Waste Disposal Options Report

Volume 2

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Project/Task Final Disposal Options

Subtask Waste Characterization

Title: Estimates of Feed and Waste Volumes, Compositions and Properties

Summary:

This EDF provides estimates of waste volumes and compositions for different alternatives being considered in the Final Disposal Options Feasibility Study. The EDF documents sources of information and assumptions used in making these estimates. The developmental nature of, and process uncertainties present in all of the options being considered contribute uncertainty to many of the estimates. Even for the "No Action" alternative, uncertainties in the flowsheet for Sodium-Bearing Waste calcination result in uncertainty in the projected calcine volume. Attached to the report is a table showing projected generation volumes by year of other ICPP wastes. Also attached to the EDF is a letter containing calculations of radionuclide inventories for Sodium-Bearing Waste (SBW). This attached inventory is more complete than what was used in generating the tables presented in this EDF.

The initial issue of this EDF was based on draft versions of Doug Wenzel's calcine activity data. This revision has been updated to be consistent with Wenzel's final EDFs. Other changes in this revision include the volumes of wastes from the TRU Separations options, assumptions for estimating waste volumes for both Cementitious Waste Options, calcine loadings in glass for the Vitriified Waste Option, grout formulation for the SBW case, neutralization waste volumes for the Separations Options, and the addition of information for the TRU / Class A Option.

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Waste Volume - No Action Alternative

The waste products of the no action alternative include:

- (1) existing calcine
- (2) calcine produced during the H4 calciner campaign, in which waste from Tank WM-188, an evaporated blend of waste previously stored in WM-189 and WM-183, is calcined
- (3) calcine from calcination of blended and evaporated wastes from WM-185 and WM-187, presently stored in WM-189, plus calcine from the remaining wastes in WM-185 and WM-187
- (4) calcine of the remaining Sodium-Bearing Waste (SBW), including waste presently in WM-180, WM-181, WM-184, and WM-186, and referred to as the "2008 composite"
- (5) calcine from other wastes generated by ICCP facilities from 1996-2012.

The volume of the existing calcine, as estimated by Dan Staiger, is 3809 m³.^(1,2)

The volume of calcine produced from WM-188 has been calculated by Robert Rivard.³ Rivard calculates calcine volumes of 158 to 248 m³ for Al to Na + K ratios of 3.2 to 6.3. I suggest that we use his calcine volume calculated at an Al to Na + K ratio of 3.467, which is 166 m³. Rivard used a calcine density of 1.653 g/cm³ in his volume calculations. The waste which was previously in WM-189 was the last tank of "high level" waste.

Blends of tank farm wastes from WM-185 (SBW) and WM-187 (a dilute-fluoride waste of second- and third cycle raffinates along with flushes and decon wastes) were evaporated in the High Level Liquid Waste Evaporator (HLLWE) in December of 1996 and January of 1997, and are being stored in WM-189.⁴ The flowsheet for calcination of this waste has not been defined, nor has the completion of the evaporation of liquids in these two tanks. To estimate the calcine volume that will be produced from this waste, I assumed an Al to Na + K mole ratio of 3.5, and used tank volumes and compositions from Reference 6 for WM-189 and WM-187, compositions of WM-185 from Reference 4 and a volume of WM-185 from a phone conversation with Clark Millet, May 22, 1997. I assumed a heel of 14,000 gal remained in each of the tanks, and a calcine density of 1.2 g/cm³. Based on the above assumptions, the estimated calcine volume for WM-185/WM-187 tanks is 160 m³. The calcine chemistry in these calculations was based on O'Brien (Reference 55).

Using the same method, calcine volumes from SBW were estimated based on a composite composition for WM-180, WM-181, WM-184, and WM-186, as given in Reference 7. The evaporated volume of this waste is estimated to be 790,000 gal or 3 million liters. The estimated calcine volume, assuming a calcine density of 1.2 g/cm³, is as follows:

Al/(Na+K) Mole Ratio	Calcine Volume based on 500°C calcination, m ³	Calcine Volume based on 600°C calcination, m ³
1.5	900	700
2.5	1150	1000
3.5	1400	1300

Operating parameters for calcining the SBW are not fixed at this time. Pilot-plant runs have shown that an Al to Na + K mole ratio of 1.5 at a temperature of 600°C produces acceptable product and operation. Additional pilot plant runs will better determine the SBW calciner flowsheet. For a given Al to Na + K ratio, the difference in the expected calcine volume from calcination at difference temperatures is related to the difference in the expected nitrate content of the calcine.

Category (5) above refers to wastes expected to be generated from other existing ICCP facilities. Most of this waste will be from deactivation and decontamination activities. Estimates of the projected volumes for this waste are

given in the J. Tripp Report,⁸ and additional characterization data for this waste is contained in Reference 9. A table showing projected volumes used for this EDF of these generated waste is attached. The total waste volume from these generated wastes, after evaporation, is 800,000 gal or 3 million liters. This waste is not sufficiently characterized to allow calculation of calcine volume based on composition. Based on an assumed calcine volume to calciner feed volume ratio of 0.2 to 0.47, the calcine volume is estimated to be 600-1400 m³. These calcine volume estimates for the generated waste are very similar to the estimates for SBW, which is logical since the generated waste will, as SBW did, result primarily from decontamination activities.

In summary, the total estimated calcine is as follows:

	Estimated Volume, m ³		Estimated Density, g/cm ³
	500°C	600°C	
Existing as of 1996	3809	(3809)	1.48
Produced from WM-188	166	(166)	1.65
Produced from WM-189	160	(160)	1.2
Produced from SBW	1400	700	1.2
Produced from generated waste, 1996-2012	<u>1400</u>	<u>600</u>	1.2
Total	6935	5435	
Total, rounded	6900	5400	

The higher estimate would be more appropriate for a no action alternative in which no modifications are made to the calciner for SBW processing, while the lower estimate would apply if calciner modifications are made for higher temperature operation.

Waste Volume - Vitrified Waste Option

In the Vitrified Waste Option (VWO), all waste is calcined as in the no action alternative. However, instead of then being stored, the calcine is mixed with glass forming additives and vitrified at high temperature. In the late 1970's and early 1980's, numerous glass formulations were tested for directly vitrifying ICPP zirconia and alumina calcines,¹⁰⁻¹⁵ and more recent work tested glass formulations for calcine from SBW.¹⁶ The waste loading in these tests was usually in the range 25-35 wt%. Recommended frit formulations for alumina calcine can be found in Reference 11, such as glass formulation 283; and for zirconia calcine in Reference 12, glass formulation 127. A typical glass density given in these references is 2.6 g/cm³. Reference 16 contains frit compositions for vitrification of SBW. The recommended glass formulations for zirconia calcine in Reference 12 and SBW in Reference 16 produce borosilicate glass, while the recommended formulation for alumina calcine in Reference 11 results in a borophosphate glass. Borosilicate glasses for alumina calcine have also been tested,¹⁰⁻¹¹ and would result in similar glass volumes. Waste loadings for the various feed types were taken from EDF-VWO-001.⁵⁰

	Calcine Volume, m ³	Calcine Density, g/cm ³	Waste Loading, wt %	Glass Volume, m ³
Existing Calcine	(3809)			
Zr Calcine	2891 ^(a)	1.6	31	5,740
Al Calcine	918 ^(a)	1.09	21	1,830
WM-188 Calcine	166	1.65	31	340
WM-189 Calcine	160	1.2	30	250
SBW Calcine	700	1.2	30	1,080
Gen'd Waste Calcine	<u>600</u>	1.2	30	<u>920</u>
Total	5435			10,160

^(a) The breakdown of existing calcine into zirconia and alumina was taken from Reference 2.

The above glass volumes assume high temperature calcination of SBW. Additional waste will be produced from the vitrification offgas treatment system, containing volatile species such as chlorides, fluorides, cesium and mercury. For additional details of the VWO process and material balance, see the Vitrified Waste Option Scoping Study Report, INEEL/EXT-97-01389.

Waste Volume - Hot Isostatic Pressing of Calcine

The Hot Isostatic Pressing (HIP) Waste Option (HWO) is similar to the Vitrified Waste Option in that all waste is first calcined. However, rather than then forming a glass waste product by vitrification, a ceramic waste product is produced by hot isostatically pressing the calcine with additives. Various studies^{22-25,37-41} have shown that a loading of 70 wt% can be achieved, and that a typical density of the ceramic waste is 3.2 g/cm³. Based on this waste loading and density, 5400 m³ of calcine would produce about 3400 m³ of ceramic waste. Additional details of the HWO can be found in the HWO Scoping Study Report and the HIP'ing Waste Option (HWO) Design Basis, EDF HWO-012.

Waste Volume - Cement via the Cementitious Waste Option

A scheme for disposal of ICPP reprocessing wastes has been proposed by Darryl Siemer in which a "hydroceramic" waste is produced.^{33,42,43} This option involves combining existing calcine with liquid SBW and calcining the resulting slurry. The recalcined material would then be mixed with cement-based stabilizing agents and cast. Optionally, the cast material could be HIPed.

The following assumptions were used to estimate the total volume of waste produced in this option:

1. Only waste in Tank WM-188 will be calcined prior to the calciner modifications needed to implement the Siemer process.
2. The recalcination of existing calcine with SBW, liquid in Tanks WM-185, -187, and -189, and additional waste generated 1996-2012 will require no additional aluminum nitrate nonahydrate (ANN), boric acid, calcium nitrate or other additives except for sugar.
3. Recalcination will result in a 3% reduction in existing calcine mass due to of nitrate destruction.
4. The density of the recalcined calcine will be 1.45 g/cm³.
5. The waste loading for recalcined material in cement is 35 wt% (35 g calcine per 100 grams cement product).⁵¹
6. The cement final density will be 1.7 g/cm³.⁵¹

Based on the above assumptions, the total calcine produced will be about 4,620 m³, the total cement produced will be about 11,000 m³. Siemer³³ states that the HIPed waste form is typically 60% more dense than the hydroceramic form, thus conceivably the waste form could have a volume of only 7000 m³. However, as the HIPing process is performed "in-can," and may need to be repackaged, it is unlikely that the volume reduction can be realized. Additional details of the Cementitious Waste Option (CWO) can be found in the CWO Scoping Study Report, INEEL/EXT-97-01400, and the Cementitious Waste Option Design Basis, EDF CWO-003.

Waste Volume - Direct Cementitious Waste Option

The Direct Cementitious Waste Option (DCWO) involves grouting all existing calcine without further processing and grouting all additional calcine produced 2012. The grouted waste could be further processed by HIPing.

The total calcine estimated to be processed in the DCWO is 5400 m³. Grouting this calcine, based on a final waste loading of 35 wt % and a grout density of 1.7 g/cm³ results in a grout volume of 13,000 m³. Additional information

on the DCWO process and material balance can be found in the Direct Cementitious Waste Option Scoping Study Report, INEEL/EXT-97-01399 and the Direct Cementitious Waste Option Process Design, EDF-DWCO-011..

Waste Volumes - Full Separations Option

The basis, assumptions and waste volumes for the Full Separations Option (FSO) are contained in Reference 9, and summarized in Reference 17. Some of the assumptions used to calculate the material balance given in Reference 9 have been changed in the Feasibility Study⁵² performed by Fluor Daniel, Inc. (FDI) for this option, and thus waste volumes reported by FDI may differ from those in this EDF.

In the Full Separations Option, SBW is assumed to be processed during 2011-2012, and calcine from 2016-2035. A grouting facility is assumed to come on line in 2011. Generated wastes are segregated between "collection wastes" and wastes that are processed through separation units in the treatment facility. The ICCP calciner is assumed to be shut down in October of 1999, following completion of calcining tanks WM-188 and WM-189 and other ICCP wastes generated prior to this period.

The volume of calcine assumed processed in this option is 4836 m³.⁽⁹⁾ Less calcine is processed in this option than the non-separations options because SBW is processed directly without being calcined. However the volume of 4836 m³ is 17% higher than that estimated above for other cases without SBW calcine (3809 + 166 + 160 = 4135), The higher estimate does include calcine from a portion of generated waste that is not included in the 4135 m³ value, and variations in calculating methods account for the remaining difference.

The volume of SBW feed in this alternative is 3 million liters. Another 1.28 million liters of waste generated 1996-2012 will be processed with the SBW. High activity waste effluents generated during SBW processing will be stored until the calcine campaigns beginning in 2016. The total grout produced during 2011-12 is estimated to be about 3200 m³ (including 3162 m³ from processing SBW and 47 m³ from processing collection wastes collected 1996-2010). (FDI reports that the grout volume from SBW processing will be 2717 m³.⁵²) No glass is produced during this period.

During 2016-2035, all calcine is dissolved, and transuranics, cesium and strontium are removed from the resulting solution. Low activity waste effluents from the separations units are grouted after evaporation and denitration, while high activity effluents are vitrified, after concentration by evaporation. The total grouted waste is estimated to amount to 23,800 m³ during this period and the total vitrified waste is estimated to amount to 470 m³, or 653 canisters. If vitrified separately, the high activity waste from SBW processing would amount to 20 m³ and the glass produced from calcine wastes alone would be 450 m³. (FDI reports a total grout volume from calcine processing of 16,920 m³, and a glass production of 780 canisters.⁵²)

The waste loadings used in the above glass volume estimates are 41.5% for SBW, 27.4% for calcine (based on a weighted average of 22.5% for alumina calcine and 29.4% for zirconia calcine), based on data in Reference 18. The glass densities used in the volume calculations were taken from Reference 19 and are 2.4 g/cm³ for glass from processing SBW, 2.46 g/cm³ for glass from alumina calcine, and 2.66 g/cm³ for glass from zirconia calcine. The waste loadings in grout, on a dry basis, are 30% for SBW, Zr calcine and other ICCP wastes and 15% for Al calcine. These loadings are consistent with the wet loadings given in Reference 18, which are 22.24% for SBW, 10.6% for alumina calcine, and 20.76% for zirconia calcine. The grout density for all cases was assumed to be 1800 kg/m³, as given in Reference 19. Additional information on the assumptions and material balance for the preferred path alternative can be found in References 9 and 17.

If, instead of being denitrated, the low activity effluents from separations units are neutralized and grouted, about 16,000 m³ of grouted waste would be produced from processing SBW and about 220,000 m³ would be produced from processing calcine. These volume estimates assume neutralization with caustic to a H⁺ concentration of 0.05

moles/liter and a waste solids loading in the grout of 12%, on a wet basis. These assumptions are based on data in Reference 49 and discussions with Alan Herbst.

Waste Volumes - TRU Separation Options

The TRU Separations Options result in a dry, containerized TRU waste product. Two cases of TRU Separations are being considered, one which produces a Class C grout, referred to as the TRU / Class C Option, and the other that produces a Class A grout, referred to as the TRU / Class A Option. No vitrified wastes are produced in the Class C option. The Class A Option produces a vitrified waste containing residues from cesium and strontium separations. As in the full separations alternative, the calciner is operated only through 1999. The SBW remaining after calciner shutdown would be stored until the separations process comes on line. In the TRU / Class C Option, separations consists only of the TRUEX process, which extracts actinides from SBW and dissolved calcine. TRUEX raffinate, TRUEX wash effluent, TRUEX rinse effluent, and other ICCP low level wastes are concentrated by evaporation, denitrated and grouted. The TRU waste effluents, including the strip effluent from TRUEX and backwash from SBW and dissolved calcine filters, are concentrated by evaporation, crystallized, dried, and packaged for shipment to the Waste Isolation Pilot Plant (WIPP). The TRU / Class A Option process is identical to the Full Separations process, except that steps are added to concentrate, crystallize and dry the TRU effluents rather than process them in the melter.

For the TRU / Class C Option, the total grout produced is estimated to be 22,700 m³, based on a density of 1800 kg/m³ and loadings as per the preferred path option. Out of the total grout volume produced, approximately 3000 m³ is from processing SBW and the remainder from processing calcine. For the TRU / Class A Option, about 23,900 m³ of grout and 120 m³ of vitrified waste are produced.

For either TRU Separations Option, the TRU waste product would amount to about 216 m³, assuming a waste density of 1500 kg/m³. Of the total volume, 205 m³ would result from processing calcine and 11 m³ from SBW. The primary constituents of the TRU waste are alumina, zirconia phosphate, calcium stabilized zirconia, and pyrophosphoric acid for calcine processing and silica, pyrophosphoric acid and zirconium sulfate for SBW processing. TRU waste from processing alumina calcine is estimated to contain about 1400 ppm by weight total actinides, including 1200 ppm uranium and 75 ppm plutonium, and the remainder primarily ²³⁷Np. For zirconia calcine, the TRU waste is estimated to contain about 1100 wt ppm by weight uranium, 130 ppm by weight plutonium and 20 ppm americium and neptunium.

As an alternative to denitration of low activity effluents for this alternative, neutralization followed by evaporation/crystallization could be considered. Waste volumes increase due to the nitrates that would crystallize and due to the cations from the neutralization agent. Assuming caustic is used to neutralize the waste effluents to a H⁺ concentration of 0.05 moles/liter, and a waste solids loading in the grout of 12%, the volume of grouted waste for this alternative is estimated to be 10,000 m³ from processing SBW and 150,000 from processing calcine.

Summary of Process Descriptions and Status

Brief process descriptions of the different options are given below. More complete and up-to-date descriptions can be found in the Scoping Study Reports for each option and the Feasibility Study for the Full Separations Option.

Calcination Calcination will be used in all alternatives, and is a process for converting a liquid waste into a solid particulate material. The existing calciner is a fluidized bed. Air is used to fluidize the bed and kerosene is used as fuel to achieve the operating temperature of 500°C. Liquid waste from the tank farm is combined with additives (aluminum nitrate nonahydrate, calcium nitrate and boric acid) and recycle liquid from the scrub system to make up the feed to the calciner. Nitrates and nitric acid in the calciner feed are converted mostly to NO_x and N₂. Volatile

species in the waste such as mercury and chlorides vaporize in the calciner, but through recycle of the scrub solution to the feed, may become incorporated, in part, in the solid calcine. Additional information on calcination chemistry can be found in Reference 20.

A conceptual design has been completed for modifications to the calciner to enable processing of sodium bearing waste.²¹ SBW has been calcined in the past only as a blend with other waste types. A feasibility study has also recently been completed for additional modifications to the calciner that would be necessary if the emissions limits of the proposed MACT rules are judged applicable to the calciner.⁴⁶

Vitrified Waste Option (VVO) Vitrification is a process for converting a feed or waste material into glass. The VVO process combines dry calcine with pre-formulated glass powder, called "frit", in a melter to produce a waste form suitable for direct disposal. The calcine is not encapsulated but becomes an integral part of the chemistry of the product glass. The melter operates at a temperature of around 1100°C. At this temperature the chemical constituents of the calcine and frit dissolve or melt in the molten glass bath, resulting in a new product material. This product is removed in the molten state and cast directly into canisters for storage and disposal. Numerous small-scale tests have been performed to determine suitable frit compositions and waste loading rates.¹⁰⁻¹⁵ Additional information on the status of the development of vitrification of calcine can be found in References 56-57.

Direct Cementitious Waste Option (DCWO) The DCWO process treats calcined HLW and calcined SBW by combining this waste material with clay, blast furnace slag, and caustic soda to produce a hydroceramic form of feldspathoid/zeolite. The process considered in this study is a marriage of Handford's "Clay Reaction Process" and Oak Ridge National Laboratory's FUETAP Process.^{58,59} The process includes mixing a thick paste of calcine and hydroceramic additives, casting the paste into a waste canister, curing the hydroceramic under temperature and pressure, removing the free water from the hydroceramic by baking, and then sealing the canister. Additional information on this option can be found in the DCWO Scoping Study Report, INEEL/EXT-97-01399, December, 1997.

Cementitious Waste Option (CWO) Darryl Siemer has proposed a process to treat HLW that combines grouting with pretreatment of the waste.³³ Prior to grouting, existing solid HLW calcine, liquid SBW and sucrose (sugar) would be slurried together and calcined. Recalcined solids would then be grouted by the same process as described above for the DCWO. Pretreatment in this manner would accomplish the following objectives: (a) Remaining SBW in the tank farm would be calcined with minimal required additives and minimal NO_x emissions, (b) Alkali metals in SBW would be redistributed throughout the calcine to facilitate grouting, (c) Mercury in calcine would be removed prior to grouting, eliminating concerns about mercury leaching from grout. The grouted waste form would be technically suitable for disposal (assuming the calcine is successfully delisted). In the event that regulatory constraints on disposal require a glass or ceramic waste form, the grouted waste could be further processed by HIP'ing (see the HWO discussion below). Siemer has performed small-scale tests to produce both grouted and grouted/HIP'ed waste forms.⁴⁵ Additional conceptual information is available on this process in an evaluation performed by Fluor Daniel, Inc.,³² and in the CWO Scoping Study Report, INEEL/EXT-97-01400.

Hot Isostatic Press (HIP) Waste Option (HWO) The HIP'ing process was invented by researchers at Battelle Columbus Laboratories in 1955, and involves heating and pressurizing a siliceous mixture until the point is reached at which phase transformation occurs. This results in the formation of a glass-ceramic having 40-60% higher density than the starting mixture, and possessing waste immobilization properties similar to those of borosilicate glass. The HWO process uses HIP'ing to convert calcine to a glass-ceramic waste form. In a conceptual flowsheet for the process, calcine from storage is mixed with amorphous silica (e.g., INEEL soil) and powdered titanium or aluminum. This mixture is then placed in a stainless steel HIP can and heated to about 650°C to drive off volatile components. The can is then sealed, decontaminated, and placed in a HIP'ing vessel. The pressure and temperature in the vessel are raised to 5,000-20,000 psi and 850-1050°C, respectively, by injecting an inert gas and activating

electric heating elements inside the vessel. After a prescribed "soak" time, the vessel is depressurized, and the HIP'ed can is removed to cool. The resulting HIP'ed waste mixture is a leach-resistant glass-ceramic. Subscale HIP'ing tests have been performed using calcine simulants.²³⁻²⁵ Chemical durability of properly-HIP'ed waste forms has been shown to be equal or superior to that of borosilicate glass, and EPA has proposed the glass-ceramic process as an acceptable technology to meet the BDAT criterion for immobilizing ICPP calcined waste.³⁸

Full Separations Option The Full Separations Option involves several processing units. Calcine is first dissolved and the solution fed to ion exchange columns to remove cesium. The effluent from cesium removal is fed to the TRUEX process, which uses an organic solvent to extract actinides. Aqueous effluents resulting from solvent cleanup are sent to low-level waste treatment, while the TRUEX strip effluent is sent to high activity waste processing. Strontium is removed from the TRUEX raffinate in the SREX process, which, like TRUEX, is a liquid-liquid extraction process using organic solvents. Low-level wastes are evaporated, denitrated, and then grouted. High activity wastes are evaporated and then vitrified. Spent ion exchange resin as well as undissolved solids from dissolution are also vitrified. A more complete description of the base case separations alternative treatment units is given in References 17 and 52.

A variation of the full separations option replaces the denitration step with neutralization and evaporation. This case is discussed in Reference 53.

TRU Separation Options There are two cases of the TRU Separations. In the TRU / Class C Option, calcine is dissolved and actinides removed from the resulting solution by the TRUEX process. TRUEX wash effluents and raffinate along with other ICPP low level wastes, are evaporated, denitrated and grouted. The TRUEX strip effluent is evaporated, crystallized, dried and packaged for shipment to WIPP. An alternative to denitration would be to neutralize and evaporate the effluents from separation. The TRU / Class A Option is identical to the Full Separation Option, except that the TRUEX strip effluent is not combined with high activity wastes, but processed separately into a dry granular product. Additional details on the TRU Separations Option can be found in the TRU Separations Scoping Study, Reference 54.

Estimates of Radionuclide and Hazardous Constituent Concentrations in Waste Products

The following tables present estimates of radionuclide and hazardous constituent concentrations in waste products that would be produced in the different options. These tables are based on the best currently available information, but may not be complete or accurate. Generally blanks in the tables denote the lack of information, and not a zero concentration for a particular species. Decay dates are given for radionuclides on most tables, and different decay dates account for a portion of the differences in values from different sources. Data from analyses of SBW and calcine that will be performed in the future should be used in future design on any of the options.

One inconsistency in a few of the tables is noted here. While radionuclide activities were generally decayed to the year 2016, activities of SBW were based on available analyses, performed at different times and not decayed. Thus tables showing activities of wastes for options in which SBW and calcine are combined are based on summations of activities at different decay dates. Calculations were made to obtain decayed and more complete activities for SBW and these are attached at the end of this EDF. However these calculations were obtained at too late a date to be incorporated into the tables.

Estimated Calcine Activity

Very little radiochemical analysis has been performed on calcine samples, and in several references containing calcine activity data, the source of the data is not documented. Table 1a shows fission product activities for existing calcine as taken from two sources. Values labeled "CBM" are from output from the CPPSIM model,

"icpp/output/xvgr/hlw-accelerated-rhif-alo2b.text", generated by Clark Millet on January 31, 1997. Documentation of the source of this data is given in Reference 26, and is from Reference 27 (WINCO-1050), modified to fill Bin Set 5 based on personal communications between Clark Millet and Dan Staiger. The numbers in Table 1a in CBM columns are activities decayed to January 1, 2002. Both the average activity for Bin Sets 1-5 and the maximum Bin Set average are shown. Since calcine in Bin Sets 1-5 accounts for 96% of the existing calcine, this data can be used for the total existing calcine.

The data reported in Table 1a for alumina and zirconia calcine are recent calculations performed by Doug Wenzel.^{47,48} These activities are decayed to 2016, and are intended to be representative of the two major calcine types. Wenzel reports activities for 57 fission products for alumina calcine and 45 for zirconia calcine. Only a partial list of these radionuclides is shown in Table 1a.

Actinide activities for existing calcine are shown in Table 1b. Table 1b includes (1) activities reported in IDO-10105 (Reference 29), (2) the same activities prorated down to the total average actinide concentration in calcine reported in WINCO-1050 (Reference 27), and (3) activities calculated by Doug Wenzel for alumina and zirconia calcine. Wenzel's activities include 83 actinides and daughter radionuclides for alumina calcine and 56 for zirconia calcine; only a partial list is shown in Table 1b. The activities shown in Table 1b as calculated by Wenzel are decayed to the year 2016.

WINCO-1050 also reports the following average actinide concentrations for each bin set:

	Ci/kg	Ci/m ³
Bin Set 1	0.217	230
Bin Set 2	0.094	128
Bin Set 3	0.054	83
Bin Set 4	0.055	83
Bin Set 5	0.065	95.

Table 1a. Fission Product Activities in Existing Calcine.

Source:	CBM	CBM	D. Wenzel	D. Wenzel	CBM	CBM	D. Wenzel	D. Wenzel
Units:	Ci/g	Ci/g	Ci/g	Ci/g	Ci/m ³	Ci/m ³	Ci/m ³	Ci/m ³
Isotope	Bin 1-5 Average	Maximum Bin Set Ave	Bin Set 1 Alumina Calcine	Bin Set 2 Zirconia Calcine	Bin 1-5 Average	Maximum Bin Set Ave	Bin Set 1 Alumina Calcine	Bin Set 2 Zirconia Calcine
Decayed to	2002	2002	2016	2016	2002	2002	2016	2016
Ba-137m			3.3E-03	9.4E-04			3,600	1,500
Ce-144	2.8E-09	1.9E-08	4.5E-23		4.2E-03	3.1E-02	4.9E-17	
Cs-134	3.3E-07	8.0E-07	1.8E-11	2.9E-09	0.50	1.2	2.0E-05	4.6E-03
Cs-137	1.7E-03	4.0E-03	3.5E-03	9.9E-04	2,500	4,800	3,800	1,600
Eu-154	8.3E-06	1.4E-05	1.6E-06	3.9E-06	13	23	1.7	6.2
Eu-155	3.7E-06	1.3E-05	9.7E-08	5.6E-09	5.5	20	0.11	9.0E-03
Pm-147	2.3E-06	8.9E-06	1.3E-08	5.9E-07	3.4	14	0.014	0.94
Ru-106	1.5E-10	4.5E-10	2.6E-19		2.3E-04	6.9E-04	2.8E-13	
Sb-125	8.5E-09	3.0E-08	5.3E-10	1.8E-08	1.3E-02	4.6E-02	5.8E-04	0.029
Sr-90	1.6E-03	3.7E-03	3.2E-03	1.3E-03	2,300	4,400	3,500	2,100
Sm-151			7.1E-05	2.2E-05			77	35
Tc-99			1.8E-06	3.1E-07			2.0	0.50
Y-90			3.2E-03	1.3E-03			3,500	2,100

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Estimates of fission product activity for calcine from waste in tanks WM-188 and WM-189 are shown in Table 2a. Two sources were used for estimating these activities. Output from the CPPSIM model (contained in Reference 9 and documented in Reference 26) contains estimated fission product activities for Bin Set 6 at January 1, 2002, at which time the Bin Set volume is estimated to be 1397 m³. Thus these activities for Bin Set 6 calcine include that produced from WM-188 and WM-189 plus additional calcine from other wastes generated after 1996. Calcine fission product concentrations were also estimated based on sample results for WM-188, contained in Reference 3. Fission products activities were not decayed from sample analysis dates (1996-1997).

Estimates of actinide concentrations in calcine from WM-188 were also made from tank waste inventories, as documented in Reference 44. These estimates are shown in Table 2b. As the tank farm inventories do not contain isotopic breakdowns for uranium, radiochemical analysis data from Bin Set 2 samples were used to obtain the isotopic breakdown for uranium:

U-234	4.0 wt%
U-235	65.6 wt%
U-236	5.8 wt%
U-238	24.7 wt%.

Table 1b. Actinide Activities in Existing Calcine.

Source	IDO- 10105(a)	IDO- 10105(a) & WINCO- 1050(b)	D. Wenzel Alumina Calcine(c)	D. Wenzel Zirconia Calcine(c)	IDO- 10105(a)	IDO- 10105(a) & WINCO- 1050(b)	D. Wenzel Alumina Calcine(c)	D. Wenzel Zirconia Calcine(c)
	Ci/g	Ci/g	Ci/g	Ci/g	Ci/m3	Ci/m3	Ci/m3	Ci/m3
Am-241	9.1E-07	3.9E-07	5.4E-07	1.7E-06	1.3E+00	5.6E-01	0.59	2.7
Am-243	8.3E-09	3.6E-09	1.9E-11	2.9E-14	1.2E-02	5.1E-03	2.1E-05	4.6E-08
Cm-242	6.5E-07	2.8E-07	1.5E-11	3.7E-13	9.4E-01	4.0E-01	1.6E-05	5.9E-07
Cm-244	5.2E-07	2.2E-07	3.0E-11	6.5E-14	7.5E-01	3.2E-01	3.3E-05	1.0E-07
Np-237	7.1E-10	3.0E-10	5.0E-09	3.8E-10	1.0E-03	4.3E-04	5.5E-03	6.1E-04
Pu-238	7.0E-05	3.0E-05	1.9E-06	1.5E-05	1.0E+02	4.3E+01	2.1	24
Pu-239	7.0E-07	3.0E-07	2.4E-07	2.4E-07	1.0E+00	4.3E-01	0.26	0.38
Pu-240	6.5E-07	2.8E-07	9.6E-08	2.2E-07	9.4E-01	4.0E-01	0.10	0.35
Pu-241	1.6E-04	6.9E-05	8.4E-07	7.0E-06	2.3E+02	9.9E+01	0.92	11
Pu-242	1.8E-09	7.7E-10	7.2E-12	5.0E-10	2.6E-03	1.1E-03	7.8E-05	8.0E-04
U-232			6.7E-13	7.4E-13			7.3E-07	1.2E-06
U-233	1.2E-15	5.2E-16	7.0E-13	4.7E-14	1.7E-09	7.5E-10	7.6E-07	7.5E-08
U-234	4.3E-13	1.8E-13	1.5E-08	1.2E-08	6.2E-07	2.6E-07	0.016	0.019
U-235	1.8E-12	7.7E-13	1.0E-10	7.6E-11	2.6E-06	1.1E-06	1.1E-04	1.2E-04
U-236	1.0E-11	4.3E-12	2.4E-10	2.0E-10	1.4E-05	6.2E-06	2.6E-04	3.2E-04
U-237	4.8E-15	2.1E-15	2.1E-11	1.7E-10	6.9E-09	3.0E-09	2.3E-05	2.7E-04
U-238	1.0E-17	4.3E-18	5.8E-12	3.7E-12	1.4E-11	6.2E-12	6.3E-06	5.9E-06
Pa-233			5.0E-09	3.8E-10			5.5E-03	6.1E-04
Total	2.33E-04	1.00E-04	3.6E-06	2.4E-05	3.36E+02	1.44E+02	4.0	39

(a) Activities reported in IDO-10105, issued in 1986, are for 3-year cooled waste.

(b) The total actinide activity is as per WINCO-1050; activities in IDO-10105 were prorated to this total.

(c) Activities reported are decayed to 2016.

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Table 2a. Estimates of Fission Product Activity in Calcine from WM-188 & WM-189.

