (WS-TWPS)
Mail Stop J594
Los Alamos, NM 87545

Appendices

Appendix A: Isotopic Data Test Cases
Appendix B: MFP and MAP Data Test Cases

Technical Review

The documentation was technically reviewed. Pm148 half-life had been erroneously calculated, corrected in NucDataR02B, and verified. Sr82 was found in FGR#11 and the dose incorporated in NucDataR02B and verified.

I certify that I have on December 10, 2009 reviewed the test plan and report, that I have confirmed the test results and changes, and therefore concur that NucDataR02B.xls is ready for general release.

Randy Lucero 12/16/09

(Date Signed)

Randy Lucero
WDP-LLWD: Low Level Waste Disposition
Mail Stop J970
Los Alamos, NM 87545
Phone: 505-606-0066

I have incorporated the changes recommended by the technical reviewer and have incorporated the results in NucDataR02B. The change documentation and the requirements and design documentation for NucData were revised and dated December 11, 2009.

12/16/09

(Date Signed)

John M. Veilleux, Ph.D.
Waste Services, TRU Waste Project Support (WS-TWPS)
Mail Stop J594
Los Alamos, NM 87545
Phone: 505-667-7434

Appendix A

Nuclear Data Constants

Version R02B, 10/23/2009

Isotopic Data

Isotopes 26

FGE, Decay Heat, Specific Activity and Half-Life selected in following order of priority: CH Trampac, TD-SWO-006, Browne & Firestone, Requirements & Design document. Dose selected in order: DOE/EH-0071, FGR11.

0	1	2	3	4	5	6	7	13	14	15	16	17	18	19	20
Sel	Isotope	FGE (g Isotope/g Pu239)	Decay Heat (W/g)	Alpha specific Activity (Ci/g)	Specific Activity (Ci/g)	PU239 Eq. Ci (Ci/g) (MAR)	PECi (Ci/g)	Half Life (Yrs)	TRU Nuclide	PECi TRU Nuclide	Atomic Weight	Atomic Number	Alpha Ratio	Dose (rem/uCi)	Dose Weighting Factor, WF
2	Be10	0.00E+00	2.68E-05	0.00E+00	2.24E-02	1.54E-05	0.00E+00	1.60E+06	0	0	10	4	0.00E+00	3.50E-01	1.46E+03
2	P33	0.00E+00	2.33E+02	0.00E+00	1.58E+05	5.89E-01	0.00E+00	6.94E-02	0	0	33	15	0.00E+00	1.90E-03	2.68E+05
2	S35	0.00E+00	1.23E+01	0.00E+00	4.26E+04	1.92E-01	0.00E+00	2.40E-01	0	0	35	16	0.00E+00	2.30E-03	2.22E+05
2	Ca45	0.00E+00	8.12E+00	0.00E+00	1.78E+04	2.13E-01	0.00E+00	4.48E-01	0	0	45	20	0.00E+00	6.10E-03	8.36E+04
2	Sc46	0.00E+00	4.25E+02	0.00E+00	3.38E+04	1.33E+00	0.00E+00	2.30E-01	0	0	46	21	0.00E+00	2.00E-02	2.55E+04
2	V49	0.00E+00	2.06E-01	0.00E+00	8.08E+03	4.44E-03	0.00E+00	9.04E-01	0	0	49	23	0.00E+00	2.80E-04	1.82E+06
2	Rb87	0.00E+00	7.32E-11	0.00E+00	8.75E-08	5.66E-13	0.00E+00	4.80E+10	0	0	87	37	0.00E+00	3.30E-03	1.55E+05
2	Zr90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+20	0	0	90	40	0.00E+00		
2	Nb93m	0.00E+00	5.01E-02	0.00E+00	2.83E+02	1.55E-02	0.00E+00	1.36E+01	0	0	93	41	0.00E+00	2.80E-02	1.82E+04
2	Nb94	0.00E+00	1.91E-03	0.00E+00	1.87E-01	1.21E-04	0.00E+00	2.03E+04	0	0	94	41	0.00E+00	3.30E-01	1.55E+03
2	Ag108	0.00E+00	2.74E+06	0.00E+00	7.35E+08	0.00E+00	0.00E+00	4.51E-06	0	0	108	47	0.00E+00		
2	Ag108m	0.00E+00	2.53E-01	0.00E+00	2.61E+01	1.02E-02	0.00E+00	1.27E+02	0	0	108	47	0.00E+00	2.00E-01	2.55E+03
2	Cd115m	0.00E+00	9.59E+01	0.00E+00	2.55E+04	3.25E+00	0.00E+00	1.22E-01	0	0	115	48	0.00E+00	6.50E-02	7.85E+03
2	In114	0.00E+00	6.32E+06	0.00E+00	1.38E+09	0.00E+00	0.00E+00	2.28E-06	0	0	114	49	0.00E+00		
2	In114m	0.00E+00	3.23E+01	0.00E+00	2.31E+04	3.53E+00	0.00E+00	1.36E-01	0	0	114	49	0.00E+00	7.80E-02	6.54E+03
2	In115m	0.00E+00	1.26E+04	0.00E+00	6.34E+06	1.49E+00	0.00E+00	5.12E-04	0	0	115	49	0.00E+00	1.20E-04	4.25E+06
2	Sb124	0.00E+00	2.32E+02	0.00E+00	1.75E+04	7.21E-01	0.00E+00	1.65E-01	0	0	124	51	0.00E+00	2.10E-02	2.43E+04
2	Te129	0.00E+00	7.48E+04	0.00E+00	2.09E+07	3.16E+00	0.00E+00	1.32E-04	0	0	129	52	0.00E+00	7.70E-05	6.62E+06
2	Te129m	0.00E+00	5.42E+01	0.00E+00	3.01E+04	1.18E+00	0.00E+00	9.20E-02	0	0	129	52	0.00E+00	2.00E-02	2.55E+04
2	Ba137	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+20	0	0	137	56	0.00E+00		
2	Ce142	0.00E+00	0.00E+00	0.00E+00	2.40E-08	0.00E+00	0.00E+00	5.00E+16	0	0	142	58	0.00E+00		
2	Pr143	0.00E+00	1.26E+02	0.00E+00	6.73E+04	9.63E-01	0.00E+00	3.72E-02	0	0	143	59	0.00E+00	7.30E-03	6.99E+04
2	Pm148	0.00E+00	1.26E+03	0.00E+00	1.64E+05	3.22E+00	0.00E+00	6.13E-04	0	0	148	61	0.00E+00	1.00E-02	5.10E+04
2	Pm148m	0.00E+00	2.73E+02	0.00E+00	2.14E+04	7.13E-01	0.00E+00	1.13E-01	0	0	148	61	0.00E+00	1.70E-02	3.00E+04
2	Tb160	0.00E+00	9.24E+01	0.00E+00	1.13E+04	4.87E-01	0.00E+00	1.98E-01	0	0	160	65	0.00E+00	2.20E-02	2.32E+04
2	Ho166m	0.00E+00	1.99E-02	0.00E+00	1.80E+00	2.54E-03	0.00E+00	1.20E+03	0	0	166	67	0.00E+00	7.20E-01	7.08E+02