	From CBM	Est'd from tank comp	From CBM	Est'd from tank comp
Decayed to	2002	1996-97	2002	1996-97
	<u>Ci/g</u>	<u>Ci/g</u>	<u>Ci/m3</u>	<u>Ci/m3</u>
Co-60		1.5E-06		2.4
Ce-144	1.8E-08		0.025	
Cs-134	1.7E-06	6.4E-06	2.4	11
Cs-137	2.4E-04	1.4E-03	340	2400
Eu-154	4.4E-06	7.3E-06	6.3	12
Eu-155	1.3E-07	2.9E-06	0.19	4.7
Ru-106	1.4E-08		0.02	
Sb-125	4.6E-08		0.07	
Sr-90	2.3E-04	1.1E-03	330	1800

Table 2b. Estimates of Actinide Activity in Calcine from WM-188 & WM-189.

	<u>Ci/g</u>	<u>Ci/m3</u>
Decayed to	1996-97	1996-97
Am-241	2.2E-07	3.6E-01
Np-237	2.7E-08	4.4E-02
Pu-238	3.0E-06	5.0E+00
Pu-239	4.6E-07	7.6E-01
U-232	6.2E-12	1.0E-05
U-234	1.2E-07	2.0E-01
U-235	6.7E-10	1.1E-03
U-236	1.8E-09	2.9E-03
U-238	3.9E-11	6.5E-05

Concentrations of radionuclides in calcine that would be produced from SBW were estimated from tank compositions for WM-180, WM-181, WM-184 and WM-185, as given in Reference 7. All tritium in the waste tanks was assumed to be volatilized in calcination and released to the atmosphere. In contrast, all other radionuclides were assumed to remain with the calcine. This will not be true for I-129, Ru-106, and possibly other radionuclides (see discussion of radionuclide volatility in calciner, Appendix B22 of Reference 20), but will provide conservative estimates. Estimates are shown in Table 3. The isotopic breakdown for uranium was assumed to be 90.59 wt% U-238, 9.35 wt% U-235, 0.02% U-233, 0.02 wt% U-234 and 0.02 wt% U-236. The U-232 concentration was estimated based on U-232 to U-238 ratios in alumina and zirconia calcine in References 47-48. A large uncertainty in the activity in the SBW calcine results from the uncertainty in the calcine volume. For Table 3, a volume of 700 m³ was assumed.

Table 3. Estimated Activity of Calcine from SBW.

	<u>Ci/g</u>	<u>Ci/m3</u>		<u>Ci/g</u>	<u>Ci/m3</u>
Decayed to	1988-93	1988-93		1988-93	1988-93
Co-60	1.0E-06	1.2E+00	Am-241	2.0E-07	2.4E-01
Ce-144	2.1E-05	2.6E+01	Np-237	8.7E-09	1.0E-02
Cs-134	4.0E-06	4.8E+00	Pu-238	2.7E-06	3.2E+00
Cs-135	1.9E-09	2.3E-03	Pu-239	2.8E-07	3.4E-01
Cs-137	1.4E-04	1.7E+02	Pu-240	6.8E-08	8.2E-02
Eu-154	8.4E-07	1.0E+00	Pu-241	2.5E-06	3.0E+00
Eu-155	1.3E-06	1.6E+00	Pu-242	4.3E-11	5.2E-05
I-129	6.7E-09	8.0E-03	U-233	6.0E-10	7.2E-04
Ni-63	1.7E-07	2.0E-01	U-234	3.9E-10	4.7E-04
Ru-106	8.7E-06	1.0E+01	U-235	6.3E-11	7.5E-05
Sb-125	1.7E-06	2.0E+00	U-236	4.0E-12	4.8E-06
Sr-90	1.4E-04	1.6E+02	U-238	9.5E-11	1.1E-04
Tc-99	3.8E-08	4.6E-02			

Insufficient data are available on the composition of wastes projected to be generated in the future to estimate activities of calcine from these wastes. In this absence of data, I recommend using either the existing calcine composition as a worst case or the Bin Set 6 composition, as a more realistic case. Estimated fission product activities for Bin Set 6, as per CPPSIM output, are shown in Table 4.

Table 4. Estimated Fission Product Activities for Bin Set 6.

	<u>Ci/g</u>	<u>Ci/m3</u>		<u>Ci/g</u>	<u>Ci/m3</u>
Decayed to	2002	2002		2002	2002
Ce-144	2.1E-08	2.5E-02	Eu-155	1.6E-07	1.9E-01
Cs-134	2.0E-06	2.4E+00	Ru-106	1.7E-08	2.0E-02
Cs-137	2.8E-04	3.4E+02	Sb-125	5.5E-08	6.6E-02
Eu-154	5.2E-06	6.3E+00	Sr-90	2.7E-04	3.3E+02

RCRA Constituents of Calcine

Little analytical data are available for RCRA-hazardous contaminants in calcine. Based on liquid waste analyses, estimates can be made for a few RCRA metals. However, until recently, analyses for hazardous organics or the full list of RCRA-hazardous metals were not performed for tank farm waste. Thus for a large percentage of the existing calcine, the concentrations of most hazardous materials, if present at all, are unknown. The available data on RCRA constituents in existing or future calcine is given in Tables 5-8.

Hazardous component concentrations in calcine provide the basis for hazardous component concentrations in many of the waste forms being considered in the EIS. Little data is available to determine, or even estimate, concentrations of hazardous organic species and some of the hazardous metals. In lieu of better data, I recommend using the following:

Existing Calcine

Hazardous metals: Use Table 5

Other hazardous metals not shown in Table 5: Use Table 6

Hazardous organics: Assume none

Others: For vanadium and KCN, use maximum concentrations of 3 mg/l (2 mg/kg) for vanadium and 0.02 mg/l (0.014 mg/kg) for KCN, based on Table 8

WM-188/WM-189 Calcine and Calcine from Other ICCP Generated Waste

Hazardous metals: Use Table 6

Hazardous organics: Assume none (based on analysis of WM-185)

Others: Assume none

SBW Calcine

Hazardous metals and Fluoride: Use Table 7

Hazardous organics: As per analyses of WM-180, WM-181 and WM-185

Others: Assume none.

Table 5 shows estimates of some RCRA metals in the calcine bin sets. Data for Bins 1-5 are based on calcine compositions calculated from calciner feed composition (from data for each bin strata, as calculated by Dan Staiger). Data for Bin Set 6 is from output from the CPPSIM model, as generated by Clark Millet (see Reference 25).

Table 5. Estimated RCRA Metal and Fluoride Concentrations in Calcine Bin Sets.

	<i>Bin Set 1</i>	<i>Bin Set 2</i>	<i>Bin Set 3</i>	<i>Bin Set 4</i>	<i>Bin Set 5</i>	<i>Bin Set 6</i>	<i>Average, Bin Sets 1-6</i>	<i>Average, Bin Sets 1-5</i>
	<u>mg/kg</u>	<u>mg/kg</u>	<u>mg/kg</u>	<u>mg/kg</u>	<u>mg/kg</u>	<u>mg/kg</u>	<u>mg/kg</u>	<u>mg/kg</u>
Cd	0	0	0	0	29,000	4,600	7,200	7,900
Cr	0	2,900	5,100	4,300	1,400	1,400	2,900	3,300
Hg	35,000	10,000	650	570	2,200	2,000	4,200	4,800
Ni	0	0	40	0	110	550	150	41
Pb	0	0	0	0	0	570	120	0
U	0	4.8	9.5	50	140	24	45	51
F	0	210,000	250,000	260,000	200,000	17,000	190,000	220,000
	<u>mg/l</u>	<u>mg/l</u>	<u>mg/l</u>	<u>mg/l</u>	<u>mg/l</u>	<u>mg/l</u>	<u>mg/l</u>	<u>mg/l</u>
Cd	0	0	0	0	44,000	5,500	10,000	12,000
Cr	0	4,200	8,100	6,900	2,200	1,600	4,100	5,000
Hg	42,000	15,000	1,000	920	3,400	2,400	6,100	7,300
Ni	0	0	59	0	170	660	210	63
Pb	0	0	0	0	0	690	170	0
U	0	7	15	79	220	28	65	77
F	0	300,000	390,000	410,000	310,000	20,000	270,000	330,000

Estimates have been made for hazardous metals in WM-188 by Schindler³⁰ and Rivard,³ and concentration ranges for hazardous materials in tank farm wastes have also been reported by Wichmann, et. al.³¹ These concentrations are shown in Table 6, along with estimates of the contaminant concentrations in calcine corresponding to the tank farm waste concentrations. As seen in Table 6, reported concentrations for WM-188 for many contaminants are an

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order of magnitude higher than the high-end values reported by Wichmann, and for a few contaminants, there is poor agreement between the values reported by Schindler and Rivard for WM-188.

Table 6. Hazardous Constituents in WM-188, Tank Farm and Corresponding Concentrations in Calcine.

Source	RJR-02-96	Schi-26-96	DOE/ID-10544	Calcine	Calcine	Calcine	Calcine
	WM-188	WM-188	Tank Farm	based on RJR-02-96	based on Schi-26-96	based on RJR-02-96	based on Schi-26-96
	<u>mg/l</u>	<u>mg/l</u>	<u>mg/l</u>	<u>mg/kg</u>	<u>mg/kg</u>	<u>mg/l</u>	<u>mg/l</u>
Fluoride	5870	6840	334- 239,400 ^(a)	18,000	20,000	22,000	24,000
Antimony	0.156	1.8		0.49	5.2	0.6	6.2
Arsenic	17	67	<3.21	54	193	65	231
Barium	15	15	6.8-7.5	48	43	57	52
Beryllium	0.0003	0.13		0.0009	0.37	0.0011	0.45
Cadmium	1460	1700	83-97	4,500	4,900	5,500	5,900
Chromium	830	770	135-201	2,600	2,200	3,100	2,700
Lead	210	266	<4.13-441	650	770	790	920
Mercury	1400	1720	190-205	4,400	4,900	5,200	5,900
Nickel	410	370	10.9-51.4	1,300	1,100	1,500	1,300
Selenium	1.3	1.5	0.82-2.42	4.1	4.3	4.9	5.2
Silver	12.76	3.2	0.48-<2.94	40	9.2	48	11
Thallium	1.5	9		4.6	26	5.5	31
Uranium	125	104		390	300	470	360

^(a) High-end concentration, equivalent to 12.6 MF, is apparently in error.

Schindler²⁹ also reports analyses performed on samples from three SBW tanks, WM-180, WM-181, and WM-185, for hazardous constituents, including VOCs. The only VOCs detected in any of the tanks were 2-hexanone, at concentrations of 1-2 ng/ml in WM-180 and 7-35 ng/ml in WM-181, and 4-methyl-2-pentanone (MIBK), at concentrations on 1 ng/ml in WM-180 and 2-4 ng/ml in WM-181. Neither of these species were detected in WM-185.

The following VOCs were not detected in any of the three tanks, the detection limit being 1 ng/ml:

1,1-dichloroethane	cis-1,3-dichloropropylene
1,1,1-trichloroethane	ethylbenzene
1,1,2-trichloroethane	methylene chloride
1,1,2,2-tetrachloroethane	stryrene
1,2-dichloroethane	tetrachloroethylene
1,2-dichloropropane	toluene
benzene	trans-1,2-dichloroethylene
bromodichloromethane	trans-1,3-dichloropropylene
bromoform	trichloroethylene
carbon tetrachloride	vinyl chloride
chloroform	xylene (m-, p- and o-).
cis-1,2-dichloroethylene	

WM-185 was also analyzed for the following species, none of which were detected:

1,1-dichloroethylene
2-butanone (MIK)
acetone
bromomethane
carbon disulfide
chlorobenzene
chloromethane.

Based on the above analyses of SBW, I recommend that we assume there will not be VOCs present in calcine that will be produced from SBW.

Concentrations of hazardous metals and fluoride in SBW are shown in Table 7, as reported by Schindler.³⁰ Also shown in Table 7 are corresponding concentrations in calcine. The calcine estimates assume no loss of metals due to volatilization in calcination. The range of concentrations shown for calcine are based on the range of concentrations of the hazardous component in the three waste tanks. Calcine concentrations are shown for Al to Na+K ratios of 1.5 and 3.5.

Table 7. Hazardous Metal and Fluoride Concentrations in SBW and SBW Calcine.

	WM-180	WM-181	WM-185	Calcine, Al/Na+K=1.5	Calcine, Al/Na+K=3.5	Calcine, Al/Na+K=1.5	Calcine, Al/Na+K=3.5
	<u>mg/l</u>	<u>mg/l</u>	<u>mg/l</u>	<u>mg/l</u>	<u>mg/l</u>	<u>mg/kg</u>	<u>mg/kg</u>
Ag	0.48	3.66	10.1	1.9-53	1.1-31	1.6-44	0.9-26
As	3.5	3	0.11	0.6-24	0.3-14	0.5-20	0.3-12
Ba	7.1	5.1	9	29-47	16-28	24-39	14-23
Cd	90	584	172	370-4,600	210-2,700	300-3,800	170-2,300
Cr	198	151	255	810-1,300	460-780	670-1,100	380-650
Hg	195	90	782	700-4,600	420-2,400	590-3,400	350-2,000
Ni	94	70	88	380-550	220-320	320-460	180-380
Pb	290	207	190	1,000-1,600	580-960	830-1,400	480-800
Se	0.82	1	1	3.3-7.8	1.9-5.2	2.8-6.5	1.6-3.9
U	78	76	86	320-700	180-350	260-500	150-370
F	800	1700	3000	3,300-16,000	1,900-7,900	2,700-13,000	1,500-7,700

Wichmann³⁰ reports concentrations of chemicals classified as "secondary waste codes" that may be present in tank farm wastes based on possible disposal of laboratory chemicals to the tank farm from 1963 to 1968. Neglecting those chemicals which were not detected in tank farm analyses, Table 8 shows these concentrations.

Because of the combustion reactions in the calciner, little if any of the VOCs and SVOCs listed in Table 8 would be expected in the calcine. Silver cyanide decomposes at 320°C, a temperature below the calcination temperature, sodium azide also decomposes upon heating, and hydrazine could also be expected to decompose in the calciner and also in the acidic tank farm solution. Thus the only potential contaminants shown in Table 8 that could be retained in calcine are vanadium pentoxide and potassium cyanide. While these contaminants could possibly be present in existing calcine, it is unlikely that they would be present in any future generated calcine because none have been disposed in the tank farm since 1988. It is unknown whether other contaminants are produced in calcination and retained in calcine because of incomplete combustion of calciner fuel.

Table 8. Potential Hazardous Constituents in Tank Farm Waste Based on Laboratory Chemicals.

	<u>mg/l</u>		<u>ppb</u>
Carbon Tetrachloride	2.7	2-Nitrophenol	89
Carbon Tetrachloride	41 ^(a)	1,2,4-Trichlorobenzene	10
Chloroform	0.3	Naphthalene	10
Methyl Ethyl Ketone	0.17	Acenaphthene	39
Pyridine	14	2,4-Dinitrotoluene	81
1,1,1-Trichloroethane	1860	2,4-Dinitrophenol	95
1,1,2-Trichloroethane	1860	Diethylphthalate	128
Carbon Disulfide	0.4	Pentachlorophenol	10
Methylene Chloride	0.04	Di-n-butylphthalate	10
Toluene	3	Butylbenzylphthalate	10
Potassium Cyanide	0.005	Di-n-octylphthalate	10
Silver Cyanide	0.13	Benzo(a)pyrene	10
Sodium Azide	0.1		
Ammonium Vanadate	0.016		mg/l
Vanadium Pentoxide	0.8		
Acetonitrile	0.05	Formic Acid	0.24
Analine	0.8	Hydrazine	0.068
1,4-Dioxane	3.7	Phenol	0.17
Formaldehyde	0.004	Thiourea	2.1

^(a) Two different concentrations are shown by Wichmann for CCl₄ under waste codes D019 and F002.

Contaminants in Vitrification Waste Option Glass

Radionuclide activities for glass in the VWO from existing calcine were based on the activities for alumina and zirconia calcine shown in Tables 1a and 1b and for calcine from SBW shown in Table 3. It was assumed that no radionuclides would volatilize in the vitrification process except for I-129, and that 100% of I-129 would volatilize.

Estimated concentrations of hazardous substances in direct vitrification glass are shown in Table 10. As for radionuclides, the concentrations in Table 10 are estimated from maximum values in calcine, from Tables 5-8. It was assumed all mercury and organics vaporize in the vitrification process, and all potassium cyanide decomposes. Although it is likely that a portion of the semivolatile metals will vaporize, none was assumed in the concentrations shown in Table 10.

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Table 9. Estimated Activity of Glass from VWO.

	<i>Alumina</i>	<i>Zirconia</i>	<i>SBW</i>	<i>Alumina</i>	<i>Zirconia</i>	<i>SBW</i>
	<i>Calcine</i>	<i>Calcine</i>		<i>Calcine</i>	<i>Calcine</i>	
	<u>Ci/g</u>	<u>Ci/g</u>	<u>Ci/g</u>	<u>Ci/m³</u>	<u>Ci/m³</u>	<u>Ci/m³</u>
Decayed to	2016	2016	1988-93	2016	2016	1988-93
Ba-137m	6.9E-04	2.9E-04		1.8E+03	7.6E+02	
Co-60		1.8E-08	3.0E-07		4.6E-02	7.8E-01
Ce-144		2.0E-16	6.3E-06	2.5E-17	5.2E-10	1.6E+01
Cs-134	3.8E-12	9.0E-10	1.2E-06	9.8E-06	2.3E-03	3.1E+00
Cs-137	7.4E-04	3.1E-04	4.2E-05	1.9E+03	8.0E+02	1.1E+02
Eu-154	3.4E-07	1.2E-06	2.5E-07	8.7E-01	3.1E+00	6.6E-01
Eu-155	2.0E-08	1.7E-09	3.9E-07	5.3E-02	4.5E-03	1.0E+00
Pm-147	2.7E-09	1.8E-07		7.1E-03	4.8E-01	
Ru-106		1.9E-14	2.6E-06	1.4E-13	4.8E-08	6.8E+00
Sb-125	1.1E-10	5.6E-09	5.1E-07	2.9E-04	1.5E-02	1.3E+00
Sm-151	1.5E-05	6.8E-06		3.9E+01	1.8E+01	
Sr-90	6.7E-04	4.0E-04	4.2E-05	1.7E+03	1.0E+03	1.1E+02
Ni-63			5.1E-08			1.3E-01
Tc-99	3.8E-07	9.6E-08	1.1E-08	9.8E-01	2.5E-01	3.0E-02
Y-90	6.7E-04	4.0E-04		1.7E+03	1.0E+03	
Am-241	1.1E-07	5.3E-07	6.0E-08	2.9E-01	1.4E+00	1.6E-01
Am-243	4.0E-12	9.0E-15		1.0E-05	2.3E-08	
Cm-242	3.2E-12	1.1E-13		8.2E-06	3.0E-07	
Cm-244	6.3E-12	2.0E-14		1.6E-05	5.2E-08	
Np-237	1.1E-09	1.2E-10	2.6E-09	2.7E-03	3.1E-04	6.8E-03
Pa-233	1.1E-09	1.2E-10	2.6E-09	2.7E-03	3.1E-04	
Pu-238	4.0E-07	4.6E-06	7.8E-07	1.0E+00	1.2E+01	2.0E+00
Pu-239	5.0E-08	7.4E-08	8.4E-08	1.3E-01	1.9E-01	2.2E-01
Pu-240	2.0E-08	6.8E-08	2.0E-08	5.2E-02	1.8E-01	5.3E-02
Pu-241	1.8E-07	2.2E-06	7.5E-07	4.6E-01	5.6E+00	2.0E+00
Pu-242	1.5E-12	1.6E-10	1.3E-11	3.9E-06	4.0E-04	3.4E-05
Th-230	1.0E-10	9.0E-13		2.7E-04	2.3E-06	
Th-231	1.8E-11	2.4E-11		4.6E-05	6.1E-05	
U-232	1.4E-13	2.3E-13		3.7E-07	6.0E-07	
U-233	1.5E-13	1.5E-14	1.8E-10	3.8E-07	3.8E-08	4.7E-04
U-234	3.2E-09	3.7E-09	1.2E-10	8.2E-03	9.7E-03	3.0E-04
U-235	2.1E-11	2.4E-11	1.9E-11	5.5E-05	6.1E-05	4.9E-05
U-236	5.0E-11	6.2E-11	1.2E-12	1.3E-04	1.6E-04	3.1E-06
U-237	4.4E-12	5.3E-11		1.1E-05	1.4E-04	
U-238	1.2E-12	1.1E-12	2.9E-11	3.2E-06	3.0E-06	7.4E-05

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Table 10. Estimated Concentrations of Nonradiological Contaminants in Glass from VWO.

<i>Contaminant</i>	<i>Glass from Existing Calcine</i>	<i>Glass from WM- 188/189 Calcine</i>	<i>Glass from SBW Calcine</i>	<i>Glass from Gen'd Wastes Calcine</i>
	<u>mg/kg</u>	<u>mg/kg</u>	<u>mg/kg</u>	<u>mg/kg</u>
Antimony		1.6		
Arsenic		59	6	
Barium		15	12	
Beryllium		0.11		
Cadmium	2,300	1,500	1,100	1,400
Chromium	930	790	330	410
Mercury	0	0	0	0
Nickel	12	390	140	170
Lead		230	420	170
Selenium		1.3	1.9	
Silver		12	13	
Thallium		7.9		
Uranium	15	120	150	7.1
Vanadium				
Pentoxide	1.1			
Fluorides	62,000	6,000	3,900	5,000
Organics	none	none	none	none
	<u>mg/l</u>	<u>mg/l</u>	<u>mg/l</u>	<u>mg/l</u>
Antimony		4.1		
Arsenic		150	16	
Barium		38	30	
Beryllium		0.3		
Cadmium	5,900	3,900	3,000	3,600
Chromium	2,400	2,000	860	1,100
Mercury	0	0	0	0
Nickel	31	1,000	360	430
Lead		600	1,100	450
Selenium		3.4	5	
Silver		32	34	
Thallium		21		
Uranium	38	310	390	19
Vanadium				
Pentoxide	2.9			
Fluorides	160,000	16,000	10,000	13,000
Organics	none	none	none	none

Contaminants in Ceramic from HIP Waste Option

Estimated concentrations of hazardous substances in the HIPed ceramic waste are shown in Table 11 and radionuclides in Table 12. The concentrations of hazardous substances are estimated from calcine concentrations shown in Tables 5-8 and the radionuclides concentrations are estimated from activities of alumina calcine, zirconia calcine, and calcine from SBW shown in Tables 1a, 1b, and 3. It was assumed all mercury and organics vaporize in

the HIPing process, and all potassium cyanide decomposes. Although it is likely that a portion of the semivolatile metals will vaporize, no vaporization was assumed in the concentrations shown in Table 11.

Table 11. Estimated Concentrations of Nonradiological Contaminants in HIP'd Ceramic.

<i>Contaminant</i>	<i>HIPed Ceramic from Existing Calcine</i>	<i>HIPed Ceramic from WM- 188/189 Calcine</i>	<i>HIPed Ceramic from SBW Calcine</i>	<i>HIPed Ceramic from Gen'd Wastes Calcine</i>
	<u>mg/kg</u>	<u>mg/kg</u>	<u>mg/kg</u>	<u>mg/kg</u>
Antimony		3.6		
Arsenic		140	14	
Barium		34	27	
Beryllium		0.26		
Cadmium	5,500	3,400	2,700	3,200
Chromium	2,300	1,800	770	950
Mercury	0	0	0	0
Nickel	29	900	320	390
Lead		540	980	400
Selenium		3.0	4.6	
Silver		28	31	
Thallium		18		
Uranium	36	270	350	17
V ₂ O ₅	2.8			
Fluorides	150,000	14,000	9,100	12,000
Organics	none	none	none	none
	<u>mg/l</u>	<u>mg/l</u>	<u>mg/l</u>	<u>mg/l</u>
Antimony		12		
Arsenic		430	45	
Barium		110	88	
Beryllium		0.8		
Cadmium	18,000	11,000	8,500	10,000
Chromium	7,300	5,800	2,500	3,000
Mercury	0	0	0	0
Nickel	92	2,900	1,000	1,300
Lead		1,700	3,100	1,300
Selenium		9.6	15	
Silver		90	100	
Thallium		58		
Uranium	110	870	1,100	53
V ₂ O ₅	8.8			
Fluorides	500,000	44,000	29,000	37,000
Organics	none	none	none	none

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Table 12. Estimated Activity of HIP'd Ceramic.

	<i>Alumina Calcine</i>	<i>Zirconia Calcine</i>	<i>SBW)</i>	<i>Alumina Calcine</i>	<i>Zirconia Calcine</i>	<i>SBW</i>
	<u>Ci/g</u>	<u>Ci/g</u>	<u>Ci/g</u>	<u>Ci/m³</u>	<u>Ci/m³</u>	<u>Ci/m³</u>
Decayed to	2016	2016	1988-93	2016	2016	1988-93
Ba-137m	2.3E-03	6.6E-04		7400	2100	
Co-60		4.0E-08	7.0E-07		0.13	2.2
Ce-144	3.2E-23	4.5E-16	1.5E-05	1.0E-16	1.4E-09	47
Cs-134	1.3E-11	2.0E-09	2.8E-06	4.0E-05	3.8	9.0
Cs-137	2.5E-03	6.9E-04	9.8E-05	7800	2200	310
Eu-154	1.1E-06	2.7E-06	5.9E-07	3.6	8.7	1.9
Eu-155	6.8E-08	3.9E-09	9.1E-07	0.22	0.013	2.9
Pm-147	9.1E-09	4.1E-07		0.03	1.3	
Ru-106		4.2E-14	6.1E-06	5.5E-13	1.3E-07	19
Sb-125	3.7E-10	1.3E-08	1.2E-06	1.2E-03	0.04	3.8
Sm-151	5.0E-05	1.5E-05		160	49	
Sr-90	2.2E-03	9.1E-04	9.8E-05	7200	2900	310
Ni-63			1.2E-07			0.38
Tc-99	1.3E-06	2.2E-07	2.7E-08	4.0	0.69	0.085
Y-90	2.2E-03	9.1E-04		7200	2900	
Am-241	3.8E-07	1.2E-06	1.4E-07	1.2	3.8	0.45
Am-243	1.3E-11	2.0E-14		4.3E-05	6.5E-08	
Cm-242	1.1E-11	2.6E-13		3.4E-05	8.3E-07	
Cm-244	2.1E-11	4.6E-14		6.7E-05	1.5E-07	
Np-237	3.5E-09	2.7E-10	6.1E-09	1.1E-02	8.5E-04	0.02
Pa-233	3.5E-09	2.7E-10		1.1E-02	8.5E-04	
Pu-238	1.3E-06	1.1E-05	1.8E-06	4.3	34	5.8
Pu-239	1.7E-07	1.7E-07	2.0E-07	0.54	0.54	0.63
Pu-240	6.7E-08	1.5E-07	4.8E-08	0.22	0.49	0.15
Pu-241	5.9E-07	4.9E-06	1.8E-06	1.9	16	5.6
Pu-242	5.0E-12	3.5E-10	3.0E-11	1.6E-05	1.1E-03	9.6E-05
Th-230	3.4E-10	2.0E-12		1.1E-03	6.5E-06	
Th-231	5.9E-11	5.3E-11		1.9E-04	1.7E-04	
U-232	4.7E-13	5.2E-13		1.5E-06	1.7E-06	
U-233	4.9E-13	3.3E-14	4.2E-10	1.6E-06	1.1E-07	1.4E-03
U-234	1.1E-08	8.4E-09	2.7E-10	0.034	0.027	8.7E-04
U-235	7.0E-11	5.3E-11	4.4E-11	2.2E-04	1.7E-04	1.4E-04
U-236	1.7E-10	1.4E-10	2.8E-12	5.4E-04	4.5E-04	9.0E-06
U-237	1.5E-11	1.2E-10		4.7E-05	3.8E-04	
U-238	4.1E-12	2.6E-12	6.7E-11	1.3E-05	8.3E-06	2.1E-04

Contaminants in Cement from the Cementitious Waste Option

If existing calcine, SBW and other wastes are truly homogenized prior to forming cement, there will be a single homogeneous cement of unvarying contaminant concentrations produced in the CWO. To estimate radionuclide concentrations in CWO cement, radionuclides in the representative alumina and zirconia calcines (from Tables 1a and 1b, Wenzel's activities) were added to radionuclides in SBW, using proportions of 0.25 wt fraction alumina calcine, 0.64 wt fraction zirconia calcine, and 0.11 wt fraction SBW calcine. These resultant concentrations are shown in Table 13. It should be noted that the actual proportions of alumina, zirconia and SBW calcine that would be expected in the CWO cement are slightly different from the above weight fractions because of the different assumptions in calcining additives between calcining SBW (Table 3) and recalcining SBW with existing calcine.

Table 13. Estimated Radionuclide Concentrations in Cement from CWO.

	<u>Ci/g</u>	<u>Ci/m3</u>		<u>Ci/g</u>	<u>Ci/m3</u>
Ba-137m	5.8E-04	9.3E+02	Am-241	5.1E-07	8.2E-01
Ce-144	9.4E-07	1.5E+00	Am-243	2.0E-12	3.1E-06
Cs-134	1.8E-07	2.9E-01	Cm-242	1.6E-12	2.6E-06
Cs-137	6.2E-04	1.0E+03	Cm-244	3.1E-12	4.9E-06
Eu-154	1.2E-06	2.0E+00	Np-237	1.0E-09	1.6E-03
Eu-155	7.0E-08	1.1E-01	Pu-238	4.2E-06	6.8E+00
Pm-147	1.6E-07	2.5E-01	Pu-239	1.0E-07	1.6E-01
Ru-106	3.9E-07	6.3E-01	Pu-240	7.1E-08	1.1E-01
Sb-125	8.1E-08	1.3E-01	Pu-241	2.0E-06	3.3E+00
Sr-90	6.7E-04	1.1E+03	Pu-242	1.3E-10	2.1E-04
Sm-151	1.3E-05	2.1E+01	U-232	2.6E-13	4.2E-07
Tc-99	2.7E-07	4.3E-01	U-233	2.7E-11	4.3E-05
Y-90	6.7E-04	1.1E+03	U-234	4.7E-09	7.5E-03
Co-60	6.0E-08	9.6E-02	U-235	3.3E-11	5.3E-05
Ni-63	7.6E-09	1.2E-02	U-236	7.7E-11	1.2E-04
			U-237	4.7E-11	7.5E-05
Th-230	5.1E-11	8.1E-05	U-238	5.8E-12	9.3E-06
Th-231	2.9E-11	4.6E-05	Pa-233	6.1E-10	9.8E-04

Estimates of nonradiological contaminant concentrations in cement produced in the CWO are shown in Table 14. The feeds will be exposed to elevated temperatures in recalcination and also moderate temperatures during curing of the cement. Organics that survive the recalcination step will likely be retained in the cement. However, no reliable data is available which shows organics are present in calcine. Estimates in Table 14 assume all volatile or semivolatile metals that vaporize in recalcination or cement processing will be returned from offgas treatment systems to be incorporated in the cement. An exception to this assumption is mercury, for which a separate recovery system of mercury from the calcine offgas gas treatment scrub solution is planned. The values in Table 14 for mercury were estimated based on assuming a 32% retention of mercury in the calcine, based on data in Reference 34 and a recalcination temperature of 500°C.

Table 14. Estimates of Nonradiological Contaminant Concentrations in CWO Cement.

	<u>mg/kg</u>	<u>mg/l</u>		<u>mg/kg</u>	<u>mg/l</u>
Ag	3	4	Se	0.4	0.6
As	6	8	Sb	0.1	0.2
Ba	3	4	Tl	0.6	0.9
Be	0.009	0.013	F	70,000	100,000
Cd	2,800	4,100			
Cr	1,100	1,700	KCN	0.007	0.01
Hg	580	830	AgCN	0.2	0.3
Ni	90	120	NaN ₃	0.1	0.2
Pb	100	150	NH ₄ VO ₃	0.02	0.03
U	48	70	V ₂ O ₅	1.1	1.7

Estimates of nonradiological hazardous contaminant concentrations in cement were made by summing the amounts of contaminants in existing and future calcine (from Table 5, Average of Bins 1-6, 6.94 million kg total calcine) with the amounts of contaminants contained in SBW, and dividing by either the mass or volume of cement. The amount of contaminants in SBW was estimated by calculating the amounts in WM-180, WM-181 and WM-185, and multiplying by the ratio of the 2009 composite SBW (1.048 million gallons, unevaporated, Reference 7) volume to the sum of WM-180, WM-181 and WM-185 (749,400 gallons, unevaporated, Reference 30) volumes. Inorganic contaminants shown in Table 8 were assumed to be present only in the existing volume of calcine (3800 m³). Some of these inorganic contaminants may decompose during recalcination; thus their concentrations shown in Table 14 could be overestimated. For contaminants not shown in Table 5, but shown in Table 6, it was assumed the concentrations of Table 6 apply to the entire volume of existing calcine.

If the cement is further processed by HIPing, the contaminant concentrations, as mg/kg, will change only slightly due to loss of gases during venting. The waste will densify by about 60%³³ and hence the contaminant concentrations as mg/l will increase by the factor 1.6.

Contaminants in Grout from the Direct Cementitious Waste Option

Estimates of nonradionuclide contaminant concentrations in grout from the DCWO are shown in Table 15 and estimates of radiological concentrations are shown in Tables 16 and 17. The values in Tables 15 and 16 are averages for all grout produced. In the DCWO, the wastes will not be exposed to temperatures that are likely to result in destruction of organics, decomposition of hazardous inorganics or vaporization of volatile metals. Thus hazardous compounds, organic and inorganic, present in the calcine will likely be retained in the grout. However, as no reliable data is available which shows organics are present in calcine, no organics are shown in Table 15.