1.47E-2 ~~NucData R02B~~ corrected on 12/11/09 AW

Sorted by atomic number for: FGE, Decay Heat, Specific Activity, TRU Nuclide, PECi Nuclide, and Atomic Weight, and Atomic # } CH-TRAMPAC

Also for Half-life & Alpha Ratio } Browne & Firestone.

Note: Zr90, stable isomer, used as 1E20 years to simulate infinity.

Ba137

Item 3: a through j

Nuclear Data Constants

Version R02B, 10/23/2009

Isotopic Data

Isotopes 37 ✓

FGE, Decay Heat, Specific Activity and Half-Life selected in following order of priority: CH Trampac, TD-SWO-006, Browne & Firestone, Requirements & Design document. Dose selected in order: DOE/EH-0071, FGR11.

0	1	2	3	4	5	6	7	13	14	15	16	17	18	19	20
Sel	Isotope	FGE (g isotope/g Pu239)	Decay Heat (W/g)	Alpha specific Activity (Ci/g)	Specific Activity (Ci/g)	PU239 Eq. Ci (Ci/g) (MAR)	PECI (Ci/g)	Half Life (Yrs)	TRU Nuclide	PECI TRU Nuclide	Atomic Weight	Atomic Number	Alpha Ratio	Dose (rem/uCi)	Dose Weighting Factor, WF
1	H3	0.00E+00	3.28E-01	0.00E+00	9.76E+03	1.21E-03	0.00E+00	1.23E+01	0	0	3	1	0.00E+00	6.30E-05 ✓	8.10E+06
1	V52	0.00E+00	1.44E+07	0.00E+00	9.63E+08	0.00E+00	0.00E+00	7.13E-06	0	0	52	23	0.00E+00	✓✓	
1	Ni56	0.00E+00	3.93E+03	0.00E+00	3.82E+05	2.85E+00	0.00E+00	1.67E-02	0	0	56	28	0.00E+00	3.80E-03 ✓	1.34E+05
1	Ni65	0.00E+00	1.34E+05	0.00E+00	1.91E+07	7.88E+00	0.00E+00	2.88E-04	0	0	65	28	0.00E+00	2.10E-04 ✓	2.43E+06
1	Zn69m	0.00E+00	8.60E+03	0.00E+00	3.30E+06	4.47E+00	0.00E+00	1.57E-03	0	0	69	30	0.00E+00	6.90E-04 ✓	7.39E+05
1	Se72	0.00E+00	7.19E+01	0.00E+00	2.16E+05	0.00E+00	0.00E+00	2.30E-02	0	0	72	34	0.00E+00	✓✓	
1	Rb82	0.00E+00	2.65E+07	0.00E+00	1.79E+09	0.00E+00	0.00E+00	2.42E-06	0	0	82	37	0.00E+00	✓✓	
1	Sr82	0.00E+00	4.91E+00	0.00E+00	6.23E+04	0.00E+00	0.00E+00	7.00E-02	0	0	82	38	0.00E+00	✓✓	
1	Y87m	0.00E+00	6.26E+03	0.00E+00	2.79E+06	0.00E+00	0.00E+00	1.47E-03	0	0	87	39	0.00E+00	✓✓	
1	Nb91m	0.00E+00	1.92E+01	0.00E+00	2.30E+04	0.00E+00	0.00E+00	1.70E-01	0	0	91	41	0.00E+00	✓✓	
1	Nb92	0.00E+00	9.69E-07	0.00E+00	1.08E-04	0.00E+00	0.00E+00	3.60E+07	0	0	92	41	0.00E+00	✓✓	
1	Nb92m	0.00E+00	8.07E+02	0.00E+00	1.40E+05	0.00E+00	0.00E+00	2.78E-02	0	0	92	41	0.00E+00	✓✓	
1	Nb93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+20	0	0	93	41	0.00E+00	✓✓	
1	Tc95	0.00E+00	7.86E+03	0.00E+00	1.65E+06	8.09E-01	0.00E+00	2.28E-03	0	0	95	43	0.00E+00	2.50E-04 ✓	2.04E+06