In the DCWO, only minimal attempts will be made to mix and homogenize the different types of calcine or waste prior to grouting. Thus contaminant concentrations will show variations as different calcines are grouted. Estimates of nonradiological contaminant concentration variations in the grout for different waste types can be calculated from the contaminant concentrations shown in Table 10 by using ratios of loadings and densities. The contaminant concentrations in grout, in units of mg/kg, are equivalent to those in Table 10 multiplied by the ratio of waste loading in grout and glass. For grout from existing calcine, from calcine from WM-188, and from calcine from SBW, these ratios are 1.22, 1.17, and 1.17 respectively. To obtain grout concentrations from Table 10 in units of mg/l, the appropriate factors include waste loading and waste density ratios. These factors, for grout from existing calcine, from calcine from WM-188, and from calcine from SBW, these ratios are 0.80, 0.76, and 0.76 respectively.

Table 15. Estimates of Nonradiological Contaminant Concentrations in Grout from DCWO.

	<u>mg/kg</u>	<u>mg/l</u>		<u>mg/kg</u>	<u>mg/l</u>
Ag	3	3	Se	0.3	0.4
As	5	6	Sb	0.1	0.14
Ba	2	3	Tl	0.5	0.7
Be	0.008	0.01	F	57,000	74,000
Cd	2,400	3,100			
Cr	1,000	1,300	KCN	0.006	0.008
Hg	1,500	2,000	AgCN	0.16	0.21
Ni	70	100	NaN3	0.1	0.2
Pb	90	110	NH4VO3	0.02	0.03
U	40	50	V2O5	1.0	1.3

Table 16. Estimates of Radionuclide Concentrations in "Average" Grout from DCWO.

	<u>Ci/g</u>	<u>Ci/m3</u>		<u>Ci/g</u>	<u>Ci/m3</u>
Ba-137m	4.9E-04	8.4E+02	Am-241	4.3E-07	7.3E-01
Ce-144	8.0E-07	1.4E+00	Am-243	1.7E-12	2.8E-06
Cs-134	1.5E-07	2.6E-01	Cm-242	1.4E-12	2.3E-06
Cs-137	5.3E-04	9.0E+02	Cm-244	2.6E-12	4.4E-06
Eu-154	1.0E-06	1.8E+00	Np-237	8.5E-10	1.4E-03
Eu-155	6.3E-08	1.1E-01	Pu-238	3.6E-06	6.1E+00
Pm-147	1.3E-07	2.2E-01	Pu-239	8.5E-08	1.4E-01
Ru-106	3.3E-07	5.6E-01	Pu-240	6.0E-08	1.0E-01
Sb-125	6.9E-08	1.2E-01	Pu-241	1.7E-06	2.9E+00
Sr-90	5.7E-04	9.7E+02	Pu-242	1.1E-10	1.9E-04
Sm-151	1.1E-05	1.9E+01	U-232	2.2E-13	3.8E-07
Tc-99	2.3E-07	3.8E-01	U-233	2.3E-11	3.9E-05
Y-90	5.7E-04	9.6E+02	U-234	4.0E-09	6.8E-03
Co-60	5.1E-08	8.6E-02	U-235	2.8E-11	4.7E-05
Ni-63	6.5E-09	1.1E-02	U-236	6.5E-11	1.1E-04
			U-237	4.0E-11	6.7E-05
Th-230	4.3E-11	7.3E-05	U-238	4.9E-12	8.4E-06
Th-231	2.4E-11	4.1E-05	Pa-233	5.2E-10	8.8E-04

One additional contaminant, mercury, will be present in some of the grout produced by direct grouting, that would not be expected in glass (and hence shown as zero in Table 10). Mercury is not expected to be present in calcine from SBW because of complete vaporization at the expected calcination temperature of 600°C.³⁴ A maximum mercury concentration in direct grout was estimated based on a mercury concentration of 1.9 wt% in calcine, the maximum concentrations of three samples of alumina calcine samples,²⁷ and is 6,700 mg/kg or 11,000 mg/l.

Concentrations of radionuclides will also vary as different calcine types are grouted. Estimates for radionuclide concentrations in grout from alumina calcine, zirconia calcine and SBW calcine are shown in Table 17.

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Table 17. Estimates of Radionuclide Concentrations in Grout from the DCWO.

	<i>Al Calcine</i>	<i>Zr Calcine</i>	<i>SBW</i>	<i>Al Calcine</i>	<i>Zr Calcine</i>	<i>SBW</i>
	<u>Ci/g</u>	<u>Ci/g</u>	<u>Ci/g</u>	<u>Ci/m3</u>	<u>Ci/m3</u>	<u>Ci/m3</u>
Ba-137m	1.2E-03	3.3E-04		2.0E+03	5.6E+02	
Ce-144		2.2E-16	7.4E-06	2.7E-17	3.8E-10	1.2E+01
Cs-134	6.3E-12	1.0E-09	1.4E-06	1.1E-05	1.7E-03	2.4E+00
Cs-137	1.2E-03	3.5E-04	4.9E-05	2.1E+03	5.9E+02	8.3E+01
Eu-154	5.6E-07	1.4E-06	2.9E-07	9.5E-01	2.3E+00	5.0E-01
Eu-155	3.4E-08	2.0E-09	4.9E-07	5.8E-02	3.3E-03	8.3E-01
Pm-147	4.6E-09	2.1E-07		7.7E-03	3.5E-01	
Ru-106	9.1E-20	2.1E-14	3.0E-06	1.5E-13	3.6E-08	5.2E+00
Sb-125	1.9E-10	6.3E-09	6.0E-07	3.2E-04	1.1E-02	1.0E+00
Sr-90	1.1E-03	4.6E-04	4.9E-05	1.9E+03	7.7E+02	8.3E+01
Sm-151	2.5E-05	7.7E-06		4.2E+01	1.3E+01	
Tc-99	6.3E-07	1.1E-07	1.3E-08	1.1E+00	1.8E-01	2.3E-02
Y-90	1.1E-03	4.6E-04		1.9E+03	7.7E+02	
Co-60		2.0E-08	3.5E-07		3.4E-02	6.0E-01
Ni-63			6.0E-08			1.0E-01
Am-241	1.9E-07	6.0E-07	7.0E-08	3.2E-01	1.0E+00	1.2E-01
Am-243	6.7E-12	1.0E-14		1.1E-05	1.7E-08	
Cm-242	5.3E-12	1.3E-13		8.9E-06	2.2E-07	
Cm-244	1.1E-11	2.3E-14		1.8E-05	3.9E-08	
Np-237	1.8E-09	1.3E-10	3.0E-09	3.0E-03	2.3E-04	5.3E-03
Pu-238	6.7E-07	5.3E-06	9.1E-07	1.1E+00	8.9E+00	1.5E+00
Pu-239	8.4E-08	8.4E-08	9.8E-08	1.4E-01	1.4E-01	1.7E-01
Pu-240	3.4E-08	7.7E-08	2.4E-08	5.7E-02	1.3E-01	4.0E-02
Pu-241	2.9E-07	2.5E-06	8.8E-07	5.0E-01	4.2E+00	1.5E+00
Pu-242	2.5E-12	1.8E-10	1.5E-11	4.3E-06	3.0E-04	2.6E-05
Th-230	1.7E-10	1.0E-12		2.9E-04	1.7E-06	
Th-231	2.9E-11	2.7E-11		5.0E-05	4.5E-05	
U-232	2.3E-13	2.6E-13		4.0E-07	4.4E-07	
U-233	2.5E-13	1.6E-14	2.1E-10	4.2E-07	2.8E-08	3.6E-04
U-234	5.3E-09	4.2E-09	1.4E-10	8.9E-03	7.1E-03	2.3E-04
U-235	3.5E-11	2.7E-11	2.2E-10	6.0E-05	4.5E-05	3.7E-05
U-236	8.4E-11	7.0E-11	1.4E-12	1.4E-04	1.2E-04	2.4E-06
U-237	7.4E-12	6.0E-11		1.2E-05	1.0E-04	
U-238	2.0E-12	1.3E-12	3.3E-11	3.5E-06	2.2E-06	5.7E-05
Pa-233	1.8E-09	1.3E-10		3.0E-03	2.3E-04	

Contaminants in Full Separations Option Wastes

The major wastes produced from the Full Separations Option are a vitrified high activity waste and Class A grout. An amalgamated mercury waste will also be produced. Estimated activities of the vitrified waste form are shown in Table 18 for wastes from processing SBW and calcine. Other ICCP wastes generated during 1996-2035 are processed cocurrently with either SBW (2011-12) or calcine (2016-35).

Table 19 shows the estimated concentrations of nonradiological contaminants in the glass product. Table 20 shows estimated radionuclide concentrations in grout, and Table 21 shows estimates of nonradiological contaminants in grout.

Table 18. Radiological Concentrations in Glass for the Full Separations Option Based on CMB-01-97.

	<i>Glass from Calcine</i>	<i>Glass from Calcine</i>	<i>Glass from SBW</i>	<i>Glass from SBW</i>
	<u>Ci/g</u>	<u>Ci/m3</u>	<u>Ci/g</u>	<u>Ci/m3</u>
Am-241	2.4E-06	6.1E+00	4.6E-06	1.2E+01
Am-243	2.1E-08	5.5E-02		
Ce-144	3.5E-08	9.1E-02	3.4E-04	8.8E+02
Cm-242	1.7E-06	4.3E+00		
Cm-244	1.3E-06	3.4E+00		
Co-60			2.5E-10	6.5E-04
Cs-134	3.8E-06	9.8E+00	2.9E-04	7.5E+02
Cs-137	8.0E-03	2.1E+04	1.6E-02	4.0E+04
Eu-154	4.3E-05	1.1E+02	1.6E-05	4.1E+01
Eu-155	1.7E-05	4.3E+01	2.2E-05	5.6E+01
Ni-63			4.2E-11	1.1E-04
Np-237	1.8E-09	4.7E-03	1.4E-07	3.6E-01
Pm-147	1.0E-05	2.7E+01	6.3E-53	1.6E-46
Pu-238	1.8E-04	4.7E+02	6.1E-05	1.6E+02
Pu-239	1.9E-06	4.9E+00	6.5E-06	1.7E+01
Pu-240	1.7E-06	4.4E+00	1.6E-06	4.0E+00
Pu-241	4.2E-04	1.1E+03	5.8E-05	1.5E+02
Pu-242	4.7E-09	1.2E-02	4.4E-10	1.1E-03
Ru-106	1.3E-09	3.4E-03	3.2E-06	8.2E+00
Sb-125	3.2E-15	8.2E-09	4.2E-10	1.1E-03
Sr-90	7.4E-03	1.9E+04	2.6E-03	6.8E+03
Tc-99			2.3E-07	5.9E-01
U-233	3.1E-15	8.1E-09	7.0E-09	1.8E-02
U-234	5.7E-08	1.5E-01	4.5E-09	1.2E-02
U-235	3.2E-10	8.2E-04	7.3E-10	1.9E-03
U-236	8.4E-10	2.2E-03	4.7E-11	1.2E-04
U-237	1.3E-14	3.2E-08		
U-238	1.9E-11	4.8E-05	1.1E-09	2.8E-03

Concentrations given in Tables 18-21 are based on the Waste Treatment Facilities (WTF) material balances given in Reference 9. The basis for the WTF material balance for calcine processing is the calcine bin set strata compositions generated by Dan Steiger, calculated from calciner feed compositions. Since calciner feed samples

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were not analyzed for all RCRA-hazardous metals, hazardous constituents other than those shown in Tables 19 and 21 may be present in the wastes. Because of this uncertainty, concentrations of hazardous metals in WM-180, WM-181, WM-185 and WM-188 were also used to estimate hazardous metal concentrations in the grout, and are shown in Table 22. It should be kept in mind that these are very rough estimates, as the composition of these tanks may not be representative of other tanks or averages for all calcine or SBW. The estimates shown in Table 22 are based on assuming all of the metal partitions to the grout. Lead and mercury were not estimated by this method, as significant portions of these metals partition to the melter feed. Also, these material balances were made prior to the Feasibility Study for the WTF. The Feasibility Study Report⁵² describes a mercury removal system operating on TRUEX and SREX carbonate wash effluents. Thus the material balance contained in the Feasibility Study for the WTF (Reference 52) should be consulted for better estimates of mercury in the waste products.

Reference 9, on which Tables 18-21 are based, provided the process flow scheme and initial material balances for the feasibility study of the WTF, the "full separations" option. More recently, radionuclide activities have been calculated for alumina calcine⁴⁷ (from Bin Set 1) and zirconia calcine⁴⁸ (from Bin Set 2). These recent calculations by Doug Wenzel provide a more complete and consistent set of activities for the two major calcine types. Table 23 presents a comparison of these new calculations to what was used in Reference 9. Tables 24 and 25 show estimates of radionuclide concentrations in glass and grout for alumina and zirconia calcine based on Doug Wenzel's calcine activities. Table 26 has been deleted in this EDF revision.

Table 19. Nonradiological Contaminant Concentrations in Full Separations Glass Based on CMB-01-97.

	<i>Calcine</i>	<i>Calcine</i>	<i>SBW</i>	<i>SBW</i>
	<u>mg/l</u>	<u>mg/kg</u>	<u>mg/l</u>	<u>mg/kg</u>
Ag			1400	550
Ba			6100	2400
Cr	0.0007	0.0003	0.5	0.2
Cu	580	230	1100	440
F	0.09	0.03	4.3	1.7
Ni	0.008	0.003	2.2	0.9
Pb	1500	580	1000	390

Table 20. Radiological Concentrations in Grout from Preferred Path Separations Facility Based on CMB-01-97.

	<i>Calcine</i>	<i>Calcine</i>	<i>SBW</i>	<i>SBW</i>
	<u>Ci/g</u>	<u>Ci/m3</u>	<u>Ci/g</u>	<u>Ci/m3</u>
Am-241	8.4E-10	1.5E-03	3.9E-13	7.1E-07
Am-243	7.6E-12	1.4E-05		
Ce-144	5.3E-11	9.5E-05	2.2E-09	3.9E-03
Cm-242	5.9E-10	1.1E-03		
Cm-244	4.7E-10	8.4E-04		
Co-60			1.5E-07	2.7E-01
Cs-134	1.2E-10	2.1E-04	1.8E-09	3.3E-03
Cs-137	2.4E-07	4.4E-01	9.8E-08	1.8E-01
Eu-154	1.5E-08	2.8E-02	1.4E-12	2.4E-06
Eu-155	5.9E-09	1.1E-02	1.9E-12	3.3E-06
H-3			1.8E-08	3.2E-02
I-129			1.4E-10	2.5E-04
Ni-63			2.5E-08	4.5E-02
Np-237			8.7E-20	1.6E-13

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	<i>Calcine</i> <u>Ci/g</u>	<i>Calcine</i> <u>Ci/m3</u>	<i>SBW</i> <u>Ci/g</u>	<i>SBW</i> <u>Ci/m3</u>
Pm-147	3.7E-09	6.6E-03		
Pu-238	7.4E-16	1.3E-09	4.8E-19	8.6E-13
Pu-239	7.7E-18	1.4E-11	5.1E-20	9.2E-14
Pu-240	7.0E-18	1.3E-11	1.2E-20	2.2E-14
Pu-241	1.7E-15	3.1E-09	4.6E-19	8.2E-13
Pu-242	1.9E-20	3.4E-14		6.3E-18
Ru-106	5.4E-10	9.7E-04	1.3E-06	2.3E+00
Sb-125	2.9E-09	5.2E-03	2.5E-07	4.6E-01
Sr-90	3.0E-13	5.3E-07	1.9E-10	3.4E-04
Tc-99			3.6E-09	6.4E-03
U-233		8.5E-23	2.4E-23	4.3E-17
U-234	8.6E-22	1.5E-15	1.5E-23	2.8E-17
U-235	4.8E-24	8.6E-18	2.5E-24	4.5E-18
U-236	1.3E-23	2.3E-17	1.6E-25	2.9E-19
U-237		3.4E-22		
U-238	2.8E-25	5.0E-19	3.8E-24	6.8E-18

Table 21. Nonradiological Contaminant Concentrations in Grout.

	<i>Calcine</i> <u>mg/l</u>	<i>Calcine</i> <u>mg/kg</u>	<i>SBW</i> <u>mg/l</u>	<i>SBW</i> <u>mg/kg</u>
Ag			2.4	1.3
As			3.6	2.0
Ba			0.00007	0.00004
Cd	1,700	940	440	240
Cr	520	290	200	110
F	53,000	30,000	1,800	1,000
Hg	980	550	230	130
Ni	9700	5400	910	510
Pb			260	140
Se			2.0	1.1

Table 22. Rough Estimates of Hazardous Metals in Grout from WTF.

<i>Contaminant</i>	<i>Based on Max of</i> <i>WM-180,181,185</i>	<i>Based on</i> <i>WM-188</i>	<i>Based on Max of</i> <i>WM-180,181,185</i>	<i>Based on</i> <i>WM-188</i>
	<u>mg/kg</u>	<u>mg/kg</u>	<u>mg/l</u>	<u>mg/l</u>
Ag	8	7	14	12
As	3	34	6	60
Ba	7	7	12	13
Be		0.06		0.1
Cd	660	850	1200	1500
Cr	190	450	340	800
Ni	80	220	140	400
Sb		0.9		1.6
Se	1.1	0.7	2.0	1.3
Tl		5		8
U	90	70	160	120

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Table 23. Comparison of Calcine Activities as Calculated by Wenzel and Assumed in CMB-01-97.

	<i>Alumina Calcine</i>			<i>Zirconia Calcine</i>			<i>Total Calcine</i>		
	Wenzel	CMB-	Ratio	Wenzel	CMB-	Ratio	CMB-	Ratio	Ratio
	(2016)	01-97		(2016)	01-97		01-97		
	<u>A1, Ci/g</u>	<u>B1, Ci/g</u>	<u>A1/B1</u>	<u>A2, Ci/g</u>	<u>B2, Ci/g</u>	<u>A2/B2</u>	<u>C</u>	<u>A1/C</u>	<u>A2/C</u>
Actinides									
Am-241	5.4E-07	3.9E-07	1.38	1.7E-06	3.9E-07	4.4	3.9E-07	1.38	4.4
Am-243	1.9E-11	3.6E-09	5.3E-03	2.9E-14	3.6E-09	8.1E-06	3.6E-09	5.3E-03	8.1E-06
Cm-242	1.5E-11	2.8E-07	5.4E-05	3.7E-13	2.8E-07	1.3E-06	2.8E-07	5.4E-05	1.3E-06
Cm-244	3.0E-11	2.2E-07	1.4E-04	6.5E-14	2.2E-07	3.0E-07	2.2E-07	1.4E-04	3.0E-07
Np-237	5.0E-09	3.0E-10	17	3.8E-10	3.0E-10	1.27	3.0E-10	17	1.27
Pa-233	5.0E-09			3.8E-10					
Pu-238	1.9E-06	3.0E-05	0.06	1.5E-05	3.0E-05	0.50	3.0E-05	0.06	0.50
Pu-239	2.4E-07	3.0E-07	0.80	2.4E-07	3.0E-07	0.80	3.0E-07	0.80	0.80
Pu-240	9.6E-08	2.8E-07	0.34	2.2E-07	2.8E-07	0.79	2.8E-07	0.34	0.79
Pu-241	8.4E-07	6.9E-05	0.01	7.0E-06	6.9E-05	0.10	6.9E-05	0.012	0.10
Pu-242	7.2E-12	7.7E-10	0.01	5.0E-10	7.7E-10	0.65	7.7E-10	0.009	0.65
Th-230	4.9E-10			2.9E-12					
Th-231	8.4E-11			7.6E-11					
U-232	6.7E-13			7.4E-13					
U-233	7.0E-13	5.2E-16	1,346	4.7E-14	5.2E-16	90	5.2E-16	1,346	90
U-234	1.5E-08	1.0E-08	1.4	1.2E-08	9.1E-09	1.3	9.5E-09	1.6	1.3
U-235	1.0E-10	7.3E-11	1.4	7.6E-11	4.3E-11	1.8	5.3E-11	1.9	1.4
U-236	2.4E-10	1.7E-10	1.4	2.0E-10	1.3E-10	1.6	1.4E-10	1.7	1.4
U-237	2.1E-11	2.1E-15	10,000	1.7E-10	2.1E-15	80,952	2.1E-15	10,000	81,000
U-238	5.8E-12	4.1E-12	1.4	3.7E-12	2.6E-12	1.4	3.1E-12	1.9	1.2
Total Act.	3.6E-06	1.0E-04	0.036	2.4E-05	1.0E-04	0.24	1.0E-04	0.036	0.24
Fission Pr.	(2016)	(2002)		(2016)	(2002)				
Ba-137m	3.3E-03			9.4E-04					
Ce-144				6.4E-16	1.9E-08	3.3E-08	6.2E-09	7.2E-15	1.0E-07
Cs-134	1.8E-11	5.1E-09	0.0036	2.9E-09	5.4E-07	0.0054	6.4E-07	2.8E-05	4.6E-03
Cs-135	4.6E-08								
Cs-137	3.5E-03	4.0E-03	0.88	9.9E-04	1.8E-03	0.56	1.3E-03	2.6	0.75
Eu-152	3.0E-08								
Eu-154	1.6E-08	8.5E-06	0.0019	3.9E-06	1.4E-05	0.27	7.3E-06	0.0022	0.53
Eu-155	9.7E-08			5.6E-09			2.8E-06	0.035	2.0E-03
Pm-147	1.3E-08	3.0E-07	0.044	5.9E-07	8.9E-06	0.067	1.7E-06	0.0074	0.34
Ru-106	2.6E-19			6.0E-14	1.6E-10	3.8E-04	3.4E-09	7.6E-11	1.8E-05
Sb-125	5.3E-10			1.8E-08			1.7E-08	0.031	1.05
Sm-151	7.1E-05			2.2E-05					
Sr-90	3.2E-03	3.7E-03	0.87	1.3E-03	1.7E-03	0.75	1.2E-03	2.6	1.05
Tc-99	1.8E-06			3.1E-07					
Y-90	3.2E-03			1.3E-03					

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Table 24. Radiological Concentrations in Glass Waste from Preferred Path Separations Facility based on Doug Wenzel's Calcine Activities.

	<i>Alumina Calcine</i>		<i>Zirconia Calcine</i>	
	<u>Ci/g</u>	<u>Ci/m3</u>	<u>Ci/g</u>	<u>Ci/m3</u>
Decayed to	2016	2016	2016	2016
Ba-137m	1.0E-02	2.6E+04	6.0E-03	1.5E+04
Ce-144			3.9E-15	1.0E-08
Cs-134	5.5E-11	1.4E-04	1.8E-08	4.7E-02
Cs-137	1.1E-02	2.8E+04	6.3E-03	1.6E+04
Eu-154	4.8E-06	1.2E+01	2.4E-05	6.3E+01
Eu-155	2.9E-07	7.6E-01	3.5E-08	9.1E-02
Pm-147	3.9E-08	1.0E-01	3.7E-06	9.5E+00
Ru-106	5.2E-20	1.3E-13	2.5E-14	6.4E-08
Sr-90	9.8E-03	2.5E+04	8.3E-03	2.1E+04
Sm-151	2.1E-04	5.3E+02	1.3E-04	3.4E+02
Tc-99	1.4E-06	3.6E+00	5.0E-07	1.3E+00
Y-90	9.7E-03	2.5E+04	8.2E-03	2.1E+04
Am-241	1.6E-06	4.2E+00	1.1E-05	2.8E+01
Am-243	5.7E-11	1.5E-04	1.8E-13	4.7E-07
Cm-242	4.5E-11	1.2E-04	2.3E-12	6.0E-06
Cm-244	9.1E-11	2.3E-04	4.1E-13	1.1E-06
Np-237	1.5E-08	3.9E-02	2.4E-09	6.2E-03
Pu-238	5.8E-06	1.5E+01	9.5E-05	2.5E+02
Pu-239	7.3E-07	1.9E+00	1.5E-06	3.9E+00
Pu-240	2.9E-07	7.6E-01	1.4E-06	3.6E+00
Pu-241	2.6E-06	6.6E+00	4.4E-05	1.1E+02
Pu-242	2.2E-11	5.7E-05	3.2E-09	8.2E-03
U-232	2.1E-12	5.3E-06	4.7E-12	1.2E-05
U-233	2.1E-12	5.5E-06	3.0E-13	7.7E-07
U-234	4.6E-08	1.2E-01	7.6E-08	2.0E-01
U-235	3.1E-10	7.9E-04	4.8E-10	1.2E-03
U-236	7.3E-10	1.9E-03	1.3E-09	3.3E-03
U-237	6.4E-11	1.7E-04	1.1E-09	2.8E-03
U-238	1.8E-11	4.6E-05	2.3E-11	6.1E-05
Th-230	5.7E-11	1.5E-04	7.0E-13	1.8E-06
Th-231	9.8E-12	2.5E-05	1.8E-11	4.7E-05

Note: Ba-137m and Y-90 concentrations are based on decay equilibrium of Cs-137 and Sr-90 respectively.

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Table 25. Radiological Concentrations in Grout from Preferred Path Separations Facility based on Doug Wenzel's Calcine Activities.

	<i>Alumina Calcine</i>		<i>Zirconia Calcine</i>	
	<u>Ci/g</u>	<u>Ci/m3</u>	<u>Ci/g</u>	<u>Ci/m3</u>
Decayed to	2016	2016	2016	2016
Ba-137m	3.5E-07	6.4E-01	2.0E-07	3.5E-01
Ce-144			6.7E-18	1.2E-11
Cs-134	1.9E-15	3.5E-09	6.0E-13	1.1E-06
Cs-137	3.7E-07	6.7E-01	2.1E-07	3.7E-01
Eu-154	2.1E-09	3.9E-03	1.0E-08	1.8E-02
Eu-155	1.3E-10	2.3E-04	1.5E-11	2.6E-05
Pm-147	1.7E-11	3.1E-05	1.5E-09	2.8E-03
Ru-106		4.7E-14	1.2E-14	2.1E-08
Sb-125	5.7E-11	1.0E-04	3.7E-09	6.7E-03
Sr-90	1.5E-13	2.7E-07	3.9E-13	6.9E-07
Sm-151	4.1E-07	7.4E-01	2.5E-07	4.5E-01
Tc-99	1.4E-07	2.6E-01	4.8E-08	8.7E-02
Y-90	1.5E-13	2.7E-07	3.9E-13	6.9E-07
Am-241	7.2E-10	1.3E-03	4.4E-09	8.0E-03
Am-243	2.5E-14	4.6E-08	7.5E-17	1.4E-10
Cm-242	2.0E-14	3.6E-08	9.6E-16	1.7E-09
Cm-244	4.0E-14	7.2E-08	1.7E-16	3.0E-10
Np-237	4.8E-22	8.6E-16	7.0E-23	1.3E-16
Pu-238	2.5E-28	4.5E-22	3.8E-27	6.9E-21
Pu-239	3.2E-29	5.7E-23	6.1E-29	1.1E-22
Pu-240	1.3E-29	2.3E-23	5.6E-29	1.0E-22
Pu-241	1.1E-28	2.0E-22	1.8E-27	3.2E-21
Pu-242	9.5E-34	1.7E-27	1.3E-31	2.3E-25
U-232	8.4E-38	1.5E-31	1.8E-37	3.3E-31
U-233	8.8E-38	1.6E-31	1.1E-38	2.1E-32
U-234	1.9E-33	3.4E-27	2.9E-33	5.3E-27
U-235	1.3E-35	2.3E-29	1.9E-35	3.3E-29
U-236	3.0E-35	5.4E-29	4.9E-35	8.8E-29
U-237	2.6E-36	4.8E-30	4.2E-35	7.5E-29
U-238	7.3E-37	1.3E-30	9.0E-37	1.6E-30
Pa-233	5.4E-10	9.6E-04	7.9E-11	1.4E-04
Th-230	5.0E-11	9.1E-05	5.8E-13	1.0E-06
Th-231	8.7E-12	1.6E-05	1.5E-11	2.7E-05

Note: Ba-137m and Y-90 concentrations are based on decay equilibrium of Cs-137 and Sr-90 respectively.

Table 26.

(Deleted)

Contaminants in TRU Separations Options

Two waste forms are produced in the TRU / Class C Option - a dried granular solid waste containing transuranic radionuclides and a Class C grout. In the TRU / Class A Option, a granular TRU waste, a Class A grout, and a vitrified waste containing cesium and strontium isotopes is produced. The TRU waste stream is the same for either the Class C or the Class A Option. Estimates of nonradiological hazardous constituent concentrations in the TRU waste are given in Table 27, and estimates of radionuclide concentrations in the TRU waste are given in Tables 31a and 31b.

Hazardous constituent concentrations are given in Table 28 for the grout produced in the Class C Option and in Table 29 for the grout produced in the Class A Option. Radionuclide concentrations in the Class C grout are given in Tables 30a and 30b, and in the Class A grout in Table 32a. Radionuclide concentrations in the vitrified waste produced in the Class A Option are given in Table 32b and hazardous specie concentrations in the vitrified waste in Table 32c.

Tables 27-32 are based on material balances from the TRU Separations Scoping Study.⁵⁴ As in previous tables, activities shown for wastes from SBW have not been decayed from sample analyses dates, while the activities shown for calcine cases are decayed to the year 2016, and are based on calcine activities taken from Wenzel (References 47-48). Estimates of contaminant concentrations in wastes produced from processing alumina calcine and zirconia calcine are shown in these tables. It should be kept in mind that many of the calcine bins contain multiple types of calcine and further blending of calcines may be performed prior to processing in a dissolution and separations facility. The WTF Feasibility Study for the Full Separations Option (Reference 52) contains material balances for five cases of blending calcine from different bin sets. The grout produced in the Full Separations Option is identical to the grout produced in the TRU / Class A Option. However, the source of radionuclide concentrations in calcine used for the Full Separations case is different from that used in the TRU Separations material balances.

TRU waste from processing SBW is estimated to be about 40% silica, 39% zirconium sulfate, 13% pyrophosphoric acid, 6% molybdenum phosphate, and 2% uranium phosphate; from processing alumina calcine, 51% alumina, 48% pyrophosphoric acid and 1% mercury nitrate; and from processing zirconia calcine, 35% zirconium phosphate, 33% calcium stabilized zirconia, 30% alumina and 1% gadolinium phosphate. The composition of the TRU waste is highly dependent on the amount and composition of undissolved solids in SBW and calcine dissolver effluent, which have not been well characterized.

Table 27. Estimated Concentrations of Hazardous Species in TRU Waste Product.

	<i>SBW</i>	<i>SBW</i>	<i>Alumina</i>	<i>Alumina</i>	<i>Zirconia</i>	<i>Zirconia</i>
	<i>mg/kg</i>	<i>mg/l</i>	<i>Calcine</i>	<i>Calcine</i>	<i>Calcine</i>	<i>Calcine</i>
	<u>mg/kg</u>	<u>mg/l</u>	<u>mg/kg</u>	<u>mg/l</u>	<u>mg/kg</u>	<u>mg/l</u>
Ag	1.8E+03	2.7E+03				
As	1.6E-07	2.5E-07				
Ba	6.1E+03	9.2E+03				
Cd	1.4E-05	2.1E-05				
Cr	6.2E-06	9.3E-06			3.0E-04	5.0E-04
F	5.6E-05	8.4E-05			2.5E+01	3.7E+01
Hg	5.6E+02	8.4E+02	1.3E+04	1.9E+04	2.6E+02	3.9E+02
Ni	2.9E-06	4.4E-06				
Pb	9.0E-06	1.4E-05				
Se	9.1E-08	1.4E-07				

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Table 28. Estimated Hazardous Constituent Concentrations in Class C Grout.

	<i>SBW</i>	<i>SBW</i>	<i>Alumina</i>	<i>Alumina</i>	<i>Zirconia</i>	<i>Zirconia</i>
			<i>Calcine</i>	<i>Calcine</i>	<i>Calcine</i>	<i>Calcine</i>
	mg/kg	mg/l	mg/kg	mg/l	mg/kg	mg/l
Ag	2	4				
As	3	6				
Ba	7	12				
Cd	260	460				
Cr	60	100			1,000	1,800
F	1,000	1,900	3,800	6,900	110,000	190,000
Hg	40	70	3,300	5,900	110	200
Ni	55	100				
Pb	170	300				
Se	2	3				

Table 29. Estimated Hazardous Consistuent Concentrations in Class A Grout.

	<i>SBW</i>	<i>SBW</i>	<i>Alumina</i>	<i>Alumina</i>	<i>Zirconia</i>	<i>Zirconia</i>
			<i>Calcine</i>	<i>Calcine</i>	<i>Calcine</i>	<i>Calcine</i>
	mg/kg	mg/l	mg/kg	mg/l	mg/kg	mg/l
Ag	2	3				
As	3	5				
Ba	6.E-05	1.E-04				
Cd	240	440				
Cr	110	200			560	1,000
F	980	1,800	2,000	3,600	56,000	100,000
Hg	41	74	1,700	3,000	60	110
Ni	51	93				
Pb	150	280				
Se	2	3				

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Table 30. Radiological Composition of Class C Grout.