1	Tc95m	0.00E+00	9.21E+01	0.00E+00	2.25E+04	1.71E-01	0.00E+00	1.67E-01	0	0	95	43	0.00E+00	3.89E-03 ✓	1.31E+05
1	Tc99m	0.00E+00	4.31E+03	0.00E+00	5.27E+06	3.31E-01	0.00E+00	6.85E-04	0	0	99	43	0.00E+00	3.20E-05 ✓	1.59E+07
1	Rh101m	0.00E+00 ✓	5.77E+02	0.00E+00	2.98E+05	3.91E-01	0.00E+00	1.19E-02	0	0	101	45	0.00E+00	6.70E-04 ✓	7.61E+05
1	Rh106m	0.00E+00 ✓	2.58E+05 ✓	0.00E+00	1.36E+07 ✓	5.35E+00	0.00E+00	2.48E-04 ✓	0	0	106 ✓	45 ✓	0.00E+00 ✓	2.00E-04 ✓	2.55E+06
1	Rh97	0.00E+00	2.78E+05	0.00E+00	6.31E+07	0.00E+00	0.00E+00	5.84E-05	0	0	97	45	0.00E+00	✓✓	
1	Ce139	0.00E+00	7.89E+00	0.00E+00	6.82E+03	1.00E-01	0.00E+00	3.77E-01	0	0	139	58	0.00E+00	7.50E-03 ✓	6.80E+04
1	Pr144	0.00E+00	5.54E+05	0.00E+00	7.56E+07	6.23E+00	0.00E+00	3.29E-05	0	0	144	59	0.00E+00	4.20E-05 ✓	1.21E+07
1	Nd144	0.00E+00	1.28E-14	1.18E-12	1.18E-12	0.00E+00	0.00E+00	2.10E+15	0	0	144	60	1.00E+00	✓✓	
1	Nd147	0.00E+00	1.97E+02	0.00E+00	8.09E+04	9.83E-01	0.00E+00	3.01E-02	0	0	147	60	0.00E+00	6.20E-03 ✓	8.23E+04
1	Ho163	0.00E+00	0.00E+00	0.00E+00	6.60E+01	0.00E+00	0.00E+00	3.30E+01	0	0	163	67	0.00E+00	✓✓	
1	Lu172m	0.00E+00	6.95E+04	0.00E+00	2.90E+08	0.00E+00	0.00E+00	7.04E-06	0	0	172	71	0.00E+00	✓✓	
1	Hf178n	0.00E+00	9.89E+07	0.00E+00	1.45E+10	0.00E+00	0.00E+00	1.27E-07	0	0	178	72	0.00E+00	✓✓	
1	Re183	0.00E+00	1.54E+01	0.00E+00	1.02E+04	0.00E+00	0.00E+00	1.92E-01	0	0	183	75	0.00E+00	✓✓	
1	Au196	0.00E+00	3.25E+02	0.00E+00	1.08E+05	0.00E+00	0.00E+00	1.69E-02	0	0	196	79	0.00E+00	✓✓	
1	Pb202	0.00E+00	1.73E-06	0.00E+00	3.37E-02	6.54E-06	0.00E+00	5.30E+04	0	0	202	82	0.00E+00	9.90E-02 ✓	5.15E+03
1	Pb203	0.00E+00	1.81E+07	0.00E+00	2.97E+05	3.02E-01	0.00E+00	5.94E-03	0	0	203	82	0.00E+00	5.20E-04 ✓	9.81E+05
1	Pb214	0.00E+00	1.49E+05	0.00E+00	3.28E+07	4.31E+02	0.00E+00	5.10E-05	0	0	214	82	0.00E+00	6.70E-03 ✓	7.61E+04
1	Po208	0.00E+00	1.80E+01	5.93E+02	5.93E+02	0.00E+00	0.00E+00	2.90E+00	0	0	208	84	1.00E+00	✓✓	
1	Fr223	0.00E+00	1.10E+05	2.32E+03	3.87E+07	4.63E+02	0.00E+00	4.14E-05	0	0	223	87	6.00E-05	6.10E-03 ✓	8.36E+04
1	Np240	0.00E+00	8.52E+04	0.00E+00	1.27E+07	1.57E+00	1.57E+00	1.18E-04	0	1	240	93	0.00E+00	6.30E-05 ✓	8.10E+06
1	Pu233	0.00E+00	1.27E+05	4.63E+04	3.86E+07	0.00E+00	0.00E+00	3.97E-05	0	1	233	94	1.20E-03	✓✓	
1	Cm243	5.00E+00	1.90E+00	5.21E+01	5.22E+01	3.58E+01	3.58E+01	2.85E+01	1	1	243	96	9.98E-01	3.50E+02 ✓	1.46E+00
1	Cm250	0.00E+00	1.59E-01	0.00E+00	2.10E-01	3.87E+00	3.87E+00	1.13E+04	0	1	250	96	0.00E+00	9398 ✓	5.43E-02

Item 3: l → p

double check marks are checked w DOE/EH-0071 & FGR#11

Item ~~3f~~ 3m JW 12/11/09

Cm 250 Dose, see FGR#11, Table 2.1, page 152

$D = 2.54 \times 10^{-3} \frac{Sv}{Bq}$; committed ~~effective~~ dose.

$1 rem = 10^{-2} Sv$

$1 Ci = 3.7 \times 10^{10} Bq$

JW

$= 2.54 \times 10^{-3} \frac{\cancel{Sv} \times}{\cancel{Bq}} 100 \frac{rem}{\cancel{Sv}} \times 3.7 \times 10^{10} \frac{\cancel{Bq} \times \cancel{10^6 \mu Ci}}{Ci}$

$= 9.398 \times 10^{9} \frac{rem}{Ci * 10^6 \frac{\mu Ci}{Ci}}$

$= 9398 \frac{rem}{\mu Ci}$ ✓

TC 95 (weekly Committed effective dose equivalent).

$D = 6.76 \times 10^{-11} \frac{Sv}{Bq} \times 100 \frac{rem}{Sv} \times 3.7 \times 10^{10} \frac{Bq}{Ci} / 10^6 \frac{\mu Ci}{Ci}$

$= 2.50 \times 10^{-4} \frac{rem}{\mu Ci}$ ✓

Tc 95m (weekly CEDE)

$D = 1.05 \times 10^{-9} \frac{Sv}{Bq} \times 100 \frac{rem}{Sv} \times 3.7 \times 10^{10} \frac{Bq}{Ci} / 10^6 \frac{\mu Ci}{Ci}$

$= 3.89 \times 10^{-3} \frac{rem}{\mu Ci}$ ✓

Item 3m (continued

Sr 82 Dose, FGR #11, Table 2.1, page 127

$D = 1.66 \times 10^{-8} \frac{Sv}{Bq}$ (using the largest of the day and year values)

$= 1.66 \times 10^{-8} \frac{Sv}{Bq} * 100 \frac{rem}{Sv} \times 3.7 \times 10^{10} \frac{Bq}{Ci} / 10^{6} \frac{\mu Ci}{Ci}$

$= 0.06142 \frac{rem}{\mu Ci}$

Added 12/11/09, JW

Item 3-O

Rh 106 m Decay heat.

Average Energies per Brunn & Firestone, p 106-2 for Rh 106 m isomer (2.17 hr.)

Photons:	2882 keV	per disintegration
Electrons:	7.4 keV	
β^-	: 307 keV	
IB	: 0.29 keV	

$$\langle E \rangle = 3.19669 \frac{keV}{dis} \equiv 3.1967 \frac{MeV}{dis}$$

$$DH = S^{A}_{Rh106} \times \langle E \rangle$$

$$= 1.364 \times 10^{7} \frac{Ci}{g} \times 3.1967 \frac{MeV}{dis} \times 3.7 \times 10^{10} \frac{dis}{s \cdot Ci} \times 1.602 \times 10^{-13} \frac{J}{MeV}$$

$$= 2.5845 \times 10^{5} \frac{J}{s\,g} \equiv \boxed{2.58 \times 10^{5} \frac{W}{g}}$$

Item 3 k Use Sc 46

Alpha Specific Activity, S^{α}_{Sc46}

$$S^{\alpha}_{Sc46} = S^{A}_{Sc46} * \alpha_{Sc46} = 3.38\times10^{4}\ \frac{Ci}{g} \times 0 = 0$$ ✓

Pu 239 Eg Ci (all isotopes = MAR)

$$S^{M}_{Sc46} = \frac{S^{A}_{Sc46} * \cancel{\delta^{P}_{Sc46}}\ 1\ M}{WF_{Sc46}} = \frac{3.38\times10^{4}\ Ci/g * 1}{2.55\times10^{4}}$$

$$= 1.33\ Ci/g$$ ✓

PECi, S^{P}_{Sc46}

$$S^{P}_{Sc46} = \frac{S^{A}_{Sc46} \times \delta^{P}_{Sc46}}{WF_{Sc46}} = \frac{3.38\times10^{4}\ \frac{Ci}{g} \times 0}{2.55\times10^{4}}$$

$$= 0$$ ✓

Appendix B

Mixed Fission and Activation products

Rev1: change neutron to be 30% by activity rather than by weight for Pu239

NOTE: MFP/MAP No longer being accepted; all waste must have isotopic contents

MFP

MFP After 10 years (Table I-3, Shuman's LAUR)

		U235 fissions	0.7
		Pu239 fission	0.3
Total Activity:	1	Total mass:	1

	Activity Fractions from:						Average Percent	
Isotopes	U235 fissions	Pu239 fissions	Weighted Ave Activity	Normalized Activity Fractions	Mass	Normalized Mass	wt%	Activity (%)
Ce144 ✓	1.30E-03 ✓	1.10E-03 ✓	1.24E-03	1.23E-03	3.81E-07	3.96E-05	0.0%	0.1%
Cs137 ✓	3.30E-01 ✓	8.20E-01 ✓	4.77E-01	4.72E-01	5.37E-03	5.57E-01	55.7%	47.2%
Eu154 ✓	2.10E-06 ✓	7.50E-05 ✓	2.40E-05	2.37E-05	8.89E-08	9.23E-06	0.0%	0.0%
Eu155 ✓	2.70E-05 ✓	4.90E-04 ✓	1.66E-04	1.64E-04	3.50E-07	3.63E-05	0.0%	0.0%
Kr85 ✓	2.60E-01 ✓	2.50E-02 ✓	1.90E-01	1.88E-01 ✓	4.73E-04 ✓	4.91E-02 ✓	4.9% ✓	18.8% ✓
Ru106 ✓	0.00E+00 ✓	1.80E-02 ✓	5.40E-03	5.35E-03	1.58E-06	1.64E-04	0.0%	0.5%
Sb125 ✓	1.70E-04 ✓	1.00E-04 ✓	1.49E-04	1.48E-04	1.42E-07	1.47E-05	0.0%	0.0%
Sm151 ✓	1.00E-06 ✓	2.10E-05 ✓	7.00E-06	6.93E-06	2.61E-07	2.71E-05	0.0%	0.0%
Sn121m ✓	1.10E-04 ✓	5.40E-04 ✓	2.39E-04	2.37E-04	4.00E-06	4.16E-04	0.0%	0.0%
Sn126 ✓	4.00E-05 ✓	3.80E-05 ✓	3.94E-05	3.90E-05	1.37E-03	1.43E-01	14.3%	0.0%
Sr90 ✓	4.20E-01 ✓	1.40E-01 ✓	3.36E-01	3.33E-01	2.41E-03	2.50E-01	25.0%	33.3%
sum	1.01E+00	1.01E+00	1.01E+00	1.00E+00	9.63E-03	1.00E+00	1.00E+00	1.00E+00