	<i>SBW</i>		<i>Alumina Calcine</i>		<i>Zirconia Calcine</i>	
	<u>Ci/m3</u>	<u>Ci/g</u>	<u>Ci/m3</u>	<u>Ci/g</u>	<u>Ci/m3</u>	<u>Ci/g</u>
Decayed to	1988-93	1988-93	2016	2016	2016	2016
Am-241	7.4E-07	4.1E-13	1.3E-03	7.2E-10	8.4E-03	4.6E-09
Am-243			2.4E-08	1.3E-14	1.4E-10	7.9E-17
Cm-242			3.6E-08	2.0E-14	1.8E-09	1.0E-15
Cm-244			7.2E-08	4.0E-14	3.2E-10	1.8E-16
Np-237	2.4E-13	1.3E-19	9.7E-15	5.4E-21	1.5E-15	8.4E-22
Pa-233	2.4E-13	1.3E-19	9.7E-15	5.4E-21	1.5E-15	8.4E-22
Pu-238	1.1E-12	6.2E-19	5.8E-11	3.2E-17	9.4E-10	5.2E-16
Pu-239	1.2E-13	6.6E-20	7.4E-12	4.1E-18	1.5E-11	8.3E-18
Pu-240	2.9E-14	1.6E-20	2.4E-12	1.3E-18	1.4E-11	7.6E-18
Pu-241	1.1E-12	5.9E-19	2.6E-11	1.4E-17	4.4E-10	2.4E-16
Pu-242	1.5E-17	8.3E-24	2.2E-16	1.2E-22	3.1E-14	1.7E-20
Th-230			9.1E-05	5.1E-11	1.1E-06	6.1E-13
Th-231			1.8E-05	1.0E-11	2.9E-05	1.6E-11
U-232			7.1E-20	3.9E-26	1.6E-19	8.9E-26
U-233	9.4E-17	5.2E-23	7.4E-20	4.1E-26	1.0E-20	5.6E-27
U-234	6.0E-17	3.4E-23	1.6E-15	8.8E-22	2.6E-15	1.4E-21
U-235	9.8E-18	5.4E-24	1.1E-17	5.9E-24	1.6E-17	9.1E-24
U-236	6.2E-19	3.5E-25	2.5E-17	1.4E-23	4.3E-17	2.4E-23
U-237			2.0E-18	1.1E-24	3.7E-17	2.0E-23
U-238	1.5E-17	8.2E-24	6.1E-19	3.4E-25	8.0E-19	4.4E-25
Ba-137m			6.4E+02	3.6E-04	3.7E+02	2.1E-04
Ce-144	2.8E-03	1.5E-09				
Co-60	4.1E-01	2.3E-07			2.3E-02	1.3E-08
Cs-134	1.1E+00	6.3E-07	3.5E-06	1.9E-12	1.1E-03	6.4E-10
Cs-135	7.8E-04	4.3E-10	8.9E-03	5.0E-09	7.5E-03	4.2E-09
Cs-137	5.5E+01	3.0E-05	6.8E+02	3.8E-04	3.9E+02	2.2E-04
Eu-152			7.2E-05	4.0E-11	2.4E-04	1.3E-10
Eu-154	2.8E-06	1.6E-12	3.9E-03	2.1E-09	1.9E-02	1.1E-08
Eu-155	1.5E-06	8.3E-13	2.3E-04	1.3E-10	2.8E-05	1.5E-11
Ni-63	6.9E-02	3.8E-08				
Pm-147			3.1E-05	1.7E-11	2.9E-03	1.6E-09
Ru-106	1.6E+00	8.9E-07	4.7E-14	2.6E-20	2.2E-08	1.2E-14
Sb-125	3.3E-01	1.8E-07	1.0E-04	5.7E-11	7.1E-03	4.0E-09
Sm-151			7.5E-01	4.1E-07	4.7E-01	2.6E-07
Sr-90	5.2E+01	2.9E-05	6.2E+02	3.4E-04	5.1E+02	2.9E-04
Tc-99	2.1E-02	1.2E-08	3.3E-01	1.8E-07	1.2E-01	6.4E-08
Y-90			6.2E+02	3.4E-04	5.1E+02	2.9E-04
I-129	2.3E-03	1.3E-09	2.7E-04	1.5E-10	9.3E-05	5.2E-11

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Table 31. Radiological Composition of TRU Waste.

	<i>SBW</i>		<i>Alumina Calcine</i>		<i>Zirconia Calcine</i>	
	<u>Ci/m3</u>	<u>Ci/g</u>	<u>Ci/m3</u>	<u>Ci/g</u>	<u>Ci/m3</u>	<u>Ci/g</u>
Decayed to	1988-93	1988-93	2016	2016	2016	2016
Am-241	2.3E+01	1.5E-05	1.4E+01	9.3E-06	5.5E+01	3.6E-05
Am-243			2.6E-04	1.7E-10	9.3E-07	6.2E-13
Cm-242			3.9E-04	2.6E-10	1.2E-05	7.9E-12
Cm-244			7.7E-04	5.1E-10	2.1E-06	1.4E-12
Np-237	9.8E-01	6.5E-07	1.3E-01	8.7E-08	1.2E-02	8.2E-09
Pa-233	9.6E-01	6.4E-07	1.3E-01	8.7E-08	1.2E-02	8.2E-09
Pu-238	3.9E+02	2.6E-04	5.0E+01	3.3E-05	4.9E+02	3.3E-04
Pu-239	3.5E+01	2.3E-05	6.3E+00	4.2E-06	7.8E+00	5.2E-06
Pu-240	8.8E+00	5.9E-06	2.1E+00	1.4E-06	7.2E+00	4.8E-06
Pu-241	3.7E+02	2.5E-04	2.2E+01	1.5E-05	2.3E+02	1.5E-04
Pu-242	5.9E-03	3.9E-09	1.9E-04	1.3E-10	1.6E-02	1.1E-08
Th-230			4.9E-04	3.2E-10	3.6E-06	2.4E-12
Th-231			9.8E-05	6.5E-11	9.4E-05	6.3E-11
U-232			1.7E-05	1.2E-11	2.4E-05	1.6E-11
U-233	6.6E-02	4.4E-08	1.8E-05	1.2E-11	1.5E-06	1.0E-12
U-234	7.1E-02	4.8E-08	3.9E-01	2.6E-07	3.9E-01	2.6E-07
U-235	7.5E-03	5.0E-09	2.6E-03	1.7E-09	2.5E-03	1.6E-09
U-236	7.4E-04	4.9E-10	6.3E-03	4.2E-09	6.5E-03	4.3E-09
U-237	1.7E-42	1.1E-48	5.0E-04	3.3E-10	5.5E-03	3.7E-09
U-238	1.1E-02	7.0E-09	1.5E-04	1.0E-10	1.2E-04	8.0E-11
Ba-137m					1.8E-04	1.2E-10
Ce-144	1.1E+03	7.3E-04				
Co-60	1.8E-08	1.2E-14			1.1E-08	7.3E-15
Cs-134	5.1E-08	3.4E-14			5.6E-10	3.7E-16
Cs-135	3.5E-11	2.3E-17			3.7E-09	2.4E-15
Cs-137	2.5E-06	1.6E-12			1.9E-04	1.3E-10
Eu-152			7.7E-01	5.1E-07	1.5E+00	1.0E-06
Eu-154	8.3E+01	5.5E-05	4.1E+01	2.7E-05	1.3E+02	8.4E-05
Eu-155	4.4E+01	2.9E-05	2.5E+00	1.7E-06	1.8E-01	1.2E-07
Ni-63	3.1E-09	2.1E-15				
Pm-147	8.9E-33	5.9E-39	3.3E-01	2.2E-07	1.9E+01	1.3E-05
Ru-106	1.0E+01	6.8E-06	4.4E-13	2.9E-19	1.3E-07	8.4E-14
Sb-125	1.5E-08	9.8E-15	8.2E-11	5.5E-17	3.5E-09	2.3E-15
Sm-151			1.7E+03	1.2E-03	6.8E+02	4.5E-04
Sr-90	2.3E-06	1.6E-12	5.0E-04	3.3E-10	2.5E-04	1.7E-10
Tc-99	1.1E+00	7.1E-07	2.5E+00	1.7E-06	5.5E-01	3.6E-07
Y-90			5.0E-04	3.3E-10	2.5E-04	1.7E-10
I-129	9.9E-02	6.6E-08	4.2E-02	2.8E-08	8.9E-03	5.9E-09

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Table 32a. Radiological Composition of Class A Grout.

	SBW		Alumina Calcine		Zirconia Calcine	
	<u>Ci/m3</u>	<u>Ci/g</u>	<u>Ci/m3</u>	<u>Ci/g</u>	<u>Ci/m3</u>	<u>Ci/g</u>
Decayed to	1988-93	1988-93	2016	2016	2016	2016
Am-241	6.9E-07	3.9E-13	1.2E-03	6.8E-10	8.2E-03	4.6E-09
Am-243			2.3E-08	1.3E-14	1.4E-10	7.8E-17
Cm-242			3.4E-08	1.9E-14	1.8E-09	1.0E-15
Cm-244			6.8E-08	3.8E-14	3.1E-10	1.7E-16
Np-237	1.9E-13	1.1E-19	8.3E-15	4.6E-21	1.5E-15	8.2E-22
Pa-233			8.3E-15	4.6E-21	1.5E-15	8.2E-22
Pu-238	8.5E-13	4.7E-19	5.0E-11	2.8E-17	8.5E-10	4.7E-16
Pu-239	9.0E-14	5.0E-20	6.4E-12	3.5E-18	1.4E-11	7.5E-18
Pu-240	2.2E-14	1.2E-20	2.1E-12	1.2E-18	1.2E-11	6.9E-18
Pu-241	8.1E-13	4.5E-19	2.2E-11	1.2E-17	3.9E-10	2.2E-16
Pu-242			1.9E-16	1.1E-22	2.8E-14	1.6E-20
Th-230			8.4E-05	4.7E-11	1.1E-06	6.0E-13
Th-231			1.7E-05	9.4E-12	2.8E-05	1.5E-11
U-232					1.1E-19	6.0E-26
U-233	8.5E-17	4.7E-23			6.9E-21	3.8E-27
U-234	5.5E-17	3.0E-23			2.5E-15	1.4E-21
U-235	8.9E-18	4.9E-24			1.6E-17	8.8E-24
U-236	5.7E-19	3.2E-25			4.1E-17	2.3E-23
U-237					3.5E-17	2.0E-23
U-238	1.3E-17	7.4E-24			7.7E-19	4.3E-25
Ba-137m			4.1E-01	2.3E-07	2.5E-01	1.4E-07
Ce-144	2.6E-03	1.4E-09			1.2E-11	6.9E-18
Co-60	3.9E-01	2.1E-07			2.2E-02	1.2E-08
Cs-134	2.1E-02	1.1E-08	2.3E-09	1.3E-15	7.7E-07	4.3E-13
Cs-135	1.4E-05	7.9E-12	5.8E-06	3.2E-12	2.8E-12	1.6E-18
Cs-137	2.2E-01	1.2E-07	4.4E-01	2.4E-07	2.6E-01	1.5E-07
Eu-152			6.6E-15	3.7E-21	2.3E-04	1.3E-10
Eu-154	2.7E-06	1.5E-12	3.6E-03	2.0E-09	1.9E-02	1.0E-08
Eu-155	1.4E-06	7.8E-13	2.2E-04	1.2E-10	2.7E-05	1.5E-11
Ni-63	6.5E-02	3.6E-08				
Pm-147			3.0E-05	1.6E-11	2.9E-03	1.6E-09
Ru-106	1.5E+00	8.4E-07			2.2E-08	1.2E-14
Sb-125	3.1E-01	1.7E-07			7.0E-03	3.9E-09
Sm-151			7.0E-01	3.9E-07	4.6E-01	2.6E-07
Sr-90	3.7E-04	2.1E-10	2.6E-07	1.4E-13	7.2E-07	4.0E-13
Tc-99	9.2E-03	5.1E-09	1.6E-01	8.6E-08	5.8E-02	3.2E-08
Y-90			2.6E-07	1.4E-13	7.2E-07	4.0E-13
I-129	3.5E-04	1.9E-10	6.7E-05	3.7E-11	2.7E-05	1.5E-11

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Table 32b. Radiological Composition of Class A Glass.

	<i>SBW</i>		<i>Alumina Calcine</i>		<i>Zirconia Calcine</i>	
	<u>Ci/m3</u>	<u>Ci/g</u>	<u>Ci/m3</u>	<u>Ci/g</u>	<u>Ci/m3</u>	<u>Ci/g</u>
Decayed to	1988-93	1988-93	2016	2016	2016	2016
Am-241	5.0E-09	1.9E-15	7.5E-08	2.9E-14	2.7E-08	1.0E-14
Am-243			1.4E-12	5.4E-19	4.6E-16	1.8E-22
Cm-242			2.1E-12	8.0E-19	5.8E-15	2.2E-21
Cm-244			4.2E-12	1.6E-18	1.0E-15	3.9E-22
Pu-238	9.7E-11	3.7E-17	1.1E-08	4.4E-15	1.0E-08	3.9E-15
Pu-239	1.0E-11	4.0E-18	1.4E-09	5.5E-16	1.6E-10	6.2E-17
Pu-240	2.5E-12	9.7E-19	4.7E-10	1.8E-16	1.5E-10	5.7E-17
Pu-241	9.3E-11	3.6E-17	5.0E-09	1.9E-15	4.7E-09	1.8E-15
Pu-242			4.3E-14	1.7E-20	3.4E-13	1.3E-19
Th-230					8.4E-14	3.2E-20
Th-231					2.2E-12	8.5E-19
U-234	9.1E-16	3.5E-22			7.7E-15	3.0E-21
U-235	1.5E-16	5.7E-23			4.9E-17	1.9E-23
U-236	9.4E-18	3.6E-24			1.3E-16	4.9E-23
U-237	0.0E+00	0.0E+00			1.1E-16	4.2E-23
U-238	2.2E-16	8.5E-23			2.4E-18	9.1E-25
Ba-137m			1.5E+06	5.7E-01	4.7E+04	1.8E-02
Ce-144	1.9E-05	7.3E-12			4.0E-17	1.6E-23
Co-60	2.8E-03	1.1E-09			7.2E-08	2.8E-14
Cs-134	5.0E+02	1.9E-04	8.1E-03	3.1E-09	1.5E-01	5.6E-08
Cs-135	3.4E-01	1.3E-07	2.1E+01	7.9E-06	9.6E-01	3.7E-07
Cs-137	2.4E+04	9.2E-03	1.6E+06	6.0E-01	5.0E+04	1.9E-02
Eu-152					7.5E-10	2.9E-16
Eu-154	1.9E-08	7.4E-15	2.2E-07	8.6E-14	6.1E-08	2.4E-14
Eu-155	1.0E-08	3.9E-15	1.4E-08	5.2E-15	8.8E-11	3.4E-17
Ni-63	1.1E-02	4.4E-09				
Pm-147			1.8E-09	7.0E-16	9.3E-09	3.6E-15
Ru-106	1.1E-02	4.2E-09			7.1E-14	2.7E-20
Sb-125	2.2E-03	8.6E-10			2.3E-08	8.7E-15
Sm-151					1.1E-06	4.1E-13
Sr-90	2.3E+04	8.8E-03	1.4E+06	5.5E-01	6.6E+04	2.5E-02
Tc-99	8.1E-01	3.1E-07	3.8E+02	1.5E-04	7.5E+00	2.9E-06
Y-90			1.4E+06	5.5E-01	6.6E+04	2.5E-02
I-129	8.6E-01	3.3E-07	4.6E-01	1.8E-07	8.9E-03	3.4E-09

Table 32c. Estimated Hazardous Constituent Concentrations in Glass from TRU Separations / Class A Option.

	<i>SBW</i>	<i>SBW</i>	<i>Alumina</i>	<i>Alumina</i>	<i>Zirconia</i>	<i>Zirconia</i>
			<i>Calcine</i>	<i>Calcine</i>	<i>Calcine</i>	<i>Calcine</i>
	mg/kg	mg/l	mg/kg	mg/l	mg/kg	mg/l
Ag	9.4E-03	0.024				
As	1.4E-02	0.038				
Ba	2,000	5,300				
Cd	1	3				
Cr	0.5	1.4			0.001	0.003
F	5	13			0.01	0.3
Hg	59	150	6,800	18,000	13	33
Ni	0.3	0.7				
Pb	1,300	3,300				
Se	8.0E-03	0.02				

Class C Grouted SBW

A sub-option being evaluated for SBW only is to directly grout SBW such that a Class C grout is produced. FY-97 results from the Grout Stabilization Development Program have shown that SBW can be grouted directly after neutralization with caustic to a pH of 1.3.⁴⁹ Loadings of 30 g waste liquid per 100 g final grout produced an acceptable grout.⁴⁹ Assuming a total SBW volume of 791,000 gallons (Reference 7), an average SBW density of 1.26 g/cm³, neutralization to a pH of 1.3 with 20% caustic, a waste loading of 30 g liquid SBW per 100 g grout, and a grout density of 1.8 g/cm³, about 7300 m³ of grout would be produced. This volume is based on evaporation of SBW prior to neutralization. If the SBW is neutralized (to a pH of 1.3) before evaporation, and evaporation concentrates the resulting waste to 520 g/l solids, the grouted volume would be about 6000 m³. Based on the volume of 7300 m³, estimated concentrations of radionuclides and nonradiological contaminants in the grouted SBW are shown in Tables 33 and 34. It should be noted that concentrations of both radionuclides and nonradiological contaminants vary from tank to tank. Ratios of the maximum concentrations to the average are shown in Table 35.

Table 33. Concentrations of Radionuclides in Grouted SBW Liquid.

	<u>Ci/m3</u>	<u>Ci/g</u>		<u>Ci/m3</u>	<u>Ci/g</u>
Ce-144	2.5E+00	1.4E-06	Am-241	2.3E-02	1.3E-08
Co-60	1.2E-01	6.6E-08	Np-237	1.0E-03	5.7E-10
Cs-134	4.7E-01	2.6E-07	Pu-238	3.1E-01	1.7E-07
Cs-135	2.5E-04	1.4E-10	Pu-239	3.2E-02	1.8E-08
Cs-137	1.7E+01	9.3E-06	Pu-240	7.8E-03	4.3E-09
Eu-154	9.7E-02	5.4E-08	Pu-241	2.9E-01	1.6E-07
Eu-155	1.6E-01	8.7E-08	Pu-242	4.1E-06	2.3E-12
H-3	1.4E-02	7.5E-09	U-233	7.0E-05	3.9E-11
I-129	7.7E-04	4.3E-10	U-234	4.5E-05	2.5E-11
Ni-63	2.0E-02	1.1E-08	U-235	7.3E-06	4.0E-12
Ru-106	1.0E+00	5.5E-07	U-236	4.7E-07	2.6E-13
Sb-125	2.0E-01	1.1E-07	U-238	1.1E-05	6.1E-12
Sr-90	1.6E+01	8.8E-06			
Tc-99	4.4E-03	2.5E-09			

Table 34. Concentrations of Nonradiological Contaminants Grouted SBW Liquid.

	mg/l	mg/kg
Ag	1.0	0.6
As	1.6	0.9
Ba	3.4	1.9
Cd	130	72
Cr	79	44
F	540	300
Ni	74	41
Pb	120	66
Se	0.9	0.5
U	36	20

Table 35. Concentration Variations in SBW Tanks, Ratio of Maximum to Average Concentration.

Species	Ratio	Species	Ratio	Species	Ratio
Am-241	1.13	Ce-144	1.43	Sr-90	1.51
Np-237	1.92	Co-60	1.31	Tc-99	1.25
Pu-238	1.41	Cs-134	3	Ag	2.64
Pu-239	1.2	Cs-135	1.5	As	<1.5
Pu-240	1.79	Cs-137	1.58	Ba	1.25
Pu-241	1.34	Eu-154	3.26	Cd	3.75
Pu-242	2	Eu-155	1	Cr	1.57
U-233	1.74	H-3	1.52	F	2.46
U-234	1.74	I-129	2.9	Ni	1.25
U-235	1.74	Ni-63	1.94	Pb	1.43
U-236	1.74	Ru-106	1.6	Se	<2.25
U-238	1.74	Sb-125	1.13	U	1.74

Physical Properties of Waste Forms

Calcine is a granular solid, consisting of "bed particles" ranging from 0.2 to 0.5 mm in diameter and "fines" mostly between 10 and 200 microns in diameter.²⁷ The bulk density is typically 1.09-1.6 g/cm³; the bed particles have a density of approximately 2.7 g/cm³, and the fines have a density of approximately 0.9 g/cm³.²⁷ A summary of physical properties is given in Table 3-1 of Reference 27, and additional data on storage and flow properties are given in Appendix A of Reference 28.

The TRU waste in the TRU waste alternative is also expected to be a particulate solid, although its form will depend upon the type of denitration and/or evaporation equipment used in its production. A density of 1.5 g/cm³ was assumed for this waste.

Grout or cement waste forms for the various alternatives include cement from the DCWO, cement from the CWO, Class A grout from the Full Separations Option, and either Class A or Class C grout produced in the TRU Separations Option. Densities of grout cubes produced in small-scale tests of surrogate wastes simulating the baseline separations low activity wastes have been measured at 1.59-1.84 g/cm³, depending on feed type, waste

loading, method of curing, and whether additives were used in denitration.³⁵ For the loadings and conditions assumed for the full separations material balance, the measured densities were 1.79-1.84 g/cm³, and a density of 1.8 g/cm³ was used to calculate grout volumes for all feed types.¹⁹ The compressive strength of grout produced from simulated low level waste from SBW, alumina calcine and zirconia calcine was measured at 2750 psi, 4350 psi, and 3570 psi respectively,³⁵ for the loadings and conditions assumed for the WTF material balance. In lieu of any data for Class C grout, densities and compressive strengths given above for Class A grout can be assumed.

For the cement produced in the CWO, a density of 1.7 g/cm³ was assumed based on information from Siemer.⁵¹ Siemer reports³³ that the cement possesses a compressive strength "well in excess of 500 psi," and he cites one example of concrete with a (simulated) waste loading of 36% that had a compressive strength of 4600 psi.

A density of 1.7 gm/cm³ was also assumed for grout from the direct grouting process. Compressive strengths for concrete from second-cycle zirconia calcine are reported to be 3470-6110 psi, for waste loadings near 50%.¹⁵ Densities of 2.4 g/cm³, 2.46 g/cm³, and 2.66 g/cm³ were used in volume calculations for glass from vitrification of high activity waste from SBW separations, alumina calcine separations, and zirconia calcine separations respectively, based on data from Krishna Vinjamuri.¹⁹ A typical fracture strength for either borosilicate glass or soda-lime glass is 14,500 psi.³⁶ A density of 2.6 g/cm³ was assumed for the glass from the TRU / Class A Option.⁵⁰

Siemer states that HIPed concretes are typically about 60% more dense than the products from which they were made.³³ If the density of concrete from Siemers process is 1.7 g/cm³, the HIPed concrete would have a density of about 2.72 g/cm³. Siemer also reports compressive strengths for HIPed concretes of 250-750 MPa (36,000-110,000 psi).³³

Berreth¹⁵ reports a density of 3.0-3.4 g/cm³ for vitrified calcine with a calcine loading of 25-35 wt%. The source of Berreth's glass property data is not given. Other literature (for example, Appendix B of Reference 14) would suggest a lower density, in the range of 2.5-2.8 g/cm³. It can be assumed that the strength of glass from direct vitrification is of the same order of magnitude as other borosilicate or alkaline glasses, namely around 100 MPa (14,500 psi).

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Based on the No Action Alternative assumptions of (1) calcination of all wastes generated through 2012 and (2) operation of the PEW, HLLWE and LET&D through 2012

ICCP Waste Generation: Sets 1-3 Designated for Tank Farm; Set 4 Low Level Waste

Volumes are gallons

Stream	Stream Number	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Total
Set 1 - No evaporation																			
NWCF Operations	2		18,000	18,000			18,000	36,000		36,000	18,000	18,000	36,000		18,000				216,000
Tank Farm Sumps	9	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	1,700
LET&D to tank farm	10	3,500																	3,500
Tank Farm Line Flushes	11	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	17,000
Total, Set 1		4,600	19,100	19,100	1,100	1,100	19,100	37,100	1,100	37,100	19,100	19,100	37,100	1,100	19,100	1,100	1,100	1,100	238,200
Set 2 - PEW & HLLWE (volumes before evaporation)																			
NWCF Turnaround	3-2				54,000	54,000			42,000			42,000		42,000		42,000			276,000
ROVER Deactivation (604)	6			10,000	10,000	10,000													30,000
Filter Leach	8		34,500	34,500	34,500	34,500	34,500	34,500	17,400	4,200	4,200	4,200	4,200	4,200	4,200	4,200	4,200	4,200	262,200
NWCF Operations via PEW	13a		15,000	15,000			15,000	30,000		30,000	15,000	15,000	30,000		15,000				180,000
FAST FSA	13b	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000						300,000
FAST FDP	13c	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	51,000
Cell Floor Drains	13d	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	612,000
NWCF Decon Room	13f	30,000	20,000	20,000	30,000	30,000	20,000	20,000	30,000	20,000	20,000	20,000	20,000	20,000	20,000	30,000	30,000	30,000	410,000
LET&D upset	13g	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	34,000
Pilot Plants	13k	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	17,000
Total, Set 2		97,000	136,500	146,500	195,500	195,500	136,500	151,500	156,400	121,200	106,200	148,200	121,200	108,200	81,200	118,200	76,200	76,200	2,172,200
Set 2 PEW & HLLWE (thru 2002) (after evaporation)																			
PEW Fact HLLWE Factor																			
20	2	3-2	0	0	0	1350	1350	0	0	1050	0	0	1050	0	1050	0	1050	0	6,900
20	2	6	0	0	250	250	250	0	0	0	0	0	0	0	0	0	0	0	750
10	2	8	0	1725	1725	1725	1725	1725	870	210	210	210	210	210	210	210	210	210	13,110
20	2	13a	0	375	375	0	0	375	750	0	750	375	375	750	0	375	0	0	4,500
30	2	13b	417	417	417	417	417	417	417	417	417	417	417	0	0	0	0	0	5,000
30	2	13c	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	850
20	2	13d	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	15,300
20	2	13f	750	500	500	750	500	500	750	500	500	500	500	500	500	750	750	750	10,250
10	2	13g	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	1,700
10	2	13k	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	850
Total			2267	4117	4367	5592	5592	4117	4492	4187	2977	2602	3652	2977	2860	2185	3110	2060	59,210
Set 3 - HLLW Evap only																			
NWCF Bed Dissolution	1		25,000	25,000			25,000	50,000		25,000	25,000	25,000	50,000		25,000				
NWCF Turnaround	3-1				72,000														
PEW direct	4	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	51,000
CPP-501 Decontamination	7	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	34,000
Discretionary	15	11,765	11,765	11,765	11,765	11,765	11,765	11,765	11,765	11,765	11,765	11,765	11,765	11,765	11,765	11,765	11,765	11,765	200,005
Total			16,765	41,765	41,765	88,765	16,765	41,765	66,765	16,765	41,765	41,765	66,765	16,765	41,765	16,765	16,765	16,765	632,005

		1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	
Set 3 - volumes after evaporation																			
Evap Factor																			
2	1	0	12,500	12,500	0	0	12,500	25,000	0	25,000	25,000	25,000	50,000	0	25,000	0	0.0	0.0	212,500
2	3-1	0	0	0	36,000	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	36,000
2	4	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	25,500
2	7	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	17,000
2	15	5,883	5,883	5,883	5,883	5,883	5,883	5,883	5,883	5,883	5,883	5,883	5,883	5,883	5,883	5,883	5,883	5,883	100,003
Total		8,383	20,883	20,883	44,383	8,383	20,883	33,383	8,383	33,383	33,383	33,383	58,383	8,383	33,383	8,383	8,383	8,383	391,003
Total Volume w/o evap		118,365	197,365	207,365	285,365	213,365	197,365	255,365	174,265	200,065	167,065	209,065	225,065	126,065	142,065	136,065	94,065	94,065	3,042,405
Total Volume w/ evap		15,249	44,099	44,349	51,074	15,074	44,099	74,974	13,669	73,459	55,084	56,134	98,459	12,343	54,668	12,593	11,543	11,543	688,413

Set 4 Low Level Waste to Grouting (volumes before evaporation)

NWCF RCRA Flush	3-3				0													100,000	100,000
603 Removal	5				600,000	600,000	300,000												1,500,000
666 FSA Deactivation	12												600,000	600,000	600,000	600,000	600,000	600,000	3,000,000
WCF Sumps	13a	4,000	1,000																5,000
CPP-603 Wet Side	13h	20,000	20,000	20,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	74,000
CPP-603 Dry Side	13i	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	85,000
Tank Farm Sumps	13j	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	1,020,000
RCRA Wells	13l	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	85,000
Misc. Balance of Plant	13m	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	510,000
Other INEL	13n	5,000	14,200	5,000	5,000	25,000	5,000	5,000	5,000	5,000	5,000	5,000	25,000	5,000	5,000	5,000	5,000	5,000	134,200
Service Waste (WM-191 flush)	13o	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	13,600
Total, Set 4		129,800	136,000	125,800	706,800	726,800	406,800	106,800	106,800	106,800	106,800	106,800	126,800	706,800	706,800	706,800	706,800	806,800	6,526,800

Set 4 Low Level Waste to Grouting (volumes after evaporation)

LLW Eva	HLW Evap																		
30	2	3-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,667	1,667
30	2	5	0	0	0	10,000	10,000	5,000	0	0	0	0	0	0	0	0	0	0	25,000
30	2	12	0	0	0	0	0	0	0	0	0	0	0	0	10,000	10,000	10,000	10,000	50,000
30	2	13a	67	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	83
30	2	13h	333	333	333	17	17	17	17	17	17	17	17	17	17	17	17	17	1,233
30	2	13i	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	1,417
30	2	13j	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	17,000
30	2	13l	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	1,417
30	2	13m	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	8,500
30	2	13n	83	237	83	83	417	83	83	83	83	83	417	83	83	83	83	83	2,237
30	2	13o	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	227
Total, Set 4			2,163	2,267	2,097	11,780	12,113	6,780	1,780	1,780	1,780	1,780	2,113	11,780	11,780	11,780	11,780	13,447	108,780
Total, Sets 1-4			17,413	46,366	46,446	62,854	27,188	50,879	76,754	15,449	75,239	56,864	57,914	100,573	24,123	66,448	24,373	23,323	797,193

LOCKHEED MARTIN

Lockheed Idaho Technologies Company

INTERDEPARTMENTAL COMMUNICATION

Date: November 26, 1997

To: N. E. Russell, MS 3765

From: D. R. Wenzel, MS 5209

Subject: CALCULATION OF RADIONUCLIDE INVENTORIES FOR SODIUM BEARING WASTES - Wen-23-97

References: (1) Rebish, K. J., Nenni, J. A., letter to B. H. O'Brien, "Tank Farm Inventory - June, 1994," KJR-02-94/JAN-03-94, June 23, 194.

(2) Radiation Shielding Information Center, *RSIC Computer Code Collection*, "ORIGEN2.1, Isotope Generation and Depletion Code Matrix Exponential Method," CCC-371, Oak Ridge, Tennessee, 1991.

The Waste Form and Characterization Scoping Study requires a knowledge of the radionuclide content of sodium bearing waste (SBW) at the ICPP in order to evaluate treatment options. Routine radiochemical analyses; however, do not identify all of the radionuclides present. Calculations have therefore been made to calculate complete radionuclide inventories for SBW.

SBW has been collected in the ICPP Tank Farm over the entire life of the ICPP. Six storage tanks, WM-180, -181, -183, -184, -185 and -186, currently contain SBW. Both the age of the wastes in the tanks and the analysis dates differ. The purpose of calculations was to calculate an average concentration of all radionuclides for the combined volume of all of the tanks.

Calculations have been based on the results of analytical analyses reported in Reference 1. All of the analytical analyses results were first decayed to a common decay time and then a weighted average of the activity in all six of the storage tanks was calculated. The ORIGEN2 code (Reference 2) was then used to calculate the activities for radionuclides that could not be established from analytical analyses.

Table 1 contains the calculated radionuclide inventories for SBW. While the activities for the actinides are relatively consistent, the concentration of fission products in Tank WM-183 is approximately 3 times higher than the calculated weighted average. It should be recognized that it probably will not be practical to blend the tanks to produce an average waste. Should wastes be processed directly from WM-183, direct radiation dose rates should be expected to be 3 times

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higher than what will be calculated for the average waste. While a rigorous uncertainty analysis was not done, the results for the weighted average activities for all of the waste storage tanks containing SBW are estimated to have an accuracy of $\pm$ a factor of 2.