MAP

Weight fractions are from Table I-4, Shuman's LAUR

total mass: 1 Years Aged: 10

						Decay Corrected		
Isotopes	mass %	Activity	Activity %		decayed mass	Activity	Wt%	Activity %
Be7 ✓	3.0% ✓	10500	69.4%		6.99E-23	1.95E-16	0.0%	0.0%
Co57 ✓	12.0% ✓	1026	6.8%		1.08E-05	7.38E-01	0.0%	0.1%
Co60 ✓	44.0% ✓	501.6 ✓	3.3% ✓		1.18E-01 ✓	1.08E+03 ✓	94.4% ✓	75.1% ✓
Mn54 ✓	18.0% ✓	1407.6	9.3%		5.41E-05	3.38E+00	0.0%	0.2%
Na22 ✓	10.0% ✓	632	4.2%		6.97E-03	3.52E+02	5.6%	24.6%
Zn65 ✓	13.0% ✓	1071.2	7.1%		4.07E-06	2.68E-01	0.0%	0.0%
Sum	100.0%	15138.4	100.0%		0.125162896	1432.120256	100.0%	100.0%

Item 3.2a

3.2b

3.2c

3.2d

Item 3.2b for Kr 85

Weighted Average Activity

$$\langle f_j^A \rangle_{\text{unnormalized}} = w_{U235} f_{Kr85}^{A(U235)} + w_{Pu239} f_{Kr85}^{A(Pu239)}$$

$$= 0.7 \times 0.26 + 0.3 \times 0.025$$

$$= 1.895 \times 10^{-1} \checkmark$$

Normalized Activity fraction

$$\langle f_j^A \rangle = \frac{\langle f_j^A \rangle}{\sum f_j} = \frac{1.895 \times 10^{-1}}{1.01} = 1.876 \times 10^{-1} \checkmark$$

Mass, m_{Kr85} per Ci

$$m_{Kr85} = \frac{\langle f_{Kr85}^A \rangle A_{Kr85}}{S_{Kr85}^A} = \frac{1.876 \times 10^{-1} \times 1 Ci}{397 Ci/g} = 4.726 \times 10^{-4} g \checkmark$$

Mass fraction & weight %

Normalized mass $= \frac{4.726 \times 10^{-4} g}{9.63 \times 10^{-3}} = 4.908 \times 10^{-2} g$

wt % = 4.908 %. ✓

Activity Fraction $= \frac{1.876 \times 10^{-1}}{1} = 0.1876$

Activity % = 18.76 % ✓

Item 3.2 d for Co 60

Activity, A

$A_j = f_j^m \, m \, S_j^A$, $m = 1\ g$.

$S_j^{Co60} = 1.14 \times 10^3\ Ci/g$.

$= 0.44 \times 1g \times 1.14 \times 10^3\ Ci/g = 501.6\ Ci$.