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Table 1: Calculated Radionuclide Activities for Sodium Bearing Wastes in Ci/L as a Function of Decay Time

Nuclide	Half-Life		2016	2035	Decay Time Since 2016 (yr)		
					1E2	5E2	1E3
(Actinides and Daughters)							
Tl207	4.770E+00	m	7.0E-11	9.4E-11	1.5E-10	3.9E-10	6.6E-10
Tl208	3.053E+00	m	8.5E-10	7.0E-10	3.2E-10	6.9E-12	
Tl209	2.200E+00	m	1.0E-14	2.8E-14	2.3E-13	4.3E-12	1.6E-11
Pb209	3.253E+00	h	4.8E-13	1.3E-12	1.1E-11	2.0E-10	7.5E-10
Pb210	2.226E+01	yr	6.7E-12	1.3E-11	6.0E-11	7.4E-10	2.3E-09
Pb211	3.610E+01	m	7.0E-11	9.4E-11	1.5E-10	3.9E-10	6.6E-10
Pb212	1.064E+01	h	2.4E-09	2.0E-09	9.0E-10	1.9E-11	1.6E-13
Pb214	2.680E+01	m	1.6E-11	2.6E-11	8.4E-11	7.4E-10	2.3E-09
Bi210m	3.000E+06	yr	2.7E-25	2.7E-25	2.7E-25	2.7E-25	2.7E-25
Bi210	5.013E+00	d	6.7E-12	1.3E-11	6.0E-11	7.4E-10	2.3E-09
Bi211	2.130E+00	m	7.0E-11	9.4E-11	1.5E-10	3.9E-10	6.6E-10
Bi212	6.055E+01	m	2.4E-09	2.0E-09	9.0E-10	1.9E-11	1.6E-13
Bi213	4.565E+01	m	4.8E-13	1.3E-12	1.1E-11	2.0E-10	7.5E-10
Bi214	1.990E+01	m	1.6E-11	2.6E-11	8.4E-11	7.4E-10	2.3E-09
Po210	1.384E+02	d	6.7E-12	1.3E-11	6.0E-11	7.4E-10	2.3E-09
Po212	3.000E-07	s	1.5E-09	1.3E-09	5.8E-10	1.2E-11	1.0E-13
Po216	1.460E-01	s	2.4E-09	2.0E-09	9.0E-10		
Po218	3.050E+00	m	1.6E-11	2.6E-11	8.4E-11	7.4E-10	2.3E-09
At217	3.230E-02	s	4.8E-13	1.3E-12	1.1E-11	2.0E-10	7.5E-10
Rn219	3.960E+00	s	7.0E-11	9.4E-11	1.5E-10	3.9E-10	6.6E-10
Rn220	5.561E+01	s	2.4E-09	2.0E-09	9.0E-10	1.9E-11	
Rn222	3.824E+00	d	1.6E-11	2.6E-11	8.4E-11	7.4E-10	2.3E-09
Fr221	4.800E+00	m	4.8E-13	1.3E-12	1.1E-11	2.0E-10	7.5E-10
Fr223	2.180E+01	m	9.7E-13	1.3E-12	2.1E-12	5.4E-12	9.1E-12
Ra223	1.143E+01	d	7.0E-11	9.4E-11	1.5E-10	3.9E-10	6.6E-10
Ra224	3.620E+00	d	2.4E-09	2.0E-09	9.0E-10	1.9E-11	1.6E-13
Ra225	1.480E+01	d	4.8E-13	1.3E-12	1.1E-11	2.0E-10	7.5E-10
Ra226	1.600E+03	yr	1.6E-11	2.6E-11	8.4E-11	7.4E-10	2.3E-09
Ra228	5.750E+00	yr	8.3E-16	9.1E-16	1.1E-15	1.9E-15	2.9E-15
Ac225	1.000E+01	d	4.8E-13	1.3E-12	1.1E-11	2.0E-10	7.5E-10
Ac227	2.177E+01	yr	7.0E-11	9.4E-11	1.5E-10	3.9E-10	6.6E-10
Ac228	6.130E+00	h	8.3E-16	9.1E-16	1.1E-15	1.9E-15	2.9E-15
Th227	1.872E+01	d	6.9E-11	9.3E-11	1.5E-10	3.8E-10	6.5E-10
Th228	1.913E+00	yr	2.4E-09	2.0E-09	9.0E-10	1.9E-11	1.6E-13
Th229	7.340E+03	yr	4.8E-13	1.3E-12	1.1E-11	2.0E-10	7.5E-10
Th230	7.700E+04	yr	1.1E-09	1.3E-09	2.1E-09	6.2E-09	1.1E-08
Th231	2.552E+01	h	2.6E-08	2.6E-08	2.6E-08	2.6E-08	2.6E-08
Th232	1.405E+10	yr	9.0E-16	9.4E-16	1.1E-15	1.9E-15	2.9E-15
Th234	2.410E+01	d	2.6E-08	2.6E-08	2.6E-08	2.6E-08	2.6E-08
Pa231	3.726E+04	yr	1.2E-10	1.3E-10	1.7E-10	3.9E-10	6.6E-10
Pa233	2.700E+01	d	3.6E-06	3.6E-06	3.6E-06	3.6E-06	3.6E-06
Pa234m	1.170E+00	m	2.6E-08	2.6E-08	2.6E-08	2.6E-08	2.6E-08
Pa234	6.700E+00	h	3.3E-11	3.3E-11	3.3E-11	3.3E-11	3.3E-11
U232	7.200E+01	yr	2.3E-09	1.9E-09	8.8E-10	1.9E-11	1.5E-13
U233	1.592E+05	yr	3.0E-10	6.0E-10	1.9E-09	8.2E-09	1.6E-08
U234	2.445E+05	yr	1.0E-06	1.0E-06	1.1E-06	1.2E-06	1.2E-06
U235	7.038E+08	yr	2.6E-08	2.6E-08	2.6E-08	2.6E-08	2.6E-08

Table 1: Calculated Radionuclide Activities for Sodium Bearing Wastes in Ci/L as a Function of Decay Time (Continued)

Nuclide	Half-Life		2016	2035	Decay Time Since 2016 (yr)		
					1E2	5E2	1E3
(Actinides and Daughters Continued)							
U236	2.342E+07	yr	4.1E-08	4.1E-08	4.1E-08	4.1E-08	4.2E-08
U237	6.750E+00	d	4.3E-09	1.7E-09	3.5E-11	8.7E-15	8.3E-15
U238	4.470E+09	yr	2.6E-08	2.6E-08	2.6E-08	2.6E-08	2.6E-08
U240	1.410E+01	h	8.4E-16	8.4E-16	8.4E-16	8.4E-16	8.4E-16
Np237	2.140E+06	yr	3.6E-06	3.6E-06	3.6E-06	3.6E-06	3.6E-06
Np238	2.117E+00	d	8.9E-11	8.1E-11	5.6E-11	9.1E-12	9.3E-13
Np239	2.355E+00	d	2.6E-08	2.6E-08	2.6E-08	2.5E-08	2.4E-08
Pu236	2.851E+00	yr	1.4E-10	1.4E-12			
Pu238	8.775E+01	yr	4.2E-04	3.6E-04	1.9E-04	8.1E-06	1.6E-07
Pu239	2.413E+04	yr	6.7E-05	6.7E-05	6.7E-05	6.6E-05	6.5E-05
Pu240	6.569E+03	yr	1.3E-05	1.2E-05	1.2E-05	1.2E-05	1.1E-05
Pu241	1.440E+01	yr	1.7E-04	7.0E-05	1.4E-06	3.5E-10	3.4E-10
Pu242	3.758E+05	yr	9.8E-09	9.8E-09	9.8E-09	9.8E-09	9.8E-09
Pu244	8.260E+07	yr	8.4E-16	8.4E-16	8.4E-16	8.4E-16	8.4E-16
Am241	4.322E+02	yr	6.6E-05	6.7E-05	6.1E-05	3.2E-05	1.4E-05
Am242m	1.520E+02	yr	1.8E-08	1.6E-08	1.1E-08	1.8E-09	1.9E-10
Am242	1.602E+01	h	1.8E-08	1.6E-08	1.1E-08	1.8E-09	1.8E-10
Am243	7.380E+03	yr	2.6E-08	2.6E-08	2.6E-08	2.5E-08	2.4E-08
Cm242	1.628E+02	d	1.5E-08	1.3E-08	9.2E-09	1.5E-09	1.5E-10
Cm243	2.850E+01	yr	2.6E-08	1.6E-08	2.3E-09	1.3E-13	7.0E-19
Cm244	1.811E+01	yr	1.3E-06	6.4E-07	2.9E-08	6.5E-15	
Cm245	8.500E+03	yr	3.7E-10	3.7E-10	3.7E-10	3.5E-10	3.4E-10
Cm246	4.750E+03	yr	2.4E-11	2.4E-11	2.4E-11	2.3E-11	2.1E-11
Cm247	1.560E+07	yr	2.7E-17	2.7E-17	2.7E-17	2.7E-17	2.7E-17
Cm248	3.390E+05	yr	2.9E-17	2.9E-17	2.9E-17	2.9E-17	2.9E-17
Cf249	3.506E+02	yr	2.1E-17	2.0E-17	1.7E-17	7.8E-18	2.9E-18
Cf250	1.308E+01	yr	8.8E-18	3.2E-18			
Cf251	9.000E+02	yr	3.3E-19	3.3E-19	3.1E-19	2.3E-19	1.5E-19
(Fission Products)							
H 3	1.228E+01	yr	6.6E-06	2.3E-06	2.4E-08	4.3E-18	
Be 10	1.600E+06	yr	3.7E-12	3.7E-12	3.7E-12	3.7E-12	3.7E-12
C 14	5.730E+03	yr	1.5E-10	1.5E-10	1.5E-10	1.4E-10	1.3E-10
Se 79	6.500E+04	yr	5.4E-07	5.4E-07	5.4E-07	5.4E-07	5.3E-07
Rb 87	4.730E+10	yr	3.6E-11	3.6E-11	3.6E-11	3.6E-11	3.6E-11
Sr 90	2.912E+01	yr	4.7E-02	3.0E-02	4.3E-03	3.2E-07	2.2E-12
Y 90	6.410E+01	h	4.7E-02	3.0E-02	4.3E-03	3.2E-07	2.2E-12
Zr 93	1.530E+06	yr	2.7E-06	2.7E-06	2.7E-06	2.7E-06	2.7E-06
Nb 93m	1.360E+01	yr	2.3E-06	2.5E-06	2.6E-06	2.6E-06	2.6E-06
Nb 94	2.030E+04	yr	1.4E-06	1.4E-06	1.4E-06	1.4E-06	1.4E-06
Tc 98	4.200E+06	yr	3.2E-12	3.2E-12	3.2E-12	3.2E-12	3.2E-12
Tc 99	2.130E+05	yr	1.2E-05	1.2E-05	1.2E-05	1.2E-05	1.2E-05
Rh102	2.900E+00	yr	4.8E-11	5.1E-13			
Ru106	3.682E+02	d	1.5E-10				
Rh106	2.992E+01	s	1.5E-10				
Pd107	6.500E+06	yr	2.0E-08	2.0E-08	2.0E-08	2.0E-08	2.0E-08
Ag108m	1.270E+02	yr	4.9E-13	4.4E-13	2.8E-13	3.2E-14	2.1E-15

N. E. Russell
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Table 1: Calculated Radionuclide Activities for Sodium Bearing Wastes in Ci/L as a Function of Decay Time (Continued)

Nuclide	Half-Life		2016	2035	Decay Time Since 2016 (yr)		
					1E2	5E2	1E3
(Fission Products Continued)							
Cd113m	1.360E+01	yr	2.2E-06	9.0E-07	1.9E-08	1.1E-16	
In115	5.100E+15	yr	1.2E-16	1.2E-16	1.2E-16	1.2E-16	1.2E-16
Sn121m	5.000E+01	yr	6.9E-08	5.3E-08	1.7E-08	6.7E-11	6.5E-14
Te123	1.000E+13	yr	4.7E-19	4.7E-19	4.7E-19	4.7E-19	4.7E-19
Sb125	2.770E+00	yr	6.2E-07	5.3E-09	8.5E-18		
Te125m	5.800E+01	d	1.5E-07	1.3E-09			
Sn126	1.000E+05	yr	5.1E-07	5.1E-07	5.1E-07	5.1E-07	5.0E-07
Sb126	1.240E+01	d	7.1E-08	7.1E-08	7.1E-08	7.1E-08	7.1E-08
Sb126m	1.900E+01	m	5.1E-07	5.1E-07	5.1E-07	5.1E-07	5.0E-07
I129	1.570E+07	yr	1.0E-05	1.0E-05	1.0E-05	1.0E-05	1.0E-05
Cs134	2.062E+00	yr	3.3E-07	5.5E-10			
Cs135	2.300E+06	yr	1.1E-06	1.1E-06	1.1E-06	1.1E-06	1.1E-06
Cs137	3.000E+01	yr	4.6E-02	3.0E-02	4.6E-03	4.4E-07	4.3E-12
Ba137m	2.552E+00	m	4.4E-02	2.8E-02	4.3E-03	4.2E-07	4.0E-12
La138	1.350E+11	yr	2.4E-16	2.4E-16	2.4E-16	2.4E-16	2.4E-16
Ce142	1.050E+11	yr	3.7E-11	3.7E-11	3.7E-11	3.7E-11	3.7E-11
Ce144	2.843E+02	d	7.3E-12				
Pr144	1.728E+01	m	7.3E-12				
Pr144m	7.200E+00	m	8.7E-14				
Nd144	2.100E+15	yr	2.0E-15	2.0E-15	2.0E-15	2.0E-15	2.0E-15
Pm146	2.020E+03	d	1.2E-08	1.1E-09	4.2E-14		
Sm146	1.030E+08	yr	3.4E-13	3.4E-13	3.4E-13	3.4E-13	3.4E-13
Pm147	2.623E+00	yr	6.8E-06	4.5E-08	2.3E-17		
Sm147	1.070E+11	yr	9.1E-12	9.1E-12	9.1E-12	9.1E-12	9.1E-12
Sm148	8.000E+15	yr	4.7E-17	4.7E-17	4.7E-17	4.7E-17	4.7E-17
Sm149	1.000E+15	yr	4.2E-18	4.2E-18	4.2E-18	4.2E-18	4.2E-18
Eu150	3.600E+01	yr	1.4E-11	9.6E-12	2.0E-12	9.1E-16	6.0E-20
Sm151	9.000E+01	yr	3.8E-04	3.2E-04	1.7E-04	8.0E-06	1.7E-07
Eu152	1.360E+01	yr	1.6E-06	6.1E-07	9.9E-09	1.4E-17	
Gd152	1.080E+14	yr	1.8E-18	1.8E-18	1.9E-18	1.9E-18	1.9E-18
Eu154	8.600E+00	yr	7.0E-05	1.5E-05	2.2E-08		
Eu155	4.960E+00	yr	3.3E-05	2.3E-06	2.8E-11		
Ho166m	1.200E+03	yr	5.7E-11	5.6E-11	5.3E-11	4.2E-11	3.2E-11
Tm171	1.920E+00	yr	5.7E-18				
(Activation Products)							
Co 60	5.271E+00	yr	8.1E-06	6.7E-07	1.6E-11		
Ni 63	1.001E+02	yr	3.5E-05	3.1E-05	1.7E-05		
Total			1.8E-01	1.2E-01	1.8E-02	1.7E-04	1.3E-04

EDF Serial Numbers **CPP-97068**

EDF-FDO-003

Functional File Numbers **1000-61**

C-02

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Evaluation of Radionuclide Inventory for Zr Calcine

By

D. R. Wenzel

October 14, 1997

Project File Number 73301 EDF Page 1 of 7

EDF Serial Number CPP-97068 & EDF-FDO-003 Function File Number 1000-61 & C-02

Project/Task NA

Subtask NA

Title: Evaluation of Radionuclide Inventory for Zr Calcine					
Summary: This summary briefly defines the problem or activity to be addressed in the EDF, gives a summary of the activities performed in addressing the problem and states the conclusions, recommendations, or results arrived at from this task.					
Treatment options for calcine stored in the ICPP Calcine Storage Bins require a knowledge about the radionuclide content of the calcine. Because radiochemical analyses of calcine did not identify all of the radionuclides present, it has been necessary to calculate a complete radionuclide inventory based on the radionuclides that have been measured. This EDF presents the results of the calculated radionuclide inventory for Zr calcine as a function of decay time.					
Distribution (complete package): J. A. Jones (copy for EDF-CPP-97068), N. E. Russell (5 copies for EDF-FDO-003), B. J. Schrader, D. R. Wenzel					
Distribution (summary package only): Distribution of summary results of this calculation have been made in a letter to N. E. Russell, Wen-20-97, "Calculation of Radionuclide Inventories for Aluminum and Zirconium Calcines," October 14, 1997.					
Author D. R. Wenzel <i>D. R. Wenzel</i> 10/14/97	Dept. RadCon	Reviewed B. J. Schrader <i>B. J. Schrader</i>	Date 10/14/97	Approved	Date
		LMITCO Review	Date	LMITCO Approval	Date

See Management Control Procedure (MCP) 6 for instructions on use of this form.

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Discussion

The most thorough analysis of Zr calcine identified was of calcine retrieved from Bin Set 2 in 1979 (Westra 1979, Staples 1979). Samples were taken from the top, middle and bottom of Bin #7. The best correlation with fuel processing that could be made was with the top sample identified in the report as 7T. The calcine represented by this sample was calcined from Tank WM-189 in the October to December 1971 time period. The Zr waste was from the third zirconium alloyed-fuel reprocessing campaign conducted earlier in 1971 (Bendixsen 1972). The analysis information available on this calcine is presented in Table 1.

Table 1: Radiochemical Analysis of Retrieved Zirconia Calcine as of 9/15/78

Radionuclide	$\mu\text{g/g calcine}$	$\mu\text{Ci/g calcine}$	Cs-137
			Normalized to 1.
Co-60	0.002	2.26E-6	1.20E-3
Sr-90	18.2	2.48E-3	1.31E+0
Cs-134	0.027	3.49E-5	1.85E-2
Cs-137	21.7	1.89E-3	1.00E+0
Eu-154	0.137	3.70E-5	1.96E-2
Eu-155	0.0006	2.79E-7	1.48E-4
U-234	1.74	1.09E-8	5.71E-6
U-235	35.2	7.61E-11	4.03E-8
U-236	3.07	1.99E-10	1.05E-7
U-238	11.1	3.73E-12	1.97E-9
Np-237	5.2 ^a	3.67E-9	1.94E-6
Pu-238	1.11	1.90E-5	1.01E-2
Pu-239	3.89	2.42E-7	1.28E-4
Pu-240	0.98	2.23E-7	1.18E-4
Pu-241	0.26	2.68E-5	1.42E-2
Pu-242	0.13	4.96E-10	2.62E-7
Am-241	0.32	1.10E-6	5.82E-4

^aCorrected by B.A. Staples

The approach chosen to evaluate the radionuclide content of the Zr calcine is to use the ORIGEN2 code (RSIC 1991) to calculate the inventory using the best available information and then adjusting the radionuclides that were measured to the measured results. The ORIGEN2 code was first used to calculate the radionuclide inventory for a kg of generic zirconium fuel. Attachment 1 contains the input and output for the ORIGEN2 run. A FORTRAN program REDUCE1 (see Attachment B) was written to extract the radionuclide data from the ORIGEN2 run to a simple table form without page headings and radionuclides with zero inventories. The output from REDUCE1 is also included in Attachment A.

Next another FORTRAN program was written to calculate the inventory normalized to the measured 1.83E-3 Ci/g calcine. The program has the provision to adjust the age of the fuel. The inventory was also normalized to a Cs-137 activity of 1.0 to simplify the comparison of the ratios of the calculated activities to the measured activities. A copy of this program called REDUCEZR is presented in Attachment C. The output from program REDUCEZR is also presented in Attachment C.

The Cs-134 to Cs-137 ratio was used to establish that the waste was approximately 8 years old at the time of being calcined in 1971. The amount of Cs-134 calculated from program REDUCERZR is a factor of 1.25

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times greater than the measured value. This is reasonable considering the 1 year resolution of data in program REDUCEZR.

The next step in the calculation was to correct the activities for all of the radionuclides that were measured. To do this, it was first necessary to convert the activities to grams to be able to re-enter them an ORIGEN2 run. The input files and the output file modified with program REDUCE1 are presented in Attachment D. A comparison was made between the column labeled "CHARGE" in Attachment D with column 2 of Attachment A to insure that after the radionuclide activities were converted to grams and re-entered into the ORIGEN2 run the activities for all of the significant radionuclides remained essentially unchanged and that values for all of the measured radionuclides presented in Table 1 were properly entered.

The evaluation of the radionuclide content of Zr calcine has been based on processing and calcination of wastes in 1971. However, it is desired to establish a maximum activity for Zr calcine that has been produced subsequent to 1971. The last fuel processing done at the ICPP was in 1988. Assuming that the time between reactor shutdown and calcination of the wastes remains the same as that for the 1971 campaign, it has been assumed that decay times normalized to 1988 would give a maximum radionuclide content for Zr calcine. Thus calcine in the year 2016 has been assumed to decay for 28 years, 2035 for 47 years, etc. At long decay times, the affects of any inaccuracy in this assumption become minimal.

The data in Attachment D has been expressed with 4 places of accuracy. This clearly is more accuracy than can be justified. The calculated radionuclide activities for Zr calcine presented in Table 2 have been rounded to 2 places of accuracy. The half-life for each of the radionuclides has also been included for convenience.

While the primary purpose of this EDF was to calculate the radionuclide concentrations for Al calcine, it was deemed prudent to extend the calculations to also provide the gamma-ray photon spectrums as a function of decay time as calculated using the ORIGEN2 program. Attachment E contains the photon spectrums for activation products, actinides and their daughters, and fission products. Attachment E also contains the sum of the individual photon spectrums. The total photon spectrum with 2 places of accuracy is also provided in Table 3.

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Table 2: Calculated Radionuclide Activities for Zr Calcine in Ci/g as a Function of Decay Time

Nuclide (Actinides and Daughters)	Half-Life	2016	2035	Decay Time Since 2016 (yr)		
				1E2	5E2	1E3
Tl207	4.770E+00 m	2.0E-12	2.5E-12	3.2E-12	3.9E-12	4.7E-12
Tl208	3.053E+00 m	2.7E-13	2.3E-13			
Pb210	2.226E+01 yr	4.1E-15	1.7E-14	2.4E-13	7.7E-12	2.9E-11
Pb211	3.610E+01 m	2.0E-12	2.5E-12	3.2E-12	3.9E-12	4.7E-12
Pb212	1.064E+01 h	7.6E-13	6.3E-13	2.9E-13	6.2E-15	
Bi210	5.013E+00 d	4.1E-15	1.7E-14	2.4E-13	7.7E-12	2.9E-11
Bi211	2.130E+00 m	2.0E-12	2.5E-12	3.2E-12	3.9E-12	4.7E-12
Bi212	6.055E+01 m	7.6E-13	6.3E-13	2.9E-13	6.2E-15	
Po210	1.384E+02 d	4.1E-15	1.7E-14	2.4E-13	7.7E-12	2.9E-11
Po212	3.000E-07 s	4.9E-13	4.1E-13	1.9E-13	4.0E-15	4.2E-17
Rn220	5.561E+01 s	7.6E-13	6.3E-13			
Rn222	3.824E+00 d	1.8E-14	5.0E-14	4.0E-13	7.7E-12	2.9E-11
Ra223	1.143E+01 d	2.0E-12	2.5E-12	3.2E-12	3.9E-12	4.7E-12
Ra224	3.620E+00 d	7.6E-13	6.3E-13	2.9E-13	6.2E-15	6.5E-17
Ra225	1.480E+01 d	1.8E-16	2.9E-16	1.4E-15	2.6E-14	1.1E-13
Ra226	1.600E+03 yr	1.8E-14	5.0E-14	4.0E-13	7.7E-12	2.9E-11
Ra228	5.750E+00 yr	4.6E-18	4.9E-18	5.8E-18	9.8E-18	1.5E-17
Ac225	1.000E+01 d	1.8E-16	2.9E-16	1.4E-15	2.6E-14	1.1E-13
Ac227	2.177E+01 yr	2.0E-12	2.5E-12	3.2E-12	3.9E-12	4.7E-12
Th227	1.872E+01 d	2.0E-12	2.5E-12	3.2E-12	3.9E-12	4.6E-12
Th228	1.913E+00 yr	7.6E-13	6.3E-13	2.9E-13	6.2E-15	6.5E-17
Th229	7.340E+03 yr	1.8E-16	2.9E-16	1.4E-15	2.6E-14	1.1E-13
Th230	7.700E+04 yr	2.9E-12	5.1E-12	1.5E-11	7.6E-11	1.6E-10
Th231	2.552E+01 h	7.6E-11	7.6E-11	7.6E-11	7.6E-11	7.6E-11
Th232	1.405E+10 yr	4.9E-18	5.0E-18	5.8E-18	9.8E-18	1.5E-17
Th234	2.410E+01 d	3.7E-12	3.7E-12	3.7E-12	3.7E-12	3.7E-12
Pa231	3.726E+04 yr	3.2E-12	3.2E-12	3.3E-12	3.9E-12	4.7E-12
Pa233	2.700E+01 d	3.8E-10	3.9E-10	4.4E-10	5.9E-10	6.9E-10
Pa234m	1.170E+00 m	3.7E-12	3.7E-12	3.7E-12	3.7E-12	3.7E-12
Pa234	6.700E+00 h	4.9E-15	4.9E-15	4.9E-15	4.9E-15	4.9E-15
U232	7.200E+01 yr	7.4E-13	6.2E-13	2.8E-13	6.0E-15	4.9E-17
U233	1.592E+05 yr	4.7E-14	7.9E-14	2.3E-13	1.1E-12	2.6E-12
U234	2.445E+05 yr	1.2E-08	1.3E-08	1.5E-08	1.8E-08	1.8E-08
U235	7.038E+08 yr	7.6E-11	7.6E-11	7.6E-11	7.6E-11	7.6E-11
U236	2.342E+07 yr	2.0E-10	2.0E-10	2.0E-10	2.0E-10	2.1E-10
U237	6.750E+00 d	1.7E-10	6.8E-11	1.4E-12		
U238	4.470E+09 yr	3.7E-12	3.7E-12	3.7E-12	3.7E-12	3.7E-12
Np237	2.140E+06 yr	3.8E-10	3.9E-10	4.4E-10	5.9E-10	6.9E-10
Np238	2.117E+00 d	2.3E-15	2.1E-15	1.4E-15	2.3E-16	
Np239	2.355E+00 d	2.9E-14	2.9E-14	2.9E-14	2.8E-14	2.6E-14
Pu236	2.851E+00 yr	2.4E-14	2.4E-16			
Pu238	8.775E+01 yr	1.5E-05	1.3E-05	6.9E-06	2.9E-07	5.7E-09
Pu239	2.413E+04 yr	2.4E-07	2.4E-07	2.4E-07	2.4E-07	2.3E-07
Pu240	6.569E+03 yr	2.2E-07	2.2E-07	2.2E-07	2.1E-07	2.0E-07
Pu241	1.440E+01 yr	7.0E-06	2.8E-06	5.6E-08	2.5E-16	2.2E-18
Pu242	3.758E+05 yr	5.0E-10	5.0E-10	5.0E-10	5.0E-10	5.0E-10
Pu244	8.260E+07 yr	8.6E-23	8.6E-23	8.6E-23	8.6E-23	8.6E-23
Am241	4.322E+02 yr	1.7E-06	1.8E-06	1.6E-06	8.7E-07	3.9E-07
Am242m	1.520E+02 yr	4.5E-13	4.1E-13	2.9E-13	4.6E-14	4.7E-15
Am242	1.602E+01 h	4.5E-13	4.1E-13	2.8E-13	4.6E-14	4.7E-15
Am243	7.380E+03 yr	2.9E-14	2.9E-14	2.9E-14	2.8E-14	2.6E-14
Cm242	1.628E+02 d	3.7E-13	3.4E-13	2.3E-13	3.8E-14	3.9E-15
Cm243	2.850E+01 yr	7.3E-15	4.6E-15	6.4E-16	3.8E-20	
Cm244	1.811E+01 yr	6.5E-14	3.1E-14	1.4E-15		
Cm245	8.500E+03 yr	2.4E-18	2.4E-18	2.4E-18	2.3E-18	2.2E-18
Cm246	4.750E+03 yr	3.7E-20	3.7E-20	3.7E-20	3.5E-20	3.2E-20

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**Table 2: Calculated Radionuclide Activities for Zr Calcine in Ci/g as a Function of Decay Time
(continued)**

Nuclide	Half-Life		2016	2035	Decay Time Since 2016 (yr)		
					1E2	5E2	1E3
(Fission Products continued)							
(Fission Products)							
H 3	1.228E+01	yr	1.3E-06	4.4E-07	4.7E-09	8.3E-19	
Be 10	1.600E+06	yr	6.3E-14	6.3E-14	6.3E-14	6.3E-14	6.3E-14
C 14	5.730E+03	yr	2.5E-12	2.5E-12	2.5E-12	2.4E-12	2.3E-12
Se 79	6.500E+04	yr	9.2E-09	9.2E-09	9.2E-09	9.1E-09	9.1E-09
Rb 87	4.730E+10	yr	6.2E-13	6.2E-13	6.2E-13	6.2E-13	6.2E-13
Sr 90	2.912E+01	yr	1.3E-03	8.1E-04	1.2E-04	8.7E-09	5.9E-14
Y 90	6.410E+01	h	1.3E-03	8.1E-04	1.2E-04	8.7E-09	5.9E-14
Zr 93	1.530E+06	yr	4.8E-08	4.8E-08	4.8E-08	4.7E-08	4.7E-08
Nb 93m	1.360E+01	yr	3.8E-08	4.2E-08	4.5E-08	4.5E-08	4.5E-08
Nb 94	2.030E+04	yr	4.8E-13	4.8E-13	4.8E-13	4.7E-13	4.7E-13
Tc 98	4.200E+06	yr	7.7E-15	7.7E-15	7.7E-15	7.7E-15	7.7E-15
Tc 99	2.130E+05	yr	3.1E-07	3.1E-07	3.1E-07	3.1E-07	3.1E-07
Rh102	2.900E+00	yr	2.7E-13	2.9E-15			
Pd107	6.500E+06	yr	3.3E-10	3.3E-10	3.3E-10	3.3E-10	3.3E-10
Ag108m	1.270E+02	yr	6.6E-16	5.9E-16	3.8E-16	4.3E-17	2.8E-18
Cd113m	1.360E+01	yr	4.7E-08	1.9E-08	4.1E-10	2.3E-18	
In115	5.100E+15	yr	3.0E-18	3.0E-18	3.0E-18	3.0E-18	3.0E-18
Sn121m	5.000E+01	yr	1.2E-09	9.2E-10	3.0E-10	1.2E-12	1.1E-15
Tel23	1.000E+13	yr	2.9E-22	2.9E-22	2.9E-22	2.9E-22	2.9E-22
Sb125	2.770E+00	yr	1.8E-08	1.5E-10	2.4E-19		
Tel25m	5.800E+01	d	4.3E-09	3.7E-11			
Sn126	1.000E+05	yr	8.1E-09	8.1E-09	8.1E-09	8.1E-09	8.1E-09
Sb126	1.240E+01	d	1.1E-09	1.1E-09	1.1E-09	1.1E-09	1.1E-09
Sb126m	1.900E+01	m	8.1E-09	8.1E-09	8.1E-09	8.1E-09	8.1E-09
I129	1.570E+07	yr	5.1E-10	5.1E-10	5.1E-10	5.1E-10	5.1E-10
Cs134	2.062E+00	yr	2.9E-09	4.8E-12			
Cs135	2.300E+06	yr	1.9E-08	1.9E-08	1.9E-08	1.9E-08	1.9E-08
Cs137	3.000E+01	yr	9.9E-04	6.4E-04	9.8E-05	9.5E-09	9.1E-14
Ba137m	2.552E+00	m	9.4E-04	6.0E-04	9.3E-05	9.0E-09	8.6E-14
La138	1.350E+11	yr	4.7E-18	4.7E-18	4.7E-18	4.7E-18	4.7E-18
Ce142	1.050E+11	yr	6.3E-13	6.3E-13	6.3E-13	6.3E-13	6.3E-13
Nd144	2.100E+15	yr	3.0E-17	3.0E-17	3.0E-17	3.0E-17	3.0E-17
Pm146	2.020E+03	d	9.3E-11	8.5E-12	3.1E-16		
Sm146	1.030E+08	yr	5.6E-16	5.6E-16	5.6E-16	5.6E-16	5.6E-16
Pm147	2.623E+00	yr	5.9E-07	3.9E-09	2.0E-18		
Sm147	1.070E+11	yr	2.2E-13	2.2E-13	2.2E-13	2.2E-13	2.2E-13
Sm148	8.000E+15	yr	2.3E-19	2.3E-19	2.3E-19	2.3E-19	2.3E-19
Sm149	1.000E+15	yr	9.3E-20	9.3E-20	9.3E-20	9.3E-20	9.3E-20
Eu150	3.600E+01	yr	7.3E-14	5.1E-14	1.1E-14	4.8E-18	3.2E-22
Sm151	9.000E+01	yr	2.2E-05	1.9E-05	1.0E-05	4.6E-07	9.9E-09
Eu152	1.360E+01	yr	4.8E-08	1.8E-08	2.9E-10	4.1E-19	
Gd152	1.080E+14	yr	2.1E-20	2.2E-20	2.2E-20	2.2E-20	2.2E-20
Eu154	8.600E+00	yr	3.9E-06	8.4E-07	1.2E-09		
Eu155	4.960E+00	yr	5.6E-09	3.9E-10	4.7E-15		
Ho166m	1.200E+03	yr	8.9E-14	8.8E-14	8.4E-14	6.7E-14	5.0E-14
(Activation Products)							
Co 60	5.271E+00	yr	5.7E-08	4.7E-09	1.1E-13		

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Table 3: Calculated Gamma-Ray Photon Spectrum for Al Calcine as a Function of Decay Time

			Photons/s/g Calcine				
Photon Group Energy (MeV)			Decay after 2035				
Lower	Upper	Average	2016	2035	100yr	500yr	1000yr
0.00E-0	>2.00E-2	1.00E-02	3.6E+07	2.3E+07	3.4E+06	1.2E+04	6.0E+03
2.00E-2	>3.00E-2	2.50E-02	7.4E+06	4.7E+06	6.9E+05	1.1E+03	6.2E+02
3.00E-2	>4.50E-2	3.75E-02	7.1E+06	4.5E+06	6.7E+05	2.0E+02	1.0E+02
4.50E-2	>7.00E-2	5.75E-02	6.9E+06	4.4E+06	6.7E+05	1.2E+04	5.5E+03
7.00E-2	>1.00E-1	8.50E-02	4.1E+06	2.6E+06	3.8E+05	2.2E+02	1.9E+02
1.00E-1	>1.50E-1	1.25E-01	2.7E+06	1.7E+06	2.5E+05	4.5E+01	2.3E+01
1.50E-1	>3.00E-1	2.25E-01	3.6E+06	2.3E+06	3.3E+05	4.4E+01	1.9E+01
3.00E-1	>4.50E-1	3.75E-01	1.5E+06	9.8E+05	1.4E+05	3.5E+02	3.4E+02
4.50E-1	>7.00E-1	5.75E-01	3.6E+07	2.3E+07	3.6E+06	1.1E+03	7.3E+02
7.00E-1	>1.00E+0	8.50E-01	3.2E+05	1.7E+05	2.3E+04	3.8E+01	3.7E+01
1.00E+0	>1.50E+0	1.25E+00	1.6E+05	6.9E+04	7.6E+03	9.5E+00	9.2E+00
1.50E+0	>2.00E+0	1.75E+00	8.6E+03	4.5E+03	5.9E+02	1.2E-01	3.0E-01
2.00E+0	>2.50E+0	2.25E+00	7.3E-01	4.5E-01	6.7E-02	2.4E-02	9.2E-02
2.50E+0	>3.00E+0	2.75E+00	1.0E-02	8.6E-03	4.1E-03	6.7E-04	1.7E-03
3.00E+0	>4.00E+0	3.50E+00	5.5E-04	5.0E-04	3.4E-04	2.3E-04	4.4E-04
4.00E+0	>6.00E+0	5.00E+00	2.2E-04	2.0E-04	1.4E-04	6.5E-05	5.9E-05
6.00E+0	>8.00E+0	7.00E+00	2.4E-05	2.2E-05	1.5E-05	7.4E-06	6.7E-06
8.00E+0	>1.10E+1	9.50E+00	2.6E-06	2.4E-06	1.6E-06	8.4E-07	7.7E-07

References

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- RSIC (Radiation Shielding Information Center), 1991, *RSIC Computer Code Collection*, "ORIGEN2.1, Isotope Generation and Depletion Code Matrix Exponential Method", CCC-371, Oak Ridge, Tennessee.
- Staples, B. A., G. S. Pomiak, E. L. Wade, 1979, *Properties of Radioactive Calcine retrieved from the Second Solids Storage Facility at ICPP*, ICP-1189, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho, March.
- Westra, A. G., Schofield, J. S., Horn, S. J., Hendricks, J. A., Pomiak, G. S., 1979, *Sampling of Stored High-Level Radioactive Calcined Waste at ICPP*, ICP-1186, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho, May.