Normalized f_j^A

$$f_j^A = \frac{A_j}{\sum A_j} = \frac{501.6\ Ci}{15138.4\ Ci} = 3.313 \times 10^{-2}$$

$$= 3.3\% \checkmark$$

Mass * Activity

Decay, 10 years.

$$m_j = m_j(0)\, e^{-\ln 2 \frac{\Delta t}{t_{1/2}}} \qquad \Delta t = 10\ yrs$$

$t_{1/2}(Co60) = 5.27\ yrs.$

$m_j(0) = f_j(0) \times 1g = 0.44 \times 1$

$$= 0.44\, e^{-\ln 2 \left(\frac{10\ yr}{5.27\ yr}\right)} = 0.44\, e^{-1.31527}$$

$$= 1.181 \times 10^{-1}\ g$$

$$f_j^m = \frac{m_j}{\sum m_j} = \frac{0.1181}{0.12516} = 0.944 \checkmark$$

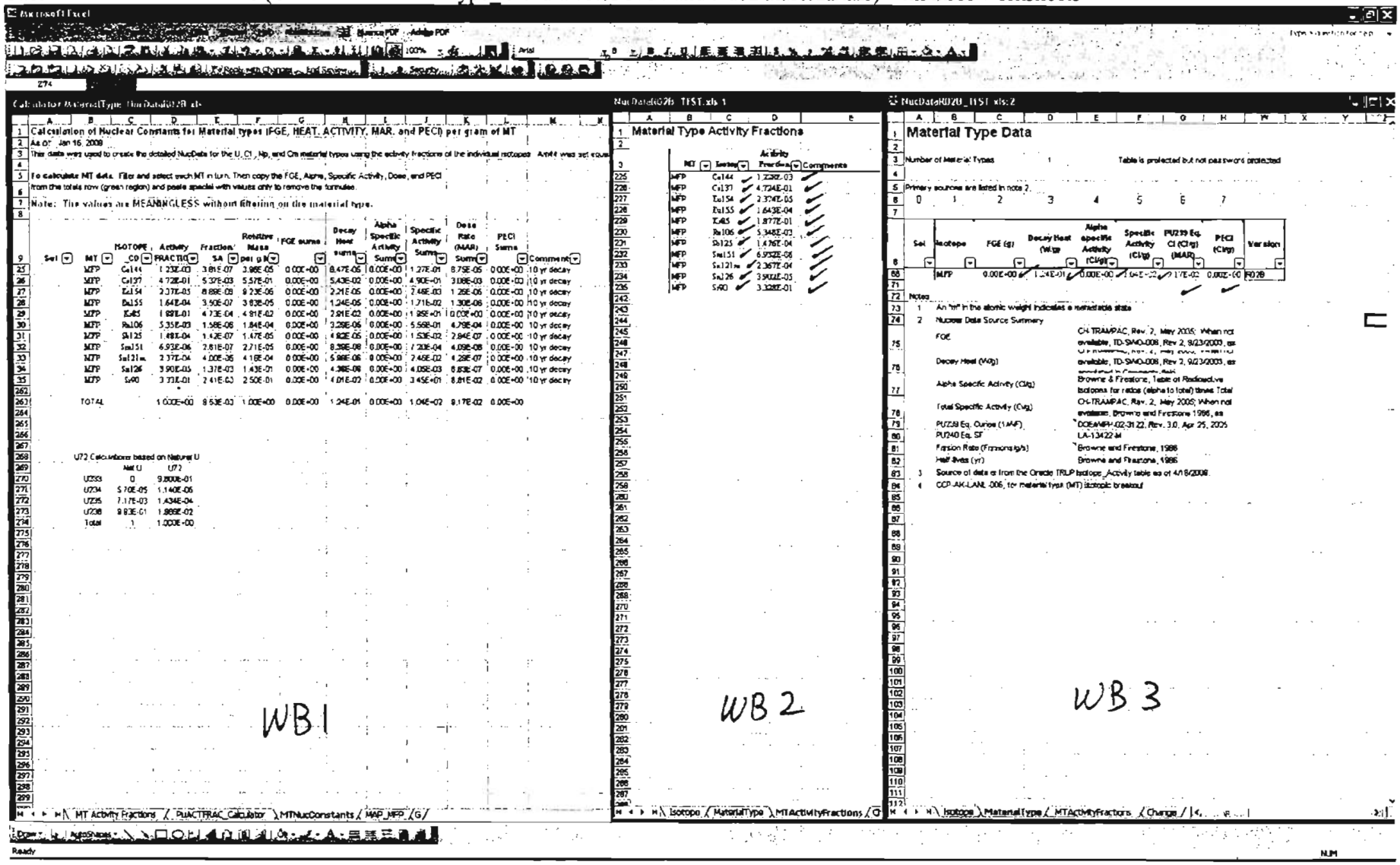
$wt\% = 94.4\% \checkmark$

$$A_j = 0.944\ (1g) \times 1.14 \times 10^{+3}\ \frac{Ci}{g} = 1.0757 \times 10^{+3}\ Ci$$

$$f_j^A = \frac{A_j}{\sum A_j} = \frac{1.0757 \times 10^3\ Ci}{1432.12\ Ci} = 0.751 \equiv 75.1\% \checkmark$$