Attachment A

**Attachment A: ORIGEN2 Input and Output for Calculating Zr Fuel Inventory as a
Function of Decay Time**

```
echo off
echo **
echo **
echo **
echo **
copy zr1.INP tape5.inp >nul
REM (NOT USED IN THIS CASE) copy zr1.u3 tape3.inp >nul
copy \ORIGEN2\libs\decay.lib+\ORIGEN2\libs\pwrus.lib tape9.inp >nul
copy \ORIGEN2\libs\gxuo2brm.lib tape10.inp >nul
\ORIGEN2\code\ORIGEN2
echo finished with ORIGEN2 calculation
rem combine and save files from run
copy tape12.out+tape6.out zr1.u6 >nul
copy tape13.out+tape11.out zr1.u11 >nul
ren tape7.out zr1.pch
ren tape15.out zr1.dbg
ren tape16.out zr1.vxs
ren tape50.out zr1.ech
rem cleanup files
del tape*.inp
del tape*.out
echo *****
echo ***** O R I G E N 2 - Version 2.1 *****
echo ***** Execution Completed *****
echo *****
echo on
```

**Attachment A: ORIGEN2 Input and Output for Calculating Zr Fuel Inventory as a
Function of Decay Time (continued)**

```

-1
-1
-1
RDA  ORIGEN2, VERSION 2.1 (8-1-91) GENERIC FUEL
BAS  PWRU FUEL
RDA  -1 = 1 KG FUEL
RDA  WARNING:  VECTORS ARE OFTEN CHANGED WITH RESPECT TO THEIR CONTENT.
RDA                THESE CHANGES WILL BE NOTED ON RDA CARDS.
CUT  -1
LIP  0 0 0
LIB  0 1 2 3 601 602 603 9 3 0 1 38
TIT  INITIAL COMPOSITIONS OF UNIT AMOUNTS OF FUEL AND STRUCT MAT'LS
RDA  READ FUEL COMPOSITION INCLUDING IMPURITIES
INP  -1 1 -1 -1 1 1
TIT  IRRADIATION OF GENERIC FUEL
MOV  -1 1 0 1.0
HED  1
                                     CHARGE
BUP
IRP  100.0 .2577 1 2 4 2
IRP  200.0 .2577 2 3 4 0
IRP  400.0 .2577 3 4 4 0
IRP  600.0 .2577 4 5 4 0
IRP  800.0 .2577 5 6 4 0
IRP  1000.0 .2577 6 7 4 0
IRP  1200.0 .2577 7 8 4 0
IRP  1400.0 .2577 8 9 4 0
IRP  1600.0 .2577 9 10 4 0
IRP  1800.0 .2577 10 11 4 0
IRP  1826.0 .2577 11 12 4 0
BUP
OPTL 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
OPTA 8 8 8 8 5 8 5 8 8 8 8 8 8 8 8 8 8 8 8 8
OPTF 8 8 8 8 8 8 5 8 8 8 8 8 8 8 8 8 8 8 8 8
MOV  12 1 0 1.0
DEC  1.0 1 2 5 4
DEC  3.0 2 3 5 0
DEC  4.0 3 4 5 0
DEC  5.0 4 5 5 0
DEC  6.0 5 6 5 0
DEC  7.0 6 7 5 0
DEC  8.0 7 8 5 0
DEC  9.0 8 9 5 0
OUT  -9 1 -1 0
OUT  9 1 -1 0
END
2 922350 1000.0 922360 .4366 922380 8.6636 0 0.0 FUEL 97%
0

```

Attachment A: ORIGEN2 Input and Output for Calculating Zr Fuel Inventory as a Function of Decay Time (continued)

Zr1 ORIGEN2 V2.1 (8-1-91), Run on 07/21/97 at 11:13:59										
	365.3D	1.0YR	5.0YR	6.0YR	7.0YR	8.0YR	9.0YR	10.0YR	11.0YR	
TL206	3.826E-25	3.826E-25	3.826E-25	3.826E-25	3.826E-25	3.826E-25	3.826E-25	3.826E-25	3.826E-25	
TL207	5.020E-10	2.492E-09	2.157E-08	2.912E-08	3.766E-08	4.720E-08	5.771E-08	6.915E-08	8.151E-08	
TL208	5.550E-08	2.046E-07	5.475E-07	5.933E-07	6.270E-07	6.522E-07	6.707E-07	6.838E-07	6.927E-07	
TL209	1.052E-13	6.260E-14	2.019E-13	2.401E-13	2.798E-13	3.210E-13	3.637E-13	4.078E-13	4.535E-13	
PB209	4.875E-12	2.898E-12	9.347E-12	1.112E-11	1.296E-11	1.486E-11	1.684E-11	1.888E-11	2.099E-11	
PB210	1.758E-14	2.373E-14	1.147E-13	1.753E-13	2.572E-13	3.636E-13	4.974E-13	6.615E-13	8.587E-13	
PB211	5.034E-10	2.499E-09	2.163E-08	2.920E-08	3.777E-08	4.733E-08	5.787E-08	6.935E-08	8.173E-08	
PB212	1.545E-07	5.694E-07	1.524E-06	1.651E-06	1.745E-06	1.815E-06	1.867E-06	1.903E-06	1.928E-06	
PB214	1.905E-14	1.334E-13	1.756E-12	2.457E-12	3.278E-12	4.220E-12	5.284E-12	6.471E-12	7.780E-12	
BI208	1.924E-25	1.924E-25	1.924E-25	1.924E-25	1.924E-25	1.924E-25	1.924E-25	1.924E-25	1.924E-25	
BI210M	3.841E-25	3.841E-25	3.841E-25	3.841E-25	3.841E-25	3.841E-25	3.841E-25	3.841E-25	3.841E-25	
BI210	1.760E-14	2.374E-14	1.147E-13	1.753E-13	2.573E-13	3.637E-13	4.976E-13	6.618E-13	8.591E-13	
BI211	5.034E-10	2.499E-09	2.163E-08	2.920E-08	3.777E-08	4.733E-08	5.787E-08	6.935E-08	8.173E-08	
BI212	1.545E-07	5.694E-07	1.524E-06	1.651E-06	1.745E-06	1.815E-06	1.867E-06	1.903E-06	1.928E-06	
BI213	4.871E-12	2.898E-12	9.347E-12	1.112E-11	1.296E-11	1.486E-11	1.684E-11	1.888E-11	2.099E-11	
BI214	1.905E-14	1.334E-13	1.756E-12	2.457E-12	3.278E-12	4.220E-12	5.284E-12	6.471E-12	7.780E-12	
PO210	5.194E-15	1.985E-14	1.148E-13	1.446E-13	2.109E-13	3.023E-13	4.197E-13	5.655E-13	7.425E-13	
PO211	1.410E-12	6.998E-12	6.057E-11	8.175E-11	1.057E-10	1.325E-10	1.620E-10	1.942E-10	2.289E-10	
PO212	9.896E-08	3.648E-07	9.764E-07	1.058E-06	1.118E-06	1.163E-06	1.196E-06	1.219E-06	1.235E-06	
PO213	4.766E-12	2.835E-12	9.145E-12	1.088E-11	1.268E-11	1.454E-11	1.647E-11	1.847E-11	2.054E-11	
PO214	1.895E-12	1.334E-13	1.755E-12	2.456E-12	3.278E-12	4.219E-12	5.283E-12	6.469E-12	7.779E-12	
PO215	5.034E-10	2.499E-09	2.163E-08	2.920E-08	3.777E-08	4.733E-08	5.787E-08	6.935E-08	8.173E-08	
PO216	1.545E-07	5.694E-07	1.524E-06	1.651E-06	1.745E-06	1.815E-06	1.867E-06	1.903E-06	1.928E-06	
PO218	1.905E-14	1.334E-13	1.756E-12	2.457E-12	3.279E-12	4.221E-12	5.285E-12	6.472E-12	7.782E-12	
AT217	4.871E-12	2.898E-12	9.347E-12	1.112E-11	1.296E-11	1.486E-11	1.684E-11	1.888E-11	2.099E-11	
RN218	1.876E-12	9.716E-18	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	
RN219	5.034E-10	2.499E-09	2.163E-08	2.920E-08	3.777E-08	4.733E-08	5.787E-08	6.935E-08	8.173E-08	
RN220	1.545E-07	5.694E-07	1.524E-06	1.651E-06	1.745E-06	1.815E-06	1.867E-06	1.903E-06	1.928E-06	
RN222	1.905E-14	1.334E-13	1.756E-12	2.457E-12	3.279E-12	4.221E-12	5.285E-12	6.472E-12	7.782E-12	
FR221	4.871E-12	2.898E-12	9.347E-12	1.112E-11	1.296E-11	1.486E-11	1.684E-11	1.888E-11	2.099E-11	
FR223	8.753E-12	3.447E-11	2.985E-10	4.022E-10	5.203E-10	6.520E-10	7.972E-10	9.552E-10	1.126E-09	
RA222	1.876E-12	9.716E-18	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	
RA223	5.034E-10	2.499E-09	2.163E-08	2.920E-08	3.777E-08	4.733E-08	5.787E-08	6.935E-08	8.173E-08	
RA224	1.545E-07	5.694E-07	1.524E-06	1.651E-06	1.745E-06	1.815E-06	1.867E-06	1.903E-06	1.928E-06	
RA225	5.404E-12	2.898E-12	9.347E-12	1.112E-11	1.296E-11	1.486E-11	1.684E-11	1.888E-11	2.099E-11	
RA226	1.905E-14	1.334E-13	1.756E-12	2.457E-12	3.279E-12	4.221E-12	5.285E-12	6.472E-12	7.782E-12	
RA228	1.251E-15	8.286E-15	9.382E-14	1.269E-13	1.637E-13	2.039E-13	2.472E-13	2.933E-13	3.418E-13	

Attachment A: ORIGEN2 Input and Output for Calculating Zr Fuel Inventory as a Function of Decay Time (continued)

Zr1 ORIGEN2 V2.1 (8-1-91), Run on 07/21/97 at 11:13:59										
	365.3D	1.0YR	5.0YR	6.0YR	7.0YR	8.0YR	9.0YR	10.0YR	11.0YR	
AC225	4.871E-12	2.898E-12	9.347E-12	1.112E-11	1.296E-11	1.486E-11	1.684E-11	1.888E-11	2.099E-11	
AC227	6.343E-10	2.498E-09	2.163E-08	2.915E-08	3.770E-08	4.725E-08	5.777E-08	6.922E-08	8.158E-08	
AC228	2.034E-09	8.287E-15	9.382E-14	1.269E-13	1.637E-13	2.039E-13	2.472E-13	2.933E-13	3.419E-13	
TH226	1.876E-12	9.716E-18	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	
TH227	5.433E-10	2.465E-09	2.133E-08	2.879E-08	3.725E-08	4.668E-08	5.708E-08	6.839E-08	8.061E-08	
TH228	1.540E-07	5.688E-07	1.523E-06	1.646E-06	1.739E-06	1.809E-06	1.860E-06	1.896E-06	1.921E-06	
TH229	1.444E-12	2.898E-12	9.347E-12	1.112E-11	1.296E-11	1.486E-11	1.684E-11	1.888E-11	2.099E-11	
TH230	1.312E-10	3.972E-10	1.483E-09	1.760E-09	2.039E-09	2.319E-09	2.603E-09	2.888E-09	3.175E-09	
TH231	1.904E-03	1.902E-03	1.902E-03	1.902E-03	1.902E-03	1.902E-03	1.902E-03	1.902E-03	1.902E-03	
TH232	3.650E-14	1.079E-13	3.938E-13	4.652E-13	5.367E-13	6.081E-13	6.796E-13	7.510E-13	8.225E-13	
TH234	2.908E-06	2.908E-06	2.908E-06	2.908E-06	2.908E-06	2.908E-06	2.908E-06	2.908E-06	2.908E-06	
PA231	3.971E-08	8.013E-08	2.413E-07	2.817E-07	3.221E-07	3.625E-07	4.029E-07	4.433E-07	4.837E-07	
PA233	1.187E-04	1.501E-04	1.501E-04	1.501E-04	1.501E-04	1.501E-04	1.501E-04	1.501E-04	1.501E-04	
PA234M	3.265E-06	2.908E-06	2.908E-06	2.908E-06	2.908E-06	2.908E-06	2.908E-06	2.908E-06	2.908E-06	
PA234	3.611E-07	3.780E-09	3.780E-09	3.780E-09	3.780E-09	3.780E-09	3.780E-09	3.780E-09	3.780E-09	
U230	1.876E-12	9.706E-18	8.801E-39	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	
U232	1.418E-06	1.589E-06	1.908E-06	1.940E-06	1.961E-06	1.974E-06	1.979E-06	1.979E-06	1.976E-06	
U233	1.502E-08	1.573E-08	1.835E-08	1.908E-08	1.981E-08	2.053E-08	2.126E-08	2.199E-08	2.271E-08	
U234	2.943E-05	2.967E-05	3.063E-05	3.087E-05	3.110E-05	3.133E-05	3.156E-05	3.179E-05	3.201E-05	
U235	1.902E-03	1.902E-03	1.902E-03	1.902E-03	1.902E-03	1.902E-03	1.902E-03	1.902E-03	1.902E-03	
U236	1.448E-03	1.448E-03	1.448E-03	1.448E-03	1.448E-03	1.448E-03	1.448E-03	1.448E-03	1.448E-03	
U237	9.213E+02	1.315E-07	1.085E-07	1.034E-07	9.855E-08	9.392E-08	8.950E-08	8.530E-08	8.129E-08	
U238	2.908E-06	2.908E-06	2.908E-06	2.908E-06	2.908E-06	2.908E-06	2.908E-06	2.908E-06	2.908E-06	
U240	1.086E-05	1.140E-17	1.140E-17	1.140E-17	1.140E-17	1.140E-17	1.140E-17	1.140E-17	1.140E-17	
NP235	3.486E-07	1.839E-07	1.426E-08	7.527E-09	3.972E-09	2.096E-09	1.106E-09	5.837E-10	3.080E-10	
NP236	3.463E-10	3.463E-10	3.463E-10	3.463E-10	3.463E-10	3.463E-10	3.463E-10	3.463E-10	3.463E-10	
NP237	1.422E-04	1.501E-04	1.501E-04	1.501E-04	1.501E-04	1.501E-04	1.501E-04	1.501E-04	1.501E-04	
NP238	3.379E+01	3.498E-10	3.435E-10	3.419E-10	3.404E-10	3.388E-10	3.373E-10	3.357E-10	3.342E-10	
NP239	3.858E+01	3.874E-09	3.872E-09	3.872E-09	3.871E-09	3.871E-09	3.871E-09	3.870E-09	3.870E-09	
NP240M	2.216E-03	1.140E-17	1.140E-17	1.140E-17	1.140E-17	1.140E-17	1.140E-17	1.140E-17	1.140E-17	
PU236	1.983E-05	1.574E-05	5.952E-06	4.667E-06	3.660E-06	2.870E-06	2.251E-06	1.765E-06	1.384E-06	
PU237	1.639E-05	6.359E-08	1.441E-17	1.955E-19	1.072E-19	0.000E+00	0.000E+00	0.000E+00	0.000E+00	
PU238	8.440E-02	8.595E-02	8.328E-02	8.263E-02	8.198E-02	8.133E-02	8.069E-02	8.006E-02	7.943E-02	
PU239	8.962E-04	9.066E-04	9.065E-04	9.064E-04	9.064E-04	9.064E-04	9.064E-04	9.063E-04	9.063E-04	
PU240	1.908E-04	1.908E-04	1.907E-04	1.907E-04	1.907E-04	1.907E-04	1.907E-04	1.906E-04	1.906E-04	
PU241	5.627E-03	5.362E-03	4.423E-03	4.215E-03	4.017E-03	3.828E-03	3.649E-03	3.477E-03	3.314E-03	
PU242	4.720E-09	4.720E-09	4.720E-09	4.720E-09	4.720E-09	4.720E-09	4.720E-09	4.720E-09	4.720E-09	

Attachment A: ORIGEN2 Input and Output for Calculating Zr Fuel Inventory as a Function of Decay Time (continued)

Zr1
ORIGEN2 V2.1 (8-1-91), Run on 07/21/97 at 11:13:59

	365.3D	1.0YR	5.0YR	6.0YR	7.0YR	8.0YR	9.0YR	10.0YR	11.0YR
PU243	1.842E-04	1.188E-21	1.188E-21	1.188E-21	1.188E-21	1.188E-21	1.188E-21	1.188E-21	1.188E-21
PU244	1.141E-17	1.141E-17	1.141E-17	1.141E-17	1.141E-17	1.141E-17	1.141E-17	1.141E-17	1.141E-17
PU246	1.884E-16	1.385E-26	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
AM241	2.424E-06	1.122E-05	4.234E-05	4.919E-05	5.570E-05	6.190E-05	6.779E-05	7.339E-05	7.871E-05
AM242M	7.028E-08	6.996E-08	6.870E-08	6.838E-08	6.807E-08	6.776E-08	6.745E-08	6.715E-08	6.684E-08
AM242	2.657E-04	6.961E-08	6.835E-08	6.804E-08	6.773E-08	6.742E-08	6.712E-08	6.681E-08	6.651E-08
AM243	3.860E-09	3.874E-09	3.872E-09	3.872E-09	3.871E-09	3.871E-09	3.871E-09	3.870E-09	3.870E-09
AM245	3.480E-12	3.717E-27	3.717E-27	3.717E-27	3.717E-27	3.717E-27	3.717E-27	3.717E-27	3.717E-27
AM246	1.884E-16	1.387E-26	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CM241	2.748E-12	2.426E-15	1.472E-27	1.300E-30	1.147E-33	1.012E-36	0.000E+00	0.000E+00	0.000E+00
CM242	5.920E-05	1.278E-05	8.235E-08	6.181E-08	5.725E-08	5.608E-08	5.564E-08	5.534E-08	5.508E-08
CM243	2.318E-09	2.262E-09	2.052E-09	2.003E-09	1.955E-09	1.908E-09	1.862E-09	1.817E-09	1.774E-09
CM244	3.394E-08	3.269E-08	2.805E-08	2.700E-08	2.599E-08	2.501E-08	2.407E-08	2.317E-08	2.230E-08
CM245	3.208E-13	3.208E-13	3.207E-13	3.207E-13	3.206E-13	3.206E-13	3.206E-13	3.206E-13	3.205E-13
CM246	4.962E-15	4.962E-15	4.959E-15	4.958E-15	4.957E-15	4.957E-15	4.956E-15	4.955E-15	4.954E-15
CM247	1.188E-21	1.188E-21	1.188E-21	1.188E-21	1.188E-21	1.188E-21	1.188E-21	1.188E-21	1.188E-21
CM248	2.332E-22	2.332E-22	2.332E-22	2.332E-22	2.332E-22	2.332E-22	2.332E-22	2.332E-22	2.332E-22
CM250	9.372E-35	9.372E-35	9.372E-35	9.372E-35	9.372E-35	9.372E-35	9.372E-35	9.372E-35	9.372E-35
BK249	3.337E-23	2.563E-22	2.563E-22	2.563E-22	2.563E-22	2.563E-22	2.563E-22	2.563E-22	2.563E-22
CF250	8.494E-30	6.247E-28	6.247E-28	6.247E-28	6.247E-28	6.247E-28	6.247E-28	6.247E-28	6.247E-28
CF251	1.606E-35	2.830E-34	2.830E-34	2.830E-34	2.830E-34	2.830E-34	2.830E-34	2.830E-34	2.830E-34
H 3	1.295E+00	1.224E+00	9.781E-01	9.247E-01	8.742E-01	8.265E-01	7.814E-01	7.387E-01	6.984E-01
BE 10	8.406E-09	8.406E-09	8.406E-09	8.406E-09	8.406E-09	8.406E-09	8.406E-09	8.406E-09	8.406E-09
C 14	3.391E-07	3.390E-07	3.389E-07	3.388E-07	3.388E-07	3.387E-07	3.387E-07	3.387E-07	3.386E-07
SE 79	1.220E-03	1.220E-03	1.220E-03	1.220E-03	1.220E-03	1.220E-03	1.220E-03	1.220E-03	1.220E-03
KR 81	3.035E-11	3.035E-11	3.035E-11	3.035E-11	3.035E-11	3.035E-11	3.035E-11	3.035E-11	3.035E-11
KR 85	3.655E+01	3.429E+01	2.648E+01	2.482E+01	2.326E+01	2.181E+01	2.044E+01	1.916E+01	1.796E+01
RB 86	1.465E+00	1.873E-06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RB 87	8.202E-08	8.204E-08	8.204E-08	8.204E-08	8.204E-08	8.204E-08	8.204E-08	8.204E-08	8.204E-08
SR 89	1.023E+04	6.806E+01	1.329E-07	8.835E-10	5.872E-12	3.903E-14	2.593E-16	1.596E-18	0.000E+00
SR 90	2.905E+02	2.837E+02	2.579E+02	2.518E+02	2.459E+02	2.401E+02	2.345E+02	2.290E+02	2.236E+02
Y 90	2.935E+02	2.837E+02	2.580E+02	2.519E+02	2.460E+02	2.402E+02	2.345E+02	2.290E+02	2.236E+02
Y 91	1.239E+04	1.647E+02	5.008E-06	6.613E-08	8.732E-10	1.153E-11	1.523E-13	2.010E-15	2.647E-17
NB 92	1.569E-10	2.364E-21	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZR 93	6.299E-03	6.309E-03	6.309E-03	6.309E-03	6.309E-03	6.309E-03	6.309E-03	6.309E-03	6.309E-03
NB 93M	1.511E-04	4.415E-04	1.465E-03	1.690E-03	1.904E-03	2.107E-03	2.301E-03	2.484E-03	2.658E-03
NB 94	6.383E-08	6.383E-08	6.382E-08	6.382E-08	6.382E-08	6.381E-08	6.381E-08	6.381E-08	6.381E-08

Attachment A: ORIGEN2 Input and Output for Calculating Zr Fuel Inventory as a Function of Decay Time (continued)

Zr1
ORIGEN2 V2.1 (8-1-91), Run on 07/21/97 at 11:13:59

	365.3D	1.0YR	5.0YR	6.0YR	7.0YR	8.0YR	9.0YR	10.0YR	11.0YR
ZR 95	1.354E+04	2.589E+02	3.461E-05	6.617E-07	1.265E-08	2.419E-10	4.626E-12	8.846E-14	1.692E-15
NB 95	1.324E+04	5.823E+02	7.683E-05	1.520E-06	2.911E-08	5.566E-10	1.064E-11	2.035E-13	3.892E-15
NB 95M	9.777E+01	1.920E+00	2.567E-07	4.909E-09	9.387E-11	1.795E-12	3.432E-14	6.562E-16	1.255E-17
TC 98	1.018E-09	1.018E-09	1.018E-09	1.018E-09	1.018E-09	1.018E-09	1.018E-09	1.018E-09	1.018E-09
TC 99	4.120E-02	4.169E-02	4.169E-02	4.169E-02	4.169E-02	4.169E-02	4.169E-02	4.169E-02	4.169E-02
RH102	1.937E-04	1.525E-04	5.863E-05	4.617E-05	3.635E-05	2.862E-05	2.254E-05	1.775E-05	1.397E-05
RU103	6.764E+03	1.075E+01	6.844E-11	1.085E-13	1.729E-16	1.990E-19	1.487E-19	1.111E-19	0.000E+00
RH103M	6.094E+03	9.688E+00	6.170E-11	9.801E-14	1.558E-16	2.475E-19	1.339E-19	1.001E-19	1.592E-22
RU106	4.475E+02	2.250E+02	1.437E+01	7.226E+00	3.633E+00	1.827E+00	9.183E-01	4.617E-01	2.321E-01
RH106	4.764E+02	2.250E+02	1.437E+01	7.226E+00	3.633E+00	1.827E+00	9.183E-01	4.617E-01	2.321E-01
AG106	1.552E-11	1.800E-24	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PD107	4.430E-05	4.430E-05	4.430E-05	4.430E-05	4.430E-05	4.430E-05	4.430E-05	4.430E-05	4.430E-05
AG108	7.505E-05	9.384E-12	9.181E-12	9.131E-12	9.081E-12	9.032E-12	8.983E-12	8.934E-12	8.885E-12
AG108M	1.060E-10	1.054E-10	1.032E-10	1.026E-10	1.020E-10	1.015E-10	1.009E-10	1.004E-10	9.983E-11
AG109M	9.839E+01	1.889E-09	2.130E-10	1.234E-10	7.151E-11	4.144E-11	2.401E-11	1.392E-11	8.064E-12
CD109	3.259E-09	1.889E-09	2.130E-10	1.234E-10	7.151E-11	4.144E-11	2.401E-11	1.392E-11	8.064E-12
AG110	8.536E+00	7.266E-04	1.263E-05	4.584E-06	1.664E-06	6.043E-07	2.194E-07	7.966E-08	2.892E-08
AG110M	1.505E-01	5.463E-02	9.494E-04	3.447E-04	1.251E-04	4.544E-05	1.650E-05	5.989E-06	2.175E-06
AG111	5.637E+01	9.865E-14	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD113M	3.698E-02	3.528E-02	2.918E-02	2.782E-02	2.653E-02	2.530E-02	2.413E-02	2.301E-02	2.194E-02
IN114	4.297E-04	7.968E-07	1.044E-15	6.483E-18	1.988E-19	1.196E-21	0.000E+00	0.000E+00	0.000E+00
IN114M	1.384E-04	8.326E-07	1.091E-15	6.774E-18	2.077E-19	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD115M	3.078E+00	1.054E-02	1.448E-12	4.956E-15	1.683E-17	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN115	3.782E-14	3.897E-14	3.897E-14	3.897E-14	3.897E-14	3.897E-14	3.897E-14	3.897E-14	3.897E-14
IN115M	3.121E+01	7.408E-07	1.017E-16	3.483E-19	1.192E-21	4.049E-24	0.000E+00	0.000E+00	0.000E+00
SN117M	2.787E-03	3.928E-11	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN119M	3.505E-01	1.247E-01	2.000E-03	7.116E-04	2.532E-04	9.011E-05	3.206E-05	1.141E-05	4.060E-06
SN121M	2.610E-04	2.574E-04	2.435E-04	2.401E-04	2.368E-04	2.335E-04	2.303E-04	2.272E-04	2.240E-04
SN123	1.051E+01	1.480E+00	5.827E-04	8.207E-05	1.156E-05	1.628E-06	2.293E-07	3.230E-08	4.550E-09
TE123	3.180E-17	3.748E-17	3.826E-17	3.826E-17	3.826E-17	3.826E-17	3.826E-17	3.826E-17	3.826E-17
TE123M	1.971E-04	2.377E-05	5.024E-09	6.058E-10	7.304E-11	8.807E-12	1.062E-12	1.280E-13	1.544E-14
SB124	2.857E-01	4.260E-03	2.105E-10	3.139E-12	4.680E-14	6.978E-16	1.047E-17	3.220E-19	0.000E+00
SN125	3.317E+01	1.304E-10	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB125	1.868E+01	1.480E+01	5.438E+00	4.234E+00	3.297E+00	2.567E+00	1.999E+00	1.556E+00	1.212E+00
TE125M	3.391E+00	3.594E+00	1.327E+00	1.033E+00	8.044E-01	6.263E-01	4.876E-01	3.797E-01	2.956E-01
SN126	1.080E-03	1.080E-03	1.080E-03	1.080E-03	1.080E-03	1.080E-03	1.080E-03	1.080E-03	1.080E-03
SB126	2.308E+00	1.513E-04	1.513E-04	1.513E-04	1.513E-04	1.512E-04	1.512E-04	1.512E-04	1.512E-04

Attachment A: ORIGEN2 Input and Output for Calculating Zr Fuel Inventory as a Function of Decay Time (continued)

Zr1

ORIGEN2 V2.1 (8-1-91), Run on 07/21/97 at 11:13:59

	365.3D	1.0YR	5.0YR	6.0YR	7.0YR	8.0YR	9.0YR	10.0YR	11.0YR
SB126M	1.082E+00	1.080E-03	1.080E-03	1.080E-03	1.080E-03	1.080E-03	1.080E-03	1.080E-03	1.080E-03
TE127	3.345E+02	4.243E+00	3.917E-04	3.839E-05	3.763E-06	3.689E-07	3.616E-08	3.544E-09	3.474E-10
TE127M	4.244E+01	4.332E+00	3.999E-04	3.920E-05	3.842E-06	3.766E-07	3.691E-08	3.618E-09	3.547E-10
XE127	9.738E-07	9.308E-10	7.768E-22	7.424E-25	7.096E-28	6.782E-31	6.482E-34	6.184E-37	0.000E+00
TE129	1.449E+03	7.639E-02	6.215E-15	3.319E-18	1.773E-21	9.467E-25	5.056E-28	2.700E-31	1.439E-34
TE129M	2.187E+02	1.174E-01	9.547E-15	5.099E-18	2.723E-21	1.454E-24	7.767E-28	4.148E-31	2.216E-34
I129	6.643E-05	6.777E-05	6.777E-05	6.777E-05	6.777E-05	6.777E-05	6.777E-05	6.777E-05	6.777E-05
XE129M	1.742E-04	3.142E-18	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I131	6.145E+03	1.335E-10	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE131M	6.843E+01	1.230E-07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS132	1.406E-01	1.465E-18	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE133	1.436E+04	1.927E-17	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS134	5.463E+01	3.904E+01	1.018E+01	7.270E+00	5.195E+00	3.712E+00	2.652E+00	1.895E+00	1.354E+00
CS135	2.451E-03	2.459E-03	2.459E-03	2.459E-03	2.459E-03	2.459E-03	2.459E-03	2.459E-03	2.459E-03
CS136	5.999E+01	2.432E-07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BA136M	9.886E+00	4.009E-08	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS137	3.014E+02	2.945E+02	2.685E+02	2.624E+02	2.564E+02	2.505E+02	2.448E+02	2.392E+02	2.337E+02
BA137M	2.857E+02	2.786E+02	2.540E+02	2.482E+02	2.425E+02	2.370E+02	2.316E+02	2.263E+02	2.211E+02
LA138	6.243E-13	6.243E-13	6.243E-13	6.243E-13	6.243E-13	6.243E-13	6.243E-13	6.243E-13	6.243E-13
BA140	1.331E+04	3.367E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
LA140	1.342E+04	3.875E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE141	1.264E+04	5.275E+00	1.565E-13	6.496E-17	2.696E-20	1.119E-23	4.644E-27	1.928E-30	8.000E-34
CE142	8.381E-08	8.384E-08	8.384E-08	8.384E-08	8.384E-08	8.384E-08	8.384E-08	8.384E-08	8.384E-08
PR143	1.234E+04	1.080E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE144	6.883E+03	2.825E+03	8.013E+01	3.289E+01	1.350E+01	5.539E+00	2.273E+00	9.328E-01	3.828E-01
PR144	6.902E+03	2.825E+03	8.013E+01	3.289E+01	1.350E+01	5.539E+00	2.273E+00	9.329E-01	3.828E-01
PR144M	8.267E+01	3.390E+01	9.616E-01	3.946E-01	1.620E-01	6.646E-02	2.728E-02	1.119E-02	4.594E-03
ND144	1.424E-12	2.929E-12	3.947E-12	3.964E-12	3.971E-12	3.974E-12	3.976E-12	3.976E-12	3.976E-12
PM146	1.144E-03	1.009E-03	6.093E-04	5.371E-04	4.735E-04	4.175E-04	3.680E-04	3.245E-04	2.860E-04
SM146	2.109E-11	2.503E-11	3.664E-11	3.874E-11	4.058E-11	4.221E-11	4.365E-11	4.492E-11	4.603E-11
ND147	4.879E+03	5.592E-07	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM147	9.983E+02	8.103E+02	2.816E+02	2.162E+02	1.660E+02	1.275E+02	9.788E+01	7.515E+01	5.770E+01
SM147	3.278E-09	9.286E-09	2.225E-08	2.385E-08	2.508E-08	2.603E-08	2.675E-08	2.731E-08	2.774E-08
PM148	5.274E+02	1.438E-02	3.220E-13	7.016E-16	1.526E-18	1.093E-20	2.626E-23	0.000E+00	0.000E+00
PM148M	1.174E+02	2.554E-01	5.717E-12	1.246E-14	2.701E-17	2.143E-19	0.000E+00	0.000E+00	0.000E+00
SM148	2.743E-14	3.005E-14	3.006E-14	3.006E-14	3.006E-14	3.006E-14	3.006E-14	3.006E-14	3.006E-14
SM149	1.073E-14	1.228E-14	1.228E-14	1.228E-14	1.228E-14	1.228E-14	1.228E-14	1.228E-14	1.228E-14

Attachment A: ORIGEN2 Input and Output for Calculating Zr Fuel Inventory as a Function of Decay Time (continued)

Zr1

ORIGEN2 V2.1 (8-1-91), Run on 07/21/97 at 11:13:59

	365.3D	1.0YR	5.0YR	6.0YR	7.0YR	8.0YR	9.0YR	10.0YR	11.0YR
EU150	1.932E-08	1.895E-08	1.755E-08	1.721E-08	1.688E-08	1.656E-08	1.624E-08	1.593E-08	1.563E-08
SM151	3.784E+00	3.787E+00	3.672E+00	3.644E+00	3.616E+00	3.588E+00	3.561E+00	3.533E+00	3.506E+00
EU152	3.984E-02	3.787E-02	3.088E-02	2.935E-02	2.789E-02	2.650E-02	2.519E-02	2.394E-02	2.275E-02
GD152	1.574E-15	1.649E-15	1.894E-15	1.948E-15	1.999E-15	2.048E-15	2.094E-15	2.138E-15	2.180E-15
GD153	1.656E-03	5.819E-04	8.862E-06	3.113E-06	1.094E-06	3.842E-07	1.350E-07	4.742E-08	1.666E-08
EU154	1.737E+00	1.602E+00	1.161E+00	1.071E+00	9.879E-01	9.114E-01	8.408E-01	7.757E-01	7.156E-01
EU155	7.380E+00	6.418E+00	3.670E+00	3.191E+00	2.775E+00	2.413E+00	2.098E+00	1.824E+00	1.586E+00
EU156	7.190E+01	4.179E-06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TB160	6.790E-02	2.047E-03	1.692E-09	5.102E-11	1.538E-12	4.638E-14	1.398E-15	4.229E-17	1.340E-18
TB161	3.130E-01	4.048E-17	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
HO166M	1.202E-08	1.201E-08	1.198E-08	1.197E-08	1.197E-08	1.196E-08	1.195E-08	1.195E-08	1.194E-08
ER169	6.858E-07	1.378E-18	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TM170	7.947E-09	1.109E-09	4.216E-13	5.886E-14	8.217E-15	1.147E-15	1.602E-16	2.234E-17	3.141E-18
TM171	1.121E-11	7.816E-12	1.844E-12	1.285E-12	8.959E-13	6.244E-13	4.352E-13	3.033E-13	2.114E-13

Attachment B

Attachment B: Program REDUCE1 Listing

```
      PROGRAM REDUCE1
C
C----- WRITTEN BY D.R. WENZEL
C
C          TO REDUCE ORIGEN2 OUTPUT
C
      CHARACTER * 1 ORGLINE(132), DCYTME(9)
      CHARACTER * 3 PBRK, PBREAK
      CHARACTER * 5 SUM, TOTAL
      CHARACTER * 7 BEGIN, START
      CHARACTER * 9 RUN
      CHARACTER * 12 DESC
      CHARACTER * 132 BUFFER
C
      EQUIVALENCE (DCYTME,ORGLINE(23)), (PBRK,ORGLINE(1)),
+              (SUM,ORGLINE(2)), (BEGIN,ORGLINE(23))
C
      DATA PBREAK /'1  '/
      DATA TOTAL /'TOTAL'/
      DATA START /'7 NUCLID'/
C
C----- DETERMINE RUN NAME
C
      CALL GETCL(RUN)
C
C----- OPEN INPUT AND OUTPUT FILES
C
      OPEN(3,FILE ='REDUCE.IN', STATUS='OLD',FORM='FORMATTED',
+          ERR = 900)
      OPEN(6,FILE ='REDUCE.OUT', STATUS='UNKNOWN', ERR = 920)
+
C
      PRINT *, 'Working -- have patience.'
C
      IFLAG = 0
      WRITE(6,600) RUN
600  FORMAT(A9)
      READ(3,300) ORGLINE
300  FORMAT(132A1)
      READ(3,300) ORGLINE
      WRITE(6,300) ORGLINE
C
C----- SEARCH FOR BEGINNING OF DESIRED DATA
C
      30  READ(3,300,END=999) ORGLINE
          IF(BEGIN .NE. START) GO TO 30
C
C----- BEGIN SEARCHING FOR SELECTED RADIONUCLIDES
C
      READ(3,300,END=999) ORGLINE
      READ(3,300,END=999) ORGLINE
      IF(IFLAG .EQ. 0) THEN
          WRITE(6,300) ORGLINE
C          WRITE(6,310) DCYTME
C 310  FORMAT(16X,9A1)
          IFLAG = 1
```

Attachment B: Program REDUCE1 Listing (continued)

```
      ENDIF
C
  40  READ(3,300,END=999) ORGLINE
      IF(PBRK .EQ. PBREAK) GO TO 50
      IF(SUM .EQ. TOTAL) GO TO 60
      WRITE(BUFFER,300) ORGLINE
      READ(BUFFER,400) DESC, VALUE
  400  FORMAT(A12,10X,E9.4)
      IF(VALUE .LE. 0.) GO TO 40
      WRITE(6,300) ORGLINE
      GO TO 40
C
C----- SKIP LINES OF PAGE BREAK
C
  50  DO 55 I=1,8
      READ(3,300,END=999) ORGLINE
  55  CONTINUE
C
      GO TO 40
C
C----- WRITE BLANK LINE FOLLOWING A TOTAL AND THEN SEARCH FOR
C          MORE OUTPUT
C
  60  WRITE(6,420)
  420  FORMAT(' ')
      GO TO 30
C
C----- ERROR STATEMENTS
C
  900  WRITE(6,9000)
  9000 FORMAT(2X,'ERROR IN OPENING FILE 3')
      GO TO 999
C
  920  WRITE(6,9020)
  9020 FORMAT(2X,'ERROR IN OPENING FILE 6')
      GO TO 999
C
C----- PROGRAM END
C
  999  CONTINUE
      END
```

Attachment C

Attachment C: Program REDUCEZR Listing and Output

```

PROGRAM REDUCEZR
C
C----- WRITTEN BY D.R. WENZEL
C
C           To calculate activity in Ci for calcine bin set 2, Bin #7
C           ICPP WTF Studies
C
C           CHARACTER * 1 ORGLINE1(111)
C           CHARACTER * 9 RUN
C           CHARACTER * 11 DESC1
C           CHARACTER * 111 BUFFER1
C           REAL      * 4 VALUE1(9)
C           REAL      * 4 ZR1(9)
C           REAL      * 4 RED1(9)
C
C-----Following data statements assume fuel 2 years old when
C           processed
C
C           AGE OF FUEL           5       6       7       8       9       10      11
C           PROCESSING YEAR       74      73      72      71      70      69      68
C           DATA ZR1 /0., 0., 0., 0., 0., 100., 0., 0., 0./
C           DATA RED1 /1., 1., 1., 1., 1., 1., 1., 1., 1./
C
C----- DETERMINE RUN NAME
C
C           CALL GETCL(RUN)
C
C----- OPEN INPUT AND OUTPUT FILES
C
C           OPEN(1,FILE = 'ZR1.OUT', STATUS='OLD',FORM='FORMATTED',
+             ERR = 900)
C           OPEN(6,FILE = 'REDUCEZR.OUT', STATUS='UNKNOWN', ERR = 920)
C
C           PRINT *, 'Working -- have patience.'
C
C----- Normalize to Staples Cs-137 data in ICP-1189
C
C           CORZR = 7.545E-8
C           WRITE(6,600) RUN
C 600   FORMAT(A9)
C
C----- READ PAST FIRST LINE
C
C           READ(1,300) ORGLINE1
C 300   FORMAT(111A1)
C
C----- READ PAST SECOND LINE
C
C           READ(1,300) ORGLINE1
C
C----- READ PAST THIRD LINE
C
C           READ(1,300) ORGLINE1
C
C----- START DATA SUMMATION PROCESS

```

Attachment C: Program REDUCEZR Listing and Output (continued)

```
C
  40  READ(1,300,END=999) ORGLINE1
      WRITE(BUFFER1,300) ORGLINE1
      READ(BUFFER1,400) DESC1, (VALUE1(I),I=1,9)
400  FORMAT(A11,9(1X,E9.4))
C
      SUM = 0.
      DO 46, J=1,7
          K = 10 - J
          SUM = SUM * RED1(K)
          SUM = SUM + VALUE1(K) * ZR1(K) * CORZR
46  CONTINUE
C
      E = SUM / 1.89E-3
      WRITE(6,401) DESC1,SUM,E
C 401  FORMAT(A11,1PE10.3)
401  FORMAT(A11,1PE10.3, 5X,E10.3)
      GO TO 40
C
C----- ERROR STATEMENTS
C
  900  WRITE(6,9000)
  9000  FORMAT(2X,'ERROR IN OPENING FILE ')
      GO TO 999
C
  920  WRITE(6,9020)
  9020  FORMAT(2X,'ERROR IN OPENING FILE 6')
C
C----- PROGRAM END
C
  999  CONTINUE
      END
```


Attachment C: Program REDUCEZR Listing and Output (continued)

Initial Relative Radionuclide Inventory Calculated using ORIGEN2

Radionuclide	<u>Normalized Cs-137 to</u>	
	1.89E-3 Ci	1.0 Ci
TL206	2.887E-30	1.527E-27
TL207	3.561E-13	1.884E-10
TL208	4.921E-12	2.604E-09
TL209	2.422E-18	1.281E-15
PB209	1.121E-16	5.932E-14
PB210	2.743E-18	1.452E-15
PB211	3.571E-13	1.889E-10
PB212	1.369E-11	7.246E-09
PB214	3.184E-17	1.685E-14
BI208	1.452E-30	7.681E-28
BI210M	2.898E-30	1.533E-27
BI210	2.744E-18	1.452E-15
BI211	3.571E-13	1.889E-10
BI212	1.369E-11	7.246E-09
BI213	1.121E-16	5.932E-14
BI214	3.184E-17	1.685E-14
PO210	2.281E-18	1.207E-15
PO211	9.997E-16	5.289E-13
PO212	8.775E-12	4.643E-09
PO213	1.097E-16	5.804E-14
PO214	3.183E-17	1.684E-14
PO215	3.571E-13	1.889E-10
PO216	1.369E-11	7.246E-09
PO218	3.185E-17	1.685E-14
AT217	1.121E-16	5.932E-14
RN219	3.571E-13	1.889E-10
RN220	1.369E-11	7.246E-09
RN222	3.185E-17	1.685E-14
FR221	1.121E-16	5.932E-14
FR223	4.919E-15	2.603E-12
RA223	3.571E-13	1.889E-10
RA224	1.369E-11	7.246E-09
RA225	1.121E-16	5.932E-14
RA226	3.185E-17	1.685E-14
RA228	1.538E-18	8.140E-16
AC225	1.121E-16	5.932E-14
AC227	3.565E-13	1.886E-10
AC228	1.538E-18	8.140E-16
TH227	3.522E-13	1.863E-10
TH228	1.365E-11	7.222E-09
TH229	1.121E-16	5.932E-14
TH230	1.750E-14	9.258E-12

Attachment C: Program REDUCEZR Listing and Output (continued)

Initial Relative Radionuclide Inventory Calculated using ORIGEN2 (continued)

Radionuclide	<u>Normalized Cs-137 to</u>	
	1.89E-3 Ci	1.0 Ci
TH231	1.435E-08	7.593E-06
TH232	4.588E-18	2.428E-15
TH234	2.194E-11	1.161E-08
PA231	2.735E-12	1.447E-09
PA233	1.133E-09	5.992E-07
PA234M	2.194E-11	1.161E-08
PA234	2.852E-14	1.509E-11
U232	1.489E-11	7.880E-09
U233	1.549E-13	8.196E-11
U234	2.364E-10	1.251E-07
U235	1.435E-08	7.593E-06
U236	1.093E-08	5.781E-06
U237	7.086E-13	3.749E-10
U238	2.194E-11	1.161E-08
U240	8.601E-23	4.551E-20
NP235	1.581E-14	8.367E-12
NP236	2.613E-15	1.382E-12
NP237	1.133E-09	5.992E-07
NP238	2.556E-15	1.353E-12
NP239	2.921E-14	1.545E-11
NP240M	8.601E-23	4.551E-20
PU236	2.165E-11	1.146E-08
PU238	6.136E-07	3.247E-04
PU239	6.839E-09	3.618E-06
PU240	1.439E-09	7.613E-07
PU241	2.888E-08	1.528E-05
PU242	3.561E-14	1.884E-11
PU243	8.963E-27	4.743E-24
PU244	8.609E-23	4.555E-20
AM241	4.670E-10	2.471E-07
AM242M	5.112E-13	2.705E-10
AM242	5.087E-13	2.691E-10
AM243	2.921E-14	1.545E-11
AM245	2.804E-32	1.484E-29
CM241	7.636E-42	4.040E-39
CM242	4.231E-13	2.239E-10
CM243	1.440E-14	7.617E-12
CM244	1.887E-13	9.984E-11
CM245	2.419E-18	1.280E-15
CM246	3.740E-20	1.979E-17
CM247	8.963E-27	4.743E-24
CM248	1.759E-27	9.309E-25

Attachment C: Program REDUCEZR Listing and Output (continued)

Initial Relative Radionuclide Inventory Calculated using ORIGEN2 (continued)

Radionuclide	<u>Normalized Cs-137 to</u>	
	1.89E-3 Ci	1.0 Ci
CM250	7.071E-40	3.741E-37
BK249	1.934E-27	1.023E-24
CF250	4.713E-33	2.494E-30
CF251	2.135E-39	1.130E-36
H 3	6.236E-06	3.299E-03
BE 10	6.342E-14	3.356E-11
C 14	2.555E-12	1.352E-09
SE 79	9.205E-09	4.870E-06
KR 81	2.290E-16	1.212E-13
KR 85	1.646E-04	8.707E-02
RB 87	6.190E-13	3.275E-10
SR 89	2.945E-19	1.558E-16
SR 90	1.812E-03	9.585E-01
Y 90	1.812E-03	9.589E-01
Y 91	8.699E-17	4.603E-14
ZR 93	4.760E-08	2.519E-05
NB 93M	1.590E-08	8.411E-06
NB 94	4.814E-13	2.547E-10
ZR 95	1.825E-15	9.657E-13
NB 95	4.200E-15	2.222E-12
NB 95M	1.354E-17	7.166E-15
TC 98	7.681E-15	4.064E-12
TC 99	3.146E-07	1.664E-04
RH102	2.159E-10	1.143E-07
RU103	1.501E-24	7.944E-22
RH103M	1.867E-24	9.880E-22
RU106	1.378E-05	7.293E-03
RH106	1.378E-05	7.293E-03
PD107	3.342E-10	1.768E-07
AG108	6.815E-17	3.606E-14
AG108M	7.658E-16	4.052E-13
AG109M	3.127E-16	1.654E-13
CD109	3.127E-16	1.654E-13
AG110	4.559E-12	2.412E-09
AG110M	3.428E-10	1.814E-07
CD113M	1.909E-07	1.010E-04
IN114	9.024E-27	4.775E-24
IN115	2.940E-19	1.556E-16
IN115M	3.055E-29	1.616E-26
SN119M	6.799E-10	3.597E-07
SN121M	1.762E-09	9.321E-07

Attachment C: Program REDUCEZR Listing and Output (continued)

Initial Relative Radionuclide Inventory Calculated using ORIGEN2 (continued)

Radionuclide	<u>Normalized Cs-137 to</u>	
	1.89E-3 Ci	1.0 Ci
SN123	1.228E-11	6.499E-09
TE123	2.887E-22	1.527E-19
TE123M	6.645E-17	3.516E-14
SB124	5.265E-21	2.786E-18
SB125	1.937E-05	1.025E-02
TE125M	4.725E-06	2.500E-03
SN126	8.149E-09	4.311E-06
SB126	1.141E-09	6.036E-07
SB126M	8.149E-09	4.311E-06
TE127	2.783E-12	1.473E-09
TE127M	2.841E-12	1.503E-09
XE127	5.117E-36	2.707E-33
TE129	7.143E-30	3.779E-27
TE129M	1.097E-29	5.804E-27
I129	5.113E-10	2.705E-07
CS134	2.801E-05	1.482E-02
CS135	1.855E-08	9.816E-06
CS137	1.890E-03	1.000E+00
BA137M	1.788E-03	9.461E-01
LA138	4.710E-18	2.492E-15
CE141	8.443E-29	4.467E-26
CE142	6.326E-13	3.347E-10
CE144	4.179E-05	2.211E-02
PR144	4.179E-05	2.211E-02
PR144M	5.014E-07	2.653E-04
ND144	2.998E-17	1.586E-14
PM146	3.150E-09	1.667E-06
SM146	3.185E-16	1.685E-13
PM147	9.620E-04	5.090E-01
SM147	1.964E-13	1.039E-10
PM148	8.247E-26	4.363E-23
PM148M	1.617E-24	8.555E-22
SM148	2.268E-19	1.200E-16
SM149	9.265E-20	4.902E-17
EU150	1.249E-13	6.611E-11
SM151	2.707E-05	1.432E-02
EU152	1.999E-07	1.058E-04
GD152	1.545E-20	8.176E-18
GD153	2.899E-12	1.534E-09
EU154	6.877E-06	3.638E-03
EU155	1.821E-05	9.633E-03
TB160	3.499E-19	1.852E-16

Attachment C: Program REDUCEZR Listing and Output (continued)

Initial Relative Radionuclide Inventory Calculated using ORIGEN2 (continued)

Radionuclide	<u>Normalized Cs-137 to</u>	
	1.89E-3 Ci	1.0 Ci
HO166M	9.024E-14	4.775E-11
TM170	8.654E-21	4.579E-18

Attachment C: Program REDUCEZR Listing and Output (continued)

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Attachment D

Attachment D: ORIGEN2 Input and Output Files

```
echo off
echo **
echo **
echo **
echo **
copy zrdecay.INP tape5.inp >nul
REM (NOT USED IN THIS CASE) copy zrdecay.u3 tape3.inp >nul
copy \origen2\libs\decay.lib+\origen2\libs\pwrus.lib tape9.inp >nul
copy \origen2\libs\gxuo2brm.lib tape10.inp >nul
\origen2\code\origen2
echo finished with origen2 calculation
rem combine and save files from run
copy tape12.out+tape6.out zrdecay.u6 >nul
copy tape13.out+tape11.out zrdecay.u11 >nul
ren tape7.out zrdecay.pch
ren tape15.out zrdecay.dbg
ren tape16.out zrdecay.vxs
ren tape50.out zrdecay.ech
rem cleanup files
del tape*.inp
del tape*.out
echo *****
echo ***** O R I G E N 2 - Version 2.1 *****
echo ***** Execution Completed *****
echo *****
echo on
```


$$\begin{matrix} -1 \\ -1 \\ -1 \end{matrix}$$

D-2

Attachment D: ORIGEN2 Input and Output Files (continued)

```
3 551350 1.610E-05 551370 2.170E-05 561371 3.320E-12 0 0.  
3 571380 2.450E-10 581420 2.640E-05 581440 1.310E-08 0 0.  
3 591440 5.530E-13 601440 2.530E-05 611460 7.110E-12 0 0.  
3 621460 1.340E-11 611470 1.040E-06 621470 8.640E-06 0 0.  
3 621480 7.510E-07 621490 3.860E-07 631500 1.890E-15 0 0.  
3 621510 1.030E-06 631520 1.160E-09 641520 7.090E-10 0 0.  
3 631540 1.370E-07 631550 6.000E-10 671661 5.030E-14 0 0.  
0
```

Attachment D: ORIGEN2 Input and Output Files (continued)

Zrdecay

ORIGEN2 V2.1 (8-1-91), Run on 08/12/97 at 16:45:42

	CHARGE	9.0YR	28.0YR	47.0YR	128.0YR	528.0YR	1028.0YR
CO 60	2.262E-06	6.925E-07	5.689E-08	4.674E-09	1.103E-13	0.000E+00	0.000E+00
TL207	3.563E-13	1.042E-12	1.992E-12	2.524E-12	3.205E-12	3.913E-12	4.673E-12
TL208	4.890E-12	4.315E-13	2.728E-13	2.279E-13	1.045E-13	2.225E-15	2.336E-17
PB210	2.742E-18	1.693E-16	4.141E-15	1.745E-14	2.444E-13	7.675E-12	2.898E-11
PB211	0.000E+00	1.045E-12	1.997E-12	2.531E-12	3.214E-12	3.924E-12	4.686E-12
PB212	1.369E-11	1.201E-12	7.593E-13	6.343E-13	2.908E-13	6.192E-15	6.501E-17
BI210	0.000E+00	1.693E-16	4.141E-15	1.746E-14	2.444E-13	7.675E-12	2.898E-11
BI211	0.000E+00	1.045E-12	1.997E-12	2.531E-12	3.214E-12	3.924E-12	4.686E-12
BI212	1.369E-11	1.201E-12	7.593E-13	6.343E-13	2.908E-13	6.192E-15	6.501E-17
PO210	2.278E-18	1.693E-16	4.141E-15	1.746E-14	2.444E-13	7.675E-12	2.898E-11
PO212	0.000E+00	7.695E-13	4.865E-13	4.064E-13	1.863E-13	3.967E-15	4.165E-17
RN220	1.366E-11	1.201E-12	7.593E-13	6.343E-13	2.908E-13	6.192E-15	6.501E-17
RN222	0.000E+00	1.841E-15	1.753E-14	5.021E-14	3.992E-13	7.678E-12	2.899E-11
RA223	0.000E+00	1.045E-12	1.997E-12	2.531E-12	3.214E-12	3.924E-12	4.686E-12
RA224	1.354E-11	1.201E-12	7.593E-13	6.343E-13	2.908E-13	6.192E-15	6.501E-17
RA225	1.122E-16	1.193E-16	1.752E-16	2.876E-16	1.436E-15	2.596E-14	1.094E-13
RA226	3.185E-17	1.841E-15	1.753E-14	5.021E-14	3.992E-13	7.678E-12	2.899E-11
RA228	1.320E-18	3.332E-18	4.590E-18	4.925E-18	5.845E-18	9.806E-18	1.483E-17
AC225	1.121E-16	1.193E-16	1.752E-16	2.876E-16	1.436E-15	2.596E-14	1.094E-13
AC227	3.567E-13	1.045E-12	1.996E-12	2.529E-12	3.214E-12	3.924E-12	4.686E-12
TH227	0.000E+00	1.031E-12	1.970E-12	2.496E-12	3.170E-12	3.870E-12	4.622E-12
TH228	1.361E-11	1.198E-12	7.593E-13	6.343E-13	2.908E-13	6.192E-15	6.501E-17
TH229	1.121E-16	1.193E-16	1.752E-16	2.876E-16	1.436E-15	2.596E-14	1.094E-13
TH230	1.751E-14	9.178E-13	2.935E-12	5.093E-12	1.545E-11	7.626E-11	1.551E-10
TH231	1.436E-08	7.612E-11	7.612E-11	7.613E-11	7.615E-11	7.624E-11	7.636E-11
TH232	4.586E-18	4.674E-18	4.861E-18	5.047E-18	5.844E-18	9.806E-18	1.483E-17
TH234	2.194E-11	3.733E-12	3.733E-12	3.733E-12	3.733E-12	3.733E-12	3.733E-12
PA231	3.109E-12	3.124E-12	3.154E-12	3.183E-12	3.308E-12	3.922E-12	4.684E-12
PA233	1.134E-09	3.704E-10	3.800E-10	3.908E-10	4.363E-10	5.937E-10	6.902E-10
PA234M	2.192E-11	3.733E-12	3.733E-12	3.733E-12	3.733E-12	3.733E-12	3.733E-12
PA234	2.860E-14	4.853E-15	4.853E-15	4.853E-15	4.853E-15	4.853E-15	4.853E-15
U232	7.880E-14	7.902E-13	7.404E-13	6.175E-13	2.831E-13	6.018E-15	4.884E-17
U233	8.261E-16	1.568E-14	4.684E-14	7.885E-14	2.254E-13	1.140E-12	2.553E-12
U234	1.088E-08	1.134E-08	1.223E-08	1.299E-08	1.521E-08	1.757E-08	1.765E-08
U235	7.612E-11	7.612E-11	7.612E-11	7.613E-11	7.615E-11	7.624E-11	7.636E-11
U236	1.987E-10	1.988E-10	1.989E-10	1.990E-10	1.995E-10	2.021E-10	2.051E-10
U237	0.000E+00	4.262E-10	1.708E-10	6.842E-11	1.386E-12	6.073E-21	5.466E-23
U238	3.733E-12	3.733E-12	3.733E-12	3.733E-12	3.733E-12	3.733E-12	3.733E-12
NP237	3.667E-10	3.704E-10	3.800E-10	3.908E-10	4.363E-10	5.937E-10	6.902E-10
NP238	0.000E+00	2.454E-15	2.251E-15	2.064E-15	1.426E-15	2.302E-16	2.355E-17
NP239	2.924E-14	2.909E-14	2.904E-14	2.899E-14	2.877E-14	2.771E-14	2.644E-14
PU236	2.163E-11	2.426E-12	2.392E-14	2.358E-16	6.606E-25	0.000E+00	0.000E+00
PU238	1.901E-05	1.771E-05	1.524E-05	1.311E-05	6.916E-06	2.935E-07	5.651E-09
PU239	2.419E-07	2.418E-07	2.417E-07	2.416E-07	2.410E-07	2.383E-07	2.348E-07
PU240	2.234E-07	2.232E-07	2.227E-07	2.223E-07	2.204E-07	2.112E-07	2.003E-07
PU241	2.680E-05	1.737E-05	6.962E-06	2.789E-06	5.650E-08	2.476E-16	2.231E-18
PU242	4.966E-10	4.966E-10	4.965E-10	4.965E-10	4.964E-10	4.961E-10	4.956E-10
PU244	8.605E-23	8.605E-23	8.605E-23	8.605E-23	8.605E-23	8.605E-23	8.605E-23
AM241	1.099E-06	1.394E-06	1.693E-06	1.779E-06	1.645E-06	8.671E-07	3.889E-07
AM242M	5.114E-13	4.908E-13	4.501E-13	4.127E-13	2.853E-13	4.604E-14	4.709E-15
AM242	5.087E-13	4.884E-13	4.479E-13	4.107E-13	2.839E-13	4.581E-14	4.686E-15
AM243	2.912E-14	2.909E-14	2.904E-14	2.899E-14	2.877E-14	2.771E-14	2.644E-14

Attachment D: ORIGEN2 Input and Output Files (continued)

Zrdecay

ORIGEN2 V2.1 (8-1-91), Run on 08/12/97 at 16:45:42

	CHARGE	9.0YR	28.0YR	47.0YR	128.0YR	528.0YR	1028.0YR
CM242	4.234E-13	4.039E-13	3.704E-13	3.396E-13	2.348E-13	3.788E-14	3.875E-15
CM243	1.441E-14	1.158E-14	7.292E-15	4.594E-15	6.407E-16	3.817E-20	1.998E-25
CM244	1.886E-13	1.336E-13	6.458E-14	3.121E-14	1.405E-15	3.154E-22	1.540E-30
CM245	2.422E-18	2.420E-18	2.416E-18	2.413E-18	2.397E-18	2.320E-18	2.227E-18
CM246	3.749E-20	3.744E-20	3.734E-20	3.723E-20	3.679E-20	3.470E-20	3.225E-20
H 3	6.198E-06	3.740E-06	1.287E-06	4.431E-07	4.699E-09	8.339E-19	5.401E-31
BE 10	6.349E-14	6.348E-14	6.348E-14	6.348E-14	6.348E-14	6.347E-14	6.346E-14
C 14	2.555E-12	2.552E-12	2.546E-12	2.540E-12	2.516E-12	2.397E-12	2.256E-12
SE 79	9.199E-09	9.198E-09	9.197E-09	9.195E-09	9.187E-09	9.148E-09	9.099E-09
RB 87	6.233E-13	6.233E-13	6.233E-13	6.233E-13	6.233E-13	6.233E-13	6.233E-13
SR 90	2.484E-03	2.005E-03	1.275E-03	8.114E-04	1.180E-04	8.651E-09	5.869E-14
Y 90	2.482E-03	2.005E-03	1.276E-03	8.116E-04	1.180E-04	8.654E-09	5.870E-14
ZR 93	4.751E-08	4.751E-08	4.751E-08	4.751E-08	4.751E-08	4.750E-08	4.749E-08
NB 93M	1.589E-08	2.665E-08	3.811E-08	4.247E-08	4.509E-08	4.512E-08	4.511E-08
NB 94	4.817E-13	4.816E-13	4.812E-13	4.809E-13	4.796E-13	4.731E-13	4.651E-13
TC 98	7.684E-15	7.684E-15	7.684E-15	7.684E-15	7.684E-15	7.683E-15	7.682E-15
TC 99	3.138E-07	3.138E-07	3.137E-07	3.137E-07	3.136E-07	3.132E-07	3.127E-07
RH102	2.164E-10	2.518E-11	2.684E-13	2.861E-15	1.118E-23	0.000E+00	0.000E+00
PD107	3.345E-10	3.345E-10	3.345E-10	3.345E-10	3.344E-10	3.344E-10	3.344E-10
AG108M	7.666E-16	7.298E-16	6.579E-16	5.931E-16	3.812E-16	4.296E-17	2.805E-18
CD113M	1.779E-07	1.160E-07	4.703E-08	1.907E-08	4.065E-10	2.267E-18	1.093E-28
IN115	3.000E-18	3.000E-18	3.000E-18	3.000E-18	3.000E-18	3.000E-18	3.000E-18
SN121M	1.763E-09	1.556E-09	1.195E-09	9.184E-10	2.986E-10	1.163E-12	1.131E-15
TE123	2.887E-22	2.887E-22	2.887E-22	2.887E-22	2.887E-22	2.887E-22	2.887E-22
SB125	1.942E-05	2.042E-06	1.759E-08	1.514E-10	2.383E-19	0.000E+00	0.000E+00
TE125M	4.721E-06	4.983E-07	4.291E-09	3.695E-11	5.814E-20	0.000E+00	0.000E+00
SN126	8.146E-09	8.145E-09	8.144E-09	8.143E-09	8.139E-09	8.116E-09	8.088E-09
SB126	1.137E-09	1.140E-09	1.140E-09	1.140E-09	1.139E-09	1.136E-09	1.132E-09
SB126M	8.172E-09	8.145E-09	8.144E-09	8.143E-09	8.139E-09	8.116E-09	8.088E-09
I129	5.122E-10	5.122E-10	5.122E-10	5.122E-10	5.122E-10	5.122E-10	5.121E-10
CS134	3.495E-05	1.696E-06	2.854E-09	4.799E-12	7.173E-24	0.000E+00	0.000E+00
CS135	1.855E-08	1.855E-08	1.855E-08	1.855E-08	1.854E-08	1.854E-08	1.854E-08
CS137	1.888E-03	1.534E-03	9.888E-04	6.375E-04	9.810E-05	9.502E-09	9.130E-14
BA137M	1.786E-03	1.451E-03	9.354E-04	6.030E-04	9.280E-05	8.989E-09	8.637E-14
LA138	4.704E-18	4.704E-18	4.704E-18	4.704E-18	4.704E-18	4.704E-18	4.704E-18
CE142	6.337E-13	6.337E-13	6.337E-13	6.337E-13	6.337E-13	6.337E-13	6.337E-13
ND144	2.994E-17	2.996E-17	2.996E-17	2.996E-17	2.996E-17	2.996E-17	2.996E-17
PM146	3.167E-09	1.019E-09	9.292E-11	8.476E-12	3.125E-16	0.000E+00	0.000E+00
SM146	4.689E-16	5.314E-16	5.583E-16	5.607E-16	5.610E-16	5.610E-16	5.610E-16
PM147	9.645E-04	8.945E-05	5.908E-07	3.902E-09	1.981E-18	0.000E+00	0.000E+00
SM147	1.964E-13	2.179E-13	2.201E-13	2.201E-13	2.201E-13	2.201E-13	2.201E-13
SM148	2.268E-19	2.268E-19	2.268E-19	2.268E-19	2.268E-19	2.268E-19	2.268E-19
SM149	9.270E-20	9.270E-20	9.270E-20	9.270E-20	9.270E-20	9.270E-20	9.270E-20
EU150	1.252E-13	1.053E-13	7.301E-14	5.064E-14	1.065E-14	4.813E-18	3.173E-22
SM151	2.711E-05	2.529E-05	2.185E-05	1.888E-05	1.011E-05	4.645E-07	9.873E-09
EU152	2.007E-07	1.269E-07	4.817E-08	1.829E-08	2.947E-10	4.130E-19	3.541E-30
GD152	1.545E-20	1.804E-20	2.080E-20	2.185E-20	2.248E-20	2.249E-20	2.249E-20
EU154	3.700E-05	1.791E-05	3.873E-06	8.376E-07	1.229E-09	1.226E-23	5.827E-41
EU155	2.792E-07	7.935E-08	5.575E-09	3.916E-10	4.743E-15	0.000E+00	0.000E+00
HO166M	9.031E-14	8.984E-14	8.886E-14	8.789E-14	8.387E-14	6.657E-14	4.987E-14