Table 1. MFP Material Type

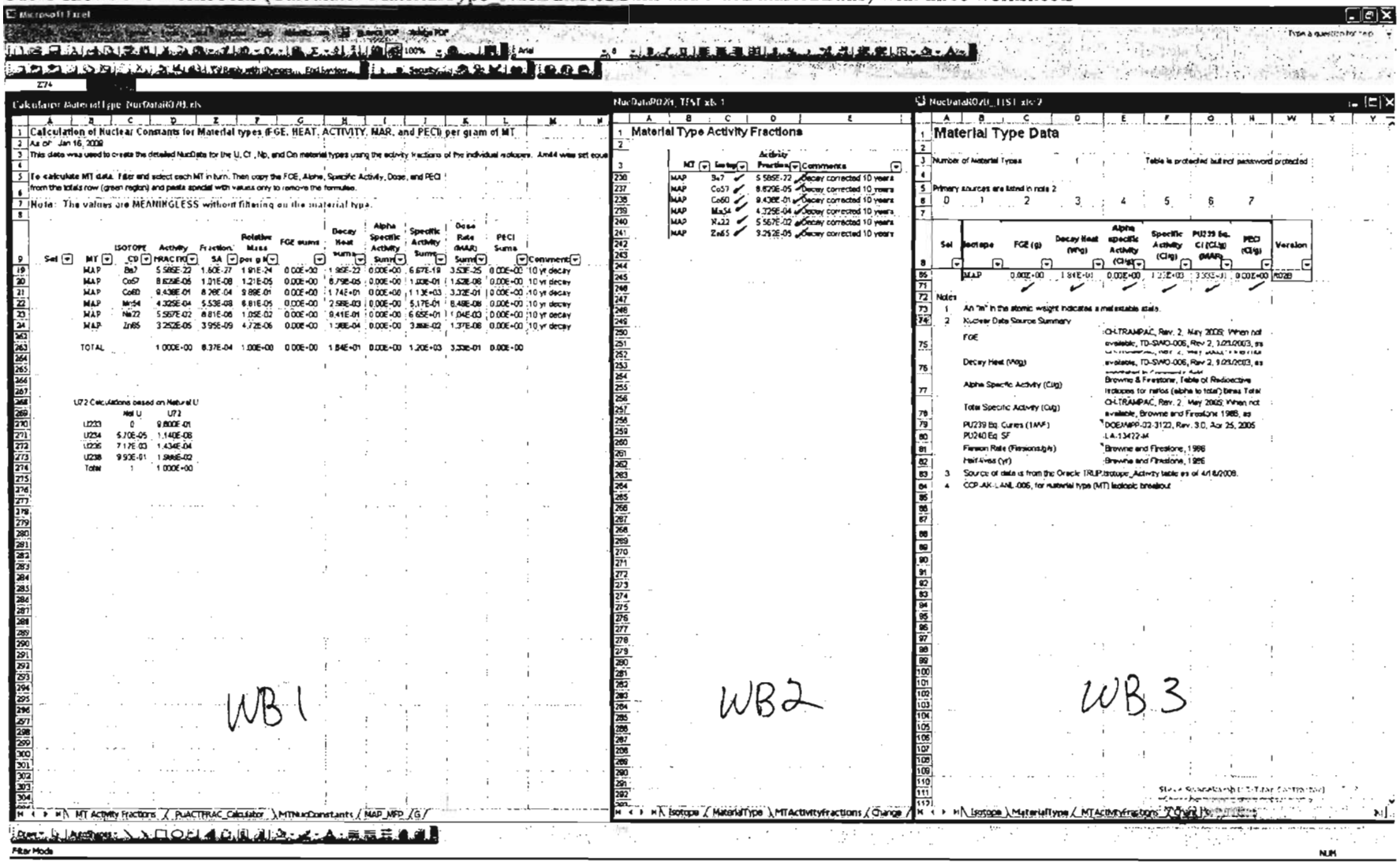
Table shows two workbooks (Calculator MaterialType_ NucDataR02B.xls and NucDataR02B.xls) with three worksheets



Item 3.2e
3.2f

Table 2. MAP Material Type

Table shows two workbooks (Calculator MaterialType_NucDataR02B.xls and NucDataR02B.xls) with three worksheets



Item 3.2g
3.2h