Attachment E

Attachment E: Photon Spectrums in photons/s/g calcine for Zr Calcine

Zr PHOTON.FP

ORIGEN2 V2.1 (8-1-91), Run on 10/13/97 at 11:35:07

PHOTON SPECTRUM FOR FISSION PRODUCTS

EMEAN	1988	1997	2016	2035	100yr	500yr	1000yr
1.000E-02	7.259E+07	5.633E+07	3.576E+07	2.277E+07	3.335E+06	1.404E+03	1.022E+03
2.500E-02	1.549E+07	1.174E+07	7.427E+06	4.729E+06	6.919E+05	3.173E+02	2.513E+02
3.750E-02	1.467E+07	1.127E+07	7.123E+06	4.539E+06	6.736E+05	1.321E+02	7.408E+01
5.750E-02	1.399E+07	1.091E+07	6.925E+06	4.406E+06	6.435E+05	1.594E+02	1.103E+02
8.500E-02	8.351E+06	6.511E+06	4.140E+06	2.635E+06	3.848E+05	2.037E+02	1.743E+02
1.250E-01	6.104E+06	4.477E+06	2.735E+06	1.717E+06	2.486E+05	3.368E+01	1.510E+01
2.250E-01	7.272E+06	5.631E+06	3.558E+06	2.259E+06	3.288E+05	4.063E+01	1.621E+01
3.750E-01	3.373E+06	2.449E+06	1.537E+06	9.772E+05	1.424E+05	3.396E+02	3.280E+02
5.750E-01	7.197E+07	5.672E+07	3.645E+07	2.349E+07	3.610E+06	1.079E+03	7.282E+02
8.500E-01	2.305E+06	7.636E+05	3.178E+05	1.734E+05	2.309E+04	3.830E+01	3.649E+01
1.250E+00	9.852E+05	4.835E+05	1.580E+05	6.861E+04	7.592E+03	9.433E+00	8.848E+00
1.750E+00	3.798E+04	2.050E+04	8.638E+03	4.544E+03	5.902E+02	4.359E-02	3.775E-04
2.250E+00	1.252E+04	6.530E+00	7.031E-01	4.473E-01	6.506E-02	4.769E-06	4.742E-11
2.750E+00	1.201E+02	2.286E-01	4.758E-07	8.556E-12	7.549E-12	7.549E-12	7.549E-12
3.500E+00	1.432E+01	2.942E-02	6.217E-08	5.690E-12	5.559E-12	5.559E-12	5.559E-12
5.000E+00	1.609E-12	1.651E-12	1.655E-12	1.655E-12	1.655E-12	1.655E-12	1.655E-12
7.000E+00	1.044E-13	1.071E-13	1.074E-13	1.074E-13	1.074E-13	1.074E-13	1.074E-13
9.500E+00	6.602E-15	6.773E-15	6.790E-15	6.791E-15	6.791E-15	6.791E-15	6.791E-15

Zr PHOTON.ACT

ORIGEN2 V2.1 (8-1-91), Run on 10/13/97 at 11:35:07

PHOTON SPECTRUM FOR ACTINIDES + DAUGHTERS

EMEAN	1988	1997	2016	2035	100yr	500yr	1000yr
1.000E-02	1.216E+05	1.163E+05	1.043E+05	9.258E+04	5.545E+04	1.059E+04	4.953E+03
2.500E-02	1.115E+03	1.308E+03	1.587E+03	1.667E+03	1.542E+03	8.147E+02	3.677E+02
3.750E-02	4.052E+02	4.035E+02	3.851E+02	3.562E+02	2.422E+02	7.200E+01	3.066E+01
5.750E-02	1.513E+04	1.920E+04	2.331E+04	2.449E+04	2.264E+04	1.194E+04	5.357E+03
8.500E-02	1.367E+02	8.020E+01	7.345E+01	6.693E+01	4.623E+01	2.102E+01	1.789E+01
1.250E-01	1.799E+01	2.015E+01	1.978E+01	1.937E+01	1.761E+01	1.145E+01	7.669E+00
2.250E-01	9.219E+00	1.102E+01	8.294E+00	6.906E+00	4.715E+00	2.893E+00	3.033E+00
3.750E-01	1.788E+01	6.943E+00	7.105E+00	7.258E+00	7.845E+00	9.915E+00	1.143E+01
5.750E-01	5.130E-01	3.994E-01	4.701E-01	4.911E-01	4.590E-01	4.030E-01	7.106E-01
8.500E-01	5.293E-01	4.393E-01	4.157E-01	3.839E-01	2.622E-01	1.188E-01	1.828E-01
1.250E+00	2.551E-02	1.558E-02	1.385E-02	1.268E-02	1.240E-02	9.942E-02	3.688E-01
1.750E+00	2.032E-02	3.952E-03	3.325E-03	3.295E-03	5.809E-03	7.907E-02	2.966E-01
2.250E+00	1.348E-03	1.288E-03	1.207E-03	1.194E-03	1.949E-03	2.447E-02	9.152E-02
2.750E+00	1.724E-01	1.586E-02	1.022E-02	8.582E-03	4.079E-03	6.744E-04	1.744E-03
3.500E+00	6.453E-04	6.135E-04	5.519E-04	4.979E-04	3.400E-04	2.344E-04	4.372E-04
5.000E+00	2.597E-04	2.469E-04	2.222E-04	2.006E-04	1.366E-04	6.537E-05	5.901E-05
7.000E+00	2.786E-05	2.649E-05	2.386E-05	2.157E-05	1.483E-05	7.368E-06	6.712E-06
9.500E+00	3.070E-06	2.919E-06	2.631E-06	2.381E-06	1.647E-06	8.372E-07	7.669E-07

Attachment D: Photon Spectrums in photons/s/g calcine for Zr Calcine (Continued)

Zr PHOTON.STR

ORIGEN2 V2.1 (8-1-91), Run on 10/13/97 at 11:35:07

PHOTON SPECTRUM FOR ACTIVATION PRODUCTS

EMEAN	1988	1997	2016	2035	100yr	500yr	1000yr
1.000E-02	4.435E+03	1.358E+03	1.115E+02	9.163E+00	2.163E-04	0.000E+00	0.000E+00
2.500E-02	7.665E+02	2.346E+02	1.928E+01	1.584E+00	3.738E-05	0.000E+00	0.000E+00
3.750E-02	4.376E+02	1.340E+02	1.101E+01	9.042E-01	2.134E-05	0.000E+00	0.000E+00
5.750E-02	4.937E+02	1.511E+02	1.242E+01	1.020E+00	2.407E-05	0.000E+00	0.000E+00
8.500E-02	1.941E+02	5.943E+01	4.882E+00	4.011E-01	9.467E-06	0.000E+00	0.000E+00
1.250E-01	7.456E+01	2.282E+01	1.875E+00	1.540E-01	3.636E-06	0.000E+00	0.000E+00
2.250E-01	2.452E+01	7.505E+00	6.166E-01	5.066E-02	1.196E-06	0.000E+00	0.000E+00
3.750E-01	6.879E+00	2.106E+00	1.730E-01	1.421E-02	3.354E-07	0.000E+00	0.000E+00
5.750E-01	3.950E-01	1.209E-01	9.933E-03	8.161E-04	1.926E-08	0.000E+00	0.000E+00
8.500E-01	6.251E+00	1.913E+00	1.572E-01	1.292E-02	3.048E-07	0.000E+00	0.000E+00
1.250E+00	1.674E+05	5.123E+04	4.209E+03	3.458E+02	8.161E-03	0.000E+00	0.000E+00
1.750E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
2.250E+00	8.870E-01	2.715E-01	2.231E-02	1.833E-03	4.325E-08	0.000E+00	0.000E+00
2.750E+00	2.745E-03	8.402E-04	6.903E-05	5.671E-06	1.338E-10	0.000E+00	0.000E+00
3.500E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
5.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
7.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
9.500E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Zr photon4.sum

ORIGEN2 V2.1 (8-1-91), Run on 10/13/97 at 11:35:07

Photon Spectrum for Zr Calcine

EMEAN	1988	1997	2016	2035	100YR	500YR	1000Y
1.000E-02	7.272E+07	5.645E+07	3.586E+07	2.286E+07	3.390E+06	1.199E+04	5.975E+03
2.500E-02	1.549E+07	1.174E+07	7.429E+06	4.731E+06	6.934E+05	1.132E+03	6.190E+02
3.750E-02	1.467E+07	1.127E+07	7.123E+06	4.539E+06	6.738E+05	2.041E+02	1.047E+02
5.750E-02	1.401E+07	1.093E+07	6.948E+06	4.430E+06	6.661E+05	1.210E+04	5.467E+03
8.500E-02	8.351E+06	6.511E+06	4.140E+06	2.635E+06	3.848E+05	2.247E+02	1.922E+02
1.250E-01	6.104E+06	4.477E+06	2.735E+06	1.717E+06	2.486E+05	4.513E+01	2.277E+01
2.250E-01	7.272E+06	5.631E+06	3.558E+06	2.259E+06	3.288E+05	4.352E+01	1.924E+01
3.750E-01	3.373E+06	2.449E+06	1.537E+06	9.772E+05	1.424E+05	3.495E+02	3.394E+02
5.750E-01	7.197E+07	5.672E+07	3.645E+07	2.349E+07	3.610E+06	1.079E+03	7.289E+02
8.500E-01	2.305E+06	7.636E+05	3.178E+05	1.734E+05	2.309E+04	3.842E+01	3.667E+01
1.250E+00	1.153E+06	5.347E+05	1.622E+05	6.896E+04	7.592E+03	9.532E+00	9.217E+00
1.750E+00	3.798E+04	2.050E+04	8.638E+03	4.544E+03	5.902E+02	1.227E-01	2.970E-01
2.250E+00	1.252E+04	6.803E+00	7.266E-01	4.503E-01	6.701E-02	2.447E-02	9.152E-02
2.750E+00	1.203E+02	2.453E-01	1.029E-02	8.588E-03	4.079E-03	6.744E-04	1.744E-03
3.500E+00	1.432E+01	3.003E-02	5.520E-04	4.979E-04	3.400E-04	2.344E-04	4.372E-04
5.000E+00	2.597E-04	2.469E-04	2.222E-04	2.006E-04	1.366E-04	6.537E-05	5.901E-05
7.000E+00	2.786E-05	2.649E-05	2.386E-05	2.157E-05	1.483E-05	7.368E-06	6.712E-06
9.500E+00	3.070E-06	2.919E-06	2.631E-06	2.381E-06	1.647E-06	8.372E-07	7.669E-07

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C-03

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Evaluation of Radionuclide Inventory for Al Calcine

By

D. R. Wenzel

October 14, 1997

Project File Number 73301 EDF Page 1 of 10

EDF Serial Number CPP-97067 & EDF-FDO-004 Function File Number 1000-60 & C-03

Project/Task NA

Subtask NA

Title: Evaluation of Radionuclide Inventory for Al Calcine					
Summary: This summary briefly defines the problem or activity to be addressed in the EDF, gives a summary of the activities performed in addressing the problem and states the conclusions, recommendations, or results arrived at from this task.					
Treatment options for calcine stored in the ICPP Calcine Storage Bins require a knowledge about the radionuclide content of the calcine. Because radiochemical analyses of calcine did not identify all of the radionuclides present, it has been necessary to calculate a complete radionuclide inventory based on the radionuclides that have been measured. This EDF presents the results of the calculated radionuclide inventory for Al calcine as a function of decay time.					
Distribution (complete package): J. A. Jones (copy for EDF-CPP-97067), N. E. Russell (5 copies for EDF-FDO-004), B. J. Schrader, D. R. Wenzel					
Distribution (summary package only): Distribution of summary results of this calculation have been made in a letter to N. E. Russell, Wen-20-97, "Calculation of Radionuclide Inventories for Aluminum and Zirconium Calcines," October 14, 1997.					
Author D. R. Wenzel <i>D.R. Wenzel</i> 10/14/97	Dept. Radcon	Reviewed B. J. Schrader <i>B.J. Schrader</i> 10/14/97	Date	Approved	Date
		LMITCO Review	Date	LMITCO Approval	Date

See Management Control Procedure (MCP) 6 for instructions on use of this form.

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Discussion

The best information located on the fission product inventory for aluminum calcine is that for Bin Set 1. The calcine in Bin Set 1 was processed in the Waste Calcining Facility (WCF) between December 1963 and October 1964 (Commander 1966). The calcined waste came primarily from the deep tanks identified in Table 1. Table 1 also contains the measured concentrations of fission products (Lakey 1963).

Table 1: Reported Activities for ICPP Deep Tanks

Volume gallons	WM-180 4,930		WM-183 129,000		WM-185 170,365		WM-187 208,245	
Radionuclide	D/s/mL	Date	D/s/mL	Date	D/s/mL	Date	D/s/mL	Date
Sr-90	1.40E+9	2/23/62	2.98E+9	2/27/62	3.34E+9	2/27/62	2.11E+9	3/16/62
Sr-89	-	-	-	-	9.65E+8	2/09/60	-	-
Zr-95	7.02E+5	3/10/60	4.27E+9	3/01/60	7.63E+7	2/19/60	2.03E+8	4/04/62
Ru-106	6.81E+7	3/08/60	9.48E+8	3/08/60	1.62E+9	2/18/60	-	-
Cs-137	1.62E+9	3/19/62	3.45E+9	3/19/62	3.75E+9	3/19/62	1.62E+9	3/19/62
Ce-144	6.43E+8	3/18/60	1.69E+10	3/17/60	2.91E+10	2/24/60	4.74E+9	4/04/62
Co-60	3.13E+5	3/10/60	1.34E+6	3/11/60	1.02E+6	2/23/60	-	-

A total activity for fission products in Bin Set 1 was calculated and reported in WINCO-1050 (Berreth 1988). The Berreth data is presented in Table 2.

Table 2: Reported Bin Set 1 Activities as of 12/31/86

Radionuclide	Ci Reported by Berreth	Berreth Data Normalized to 1 Ci Cs-137
Sr-90	1.43E+6	8.87E-1
Cs-137	1.65E+6	1.00E+0
Cs-134	2. E+2	1.2 E-4
Pm-147	4. E+3	2.4 E-3
Eu-154	4. E+3	2.4 E-3

Because the two reports contain different fission products, it appeared prudent to determine if the data in these two documents is consistent. This was done by calculating the total Cs-137 going into Bin Set 1 as reported by Lakey and comparing it to the value reported by Berreth. Table shows the total amount of CS-137 on 3/19/62 that was calculated to have gone into Bin Set 1 based on the Lakey data.

Table 3: Total Cs-137 Going Into Bin Set 1 as Calculated from Lakey Data

Tank	gallons	Cs-137	
		D/s/mL	Ci on 3/19/62
WM-180	4,930	1.62E+9	0.05E+6
WM-183	129,000	3.45E+9	0.76E+6
WM-185	170,365	3.75E+9	1.09E+6
WM-187	208,245	1.62E+9	0.58E+6
Total			2.48E+6

The decay time between 3/19/62 and 12/31/86 is 24.78 years. The Cs-137 was decayed as follows:

$$e^{-(\ln 2) (24.78/30.17)} = 0.5659$$

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$$(2.48\text{E}+6) (0.5659) = 1.40\text{E}+6 \text{ Ci}$$

Comparing $1.4\text{E}+6$ to the Berreth value of $1.65\text{E}+6$ shows that the agreement is within 18%. This is considered good and helps build confidence in the Berreth data.

The approach chosen to evaluate the remainder of the radionuclide content of the Al calcine was to use the ORIGEN2 code (RSIC 1991) to calculate the inventory as well as possible based on the relative amounts of different fission product activities calculated from the Berreth data. The plan then was to correct the calculated actinide activities based on the results analytical analyses of Al calcine.

The dominant waste in Bin Set 1 calcine is that from the Materials Testing Reactor (MTR). The ORIGEN2 code was used to calculate the radionuclide inventory for a MTR fuel element as a function of decay time. The fuel from MTF Cycle No. 198 (Dykes 1963) was taken as typical for the fuel processed at the ICPP. The reactor contained 4842 g U-235 and had 684 MWd of operation over a 417-day period. For calculational purposes, inventories were normalized to the activity in a typical 200-g element. By studying the ratios of the various radionuclides reported in the Berreth data, it was determined that the data was best fit when a pseudo MTR element operated at $1/8^{\text{th}}$ of the actual power level but for 8 times the irradiation time for a single MTR cycle was used. Attachment A contains the inputs and summarized outputs for two ORIGEN2 runs which decay the inventory over a period of 22 to 36 years.

A FORTRAN program named REDUCE1 (see Attachment B) was written to extract the radionuclide data from the ORIGEN2 run to a simple table form without page headings and radionuclides with zero inventories. Program REDUCE1 was used to produce the summarized ORIGEN2 outputs presented in Attachment A.

A FORTRAN program named REDUCE86 (see Attachment C) was written to calculate the radionuclide inventory anticipated in Al calcine. This program weights the radionuclide inventories in proportion to the quantity of Al fuel processed between 1958 and 1963 and then normalizes the results to the Cs-137 activity reported by Berreth to be in Bin Set 1. The output from REDUCE86 is presented in Attachment D. A comparison of the REDUCE86 calculated data to the Berreth data is presented in Table 4.

Table 4: Comparison of Initial Calculated Inventory with Berreth Data

Radionuclide	Total Bin Set 1 Activity (CI)		Berreth/
	Berreth	REDUCE86	REDUCE86
Sr-90	1.43E+6	1.56E+6	0.92
Cs-137	1.65E+6	1.65E+6	1.0
Cs-134	2. E+2	1.04E+2	1.9
Pm-147	4. E+3	8.38E+3	0.48
Eu-154	4. E+3	4.33E+3	0.92

The agreement is approximately within a factor of 2.

The disadvantage of the Berreth data is that it does not present activities for the individual actinides. Also, the uranium isotope inventories calculated by ORIGEN2 can not be used because there has been no correction for the removal of uranium by the fuel recovery processing. The plutonium and other actinide inventories calculated by ORIGEN2 also can not be used because a large fraction of these actinides were carried over to the 2nd and 3rd process cycles and therefore would not be present in the Al calcine in Bin Set 1. A further complication is caused by the fact that unknown quantities of depleted uranium have been disposed to the waste tanks from periodic process development activities. The disposal of depleted uranium affects the amounts of

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U-234 and U-238 present in the Al calcine. Additional information on Al calcine was therefore obtained from the analysis of samples that were retrieved from Bin Set 2 in 1979 (Westra 1979, Staples 1979). Bin #3 of Bin Set 2 contains Al calcine like that in Bin Set 1. Samples from Bin Set 2 were taken from the top, middle and bottom of Bin #3 and are respectively identified as 3T, 3M and 3B. The analysis information available on these calcine samples is presented in Table 5.

Table 5: Radiochemical Analysis of Retrieved Aluminum Calcine as of 9/15/78 ($\mu\text{g/g}$ calcine)

Radionuclide	As Reported for 9/15/78				Average Decayed to 12/31/86
	3T	3M	3B	Average	
Co-60	0.003	-	-	-	-
Sr-90	38.0	40.5	32.7	37.1	30.4
Cs-134	0.085	0.004	0.094	a	-
Cs-137	73.5	73.5	60.0	69.0	57.0
Eu-154	0.095	0.133	0.094	0.107	0.055
Eu-155	-	0.0014	-	-	-
U-234	2.99	0.585	1.44	1.67	1.67
U-235	38.9	36.9	25.4	33.7	33.7
U-236	4.01	1.97	1.89	2.62	2.62
U-238	13.9	13.7	9.15	12.3	12.3
Np-237	5.2 ^b	5.9 ^b	4.0 ^b	5.0	5.0
Pu-238	0.10	0.10	0.10	0.10	0.094
Pu-239	2.96	2.98	2.33	2.76	2.76
Pu-240	0.32	0.32	0.27	3.03	3.03
Pu-241	0.03	0.03	0.02	0.03	0.02
Pu-242	0.01	0.01	0.008	0.01	0.01
Am-241	0.09	0.09	0.11	0.10	0.099

^aRatios for Cs-134 appear to be inconsistent, no average calculated.

^bCorrected by B.A. Staples

Because of possible inconsistencies in the Staples Cs-134 data, the fission product data from the Staples report other than for Cs-137 was not used in subsequent calculations.

While the Berreth data is for Bin Set 1 and the Staples measurements are for Bin Set 2, it has been assumed that the relative amounts of the actinides normalized to Cs-137 are the same provided the Staples data is decayed to 12/31/86. There is a slight complication in that the Berreth data is expressed in Ci/Bin Set while the Staples data is expressed in $\mu\text{g/g}$ calcine. The approach used was to write a companion program to FORTRAN program REDUCE86 that calculates the inventory of the individual radionuclides in $\mu\text{g/g}$ calcine and normalized the inventory to the average Cs-137 activity measured by Staples. However, it is necessary to decay the Cs-137 activity from 9/15/87 to 12/31/86, a period of 8.29 years. This yields a Cs-137 activity of 57.0 $\mu\text{g/g}$. It was also necessary to express the inventory as a function of decay time for the pseudo MTR fuel in grams. The ORIGEN2 output equivalent to that in Attachment A expressed in grams is presented in Attachment E. The companion program to REDUCE86 is called REDUCES and is presented in Attachment F. Attachment F also contains the output from program REDUCES. The calculated activities for the actinides are compared to the measured activities decayed to 12/31/86 in Table 6.

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Table 6: Correction Factors to Adjust Calculated Actinide Quantities to Measured Quantities

Radionuclide	Calculated Using REDUCES	Staples Average	Calculated / Staples Avg
U-234	2.194E+2	1.67	131.
U-235	1.699E+4	33.7	504.
U-236	7.130E+2	2.62	272.
U-238	1.163E+3	12.3	94.5
Np-237	1.415E+1	5.0	2.8
Pu-238	4.059E-1	0.10	4.1
Pu-239	2.267E+1	2.76	8.21
Pu-240	1.827E+0	0.30	6.1
Pu-241	1.481E-1	0.03	6.
Pu-242	2.020E-2	0.01	15.
Am-241	4.055E-1	0.10	4.1

The next step in the calculations was to adjust the actinides calculated using REDUCE86 by the calculated/measured ratios in Table 6. This was done using the FORTRAN program ADJUSTG. The source listing, input and output for program ADJUSTG are presented in Attachment G. Correction factors used in ADJUSTG are those taken from the last column of Table 6. However, not all of the uranium and plutonium isotopes were measured and reported in the Staples data. An average correction factors of 250 for remaining uranium isotopes and a factor of 8 for plutonium isotopes was therefore used. A correction factor of 8 was also applied to other unmeasured actinides.

The next calculation done was to re-enter the data from ADJUSTG back into ORIGEN2 and calculate the activities of the radionuclides as a function of decay time. The input and summarized output for the ORIGEN2 run are presented in Attachment H. The first decay time decays the activity to 8/31/86 to allow an easy check to verify that the conversion of the inventory to grams and back to Ci did not significantly change the inventory calculated for the fission products using REDUCE86 (see Attachment A).

All that remains is to convert the total Ci calculated in Bin Set 1 to Ci/g calcine. Calculations up to this point have been carried with 4 places of accuracy to minimize calculational errors. The final results have been rounded to 2 places of accuracy. This was done by writing another FORTRAN program called ROUND. The source listing, input and output for program ROUND is presented in Attachment I. For the convenience of those using the calculated inventory, the half-life of each of the radionuclides was also added. The conversion of total Ci in Bin Set 1 to Ci/g calcine was based on a volume of 217 m³ (Berreth 1988) and a calcine density of 1.09 g/cm³. The final calculated inventory for Al calcine expressed in Ci/g is presented in Table 7. The inventory expressed in Table 7 is an average for the calcine stored in Bin Set 1. While a rigorous uncertainty analysis was not done, the results are estimated to have an accuracy of $\pm$ a factor of 2.

While the primary purpose of this EDF was to calculate the radionuclide concentrations for Al calcine, it was deemed prudent to extend the calculations to also provide the gamma-ray photon spectrums as a function of decay time as calculated using the ORIGEN2 program. Attachment J contains the photon spectrums for activation products, actinides and their daughters, and fission products. Attachment J also contains the sum of the individual photon spectrums. The total photon spectrum with 2 places of accuracy is also provided in Table 8.

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Table 7: Calculated Radionuclide Activities for Al Calcine in Ci/g as a Function of Decay Time

Nuclide (Actinides and Daughters)	Half-Life		2016	2035	Decay Time Since 2016 (yr)		
					1E2	5E2	1E3
Tl207	4.770E+00	m	2.4E-11	2.7E-11	3.1E-11	3.2E-11	3.3E-11
Tl208	3.053E+00	m	2.5E-13	2.1E-13	7.9E-14	3.4E-15	1.8E-15
Tl209	2.200E+00	m	4.8E-16	5.1E-16	9.6E-16	7.1E-15	2.4E-14
Pb209	3.253E+00	h	2.2E-14	2.4E-14	4.4E-14	3.3E-13	1.1E-12
Pb210	2.226E+01	yr	4.3E-12	7.5E-12	2.7E-11	1.1E-10	2.1E-10
Pb211	3.610E+01	m	2.4E-11	2.7E-11	3.1E-11	3.2E-11	3.3E-11
Pb212	1.064E+01	h	6.9E-13	5.7E-13	2.2E-13	9.5E-15	5.0E-15
Pb214	2.680E+01	m	9.3E-12	1.3E-11	3.4E-11	1.1E-10	2.1E-10
Bi210M	3.000E+06	yr	9.1E-29	9.1E-29	9.1E-29	9.1E-29	9.1E-29
Bi210	5.013E+00	d	4.3E-12	7.5E-12	2.7E-11	1.1E-10	2.1E-10
Bi211	2.130E+00	m	2.4E-11	2.7E-11	3.1E-11	3.2E-11	3.3E-11
Bi212	6.055E+01	m	6.9E-13	5.7E-13	2.2E-13	9.5E-15	5.0E-15
Bi213	4.565E+01	m	2.2E-14	2.4E-14	4.4E-14	3.3E-13	1.1E-12
Bi214	1.990E+01	m	9.3E-12	1.3E-11	3.4E-11	1.1E-10	2.1E-10
Po210	1.384E+02	d	4.3E-12	7.5E-12	2.7E-11	1.1E-10	2.1E-10
Po211	5.160E-01	s	6.6E-14	7.6E-14	8.8E-14	9.0E-14	9.3E-14
Po212	3.000E-07	s	4.4E-13	3.7E-13	1.4E-13	6.1E-15	3.2E-15
Po213	4.200E-06	s	2.2E-14	2.3E-14	4.3E-14	3.2E-13	1.1E-12
Po214	1.637E-04	s	9.3E-12	1.3E-11	3.4E-11	1.1E-10	2.1E-10
Po215	1.778E-03	s	2.4E-11	2.7E-11	3.1E-11	3.2E-11	3.3E-11
Po216	1.460E-01	s	6.9E-13	5.7E-13	2.2E-13	9.5E-15	5.0E-15
Po218	3.050E+00	m	9.3E-12	1.3E-11	3.4E-11	1.1E-10	2.1E-10
At217	3.230E-02	s	2.2E-14	2.4E-14	4.4E-14	3.3E-13	1.1E-12
Rn219	3.960E+00	s	2.4E-11	2.7E-11	3.1E-11	3.2E-11	3.3E-11
Rn220	5.561E+01	s	6.9E-13	5.7E-13	2.2E-13	9.5E-15	5.0E-15
Rn222	3.824E+00	d	9.3E-12	1.3E-11	3.4E-11	1.1E-10	2.1E-10
Fr221	4.800E+00	m	2.2E-14	2.4E-14	4.4E-14	3.3E-13	1.1E-12
Fr223	2.180E+01	m	3.3E-13	3.8E-13	4.3E-13	4.5E-13	4.6E-13
Ra223	1.143E+01	d	2.4E-11	2.7E-11	3.1E-11	3.2E-11	3.3E-11
Ra224	3.620E+00	d	6.9E-13	5.7E-13	2.2E-13	9.5E-15	5.0E-15
Ra225	1.480E+01	d	2.2E-14	2.4E-14	4.4E-14	3.3E-13	1.1E-12
Ra226	1.600E+03	yr	9.3E-12	1.3E-11	3.4E-11	1.1E-10	2.1E-10
Ra228	5.750E+00	yr	8.9E-17	9.0E-17	9.1E-17	9.6E-17	1.0E-16
Ac225	1.000E+01	d	2.2E-14	2.4E-14	4.4E-14	3.3E-13	1.1E-12
Ac227	2.177E+01	yr	2.4E-11	2.7E-11	3.1E-11	3.2E-11	3.3E-11
Ac228	6.130E+00	h	8.9E-17	9.0E-17	9.1E-17	9.6E-17	1.0E-16
Th227	1.872E+01	d	2.3E-11	2.7E-11	3.1E-11	3.2E-11	3.3E-11
Th228	1.913E+00	yr	6.9E-13	5.7E-13	2.2E-13	9.5E-15	5.0E-15
Th229	7.340E+03	yr	2.2E-14	2.4E-14	4.4E-14	3.3E-13	1.1E-12
Th230	7.700E+04	yr	4.9E-10	5.0E-10	5.1E-10	5.6E-10	6.3E-10
Th231	2.552E+01	h	1.0E-10	1.0E-10	1.0E-10	1.0E-10	1.0E-10
Th232	1.405E+10	yr	9.0E-17	9.0E-17	9.1E-17	9.6E-17	1.0E-16
Th234	2.410E+01	d	5.8E-12	5.8E-12	5.8E-12	5.8E-12	5.8E-12
Pa231	3.726E+04	yr	3.2E-11	3.2E-11	3.2E-11	3.2E-11	3.3E-11
Pa233	2.700E+01	d	5.0E-09	5.0E-09	5.0E-09	5.1E-09	5.1E-09
Pa234M	1.170E+00	m	5.8E-12	5.8E-12	5.8E-12	5.8E-12	5.8E-12
Pa234	6.700E+00	h	7.6E-15	7.6E-15	7.6E-15	7.6E-15	7.6E-15
U232	7.200E+01	yr	6.7E-13	5.6E-13	2.2E-13	9.3E-15	4.9E-15
U233	1.592E+05	yr	7.0E-13	1.1E-12	3.3E-12	1.2E-11	2.3E-11
U234	2.445E+05	yr	1.5E-08	1.5E-08	1.5E-08	1.6E-08	1.6E-08
U235	7.038E+08	yr	1.0E-10	1.0E-10	1.0E-10	1.0E-10	1.0E-10
U236	2.342E+07	yr	2.4E-10	2.4E-10	2.4E-10	2.4E-10	2.4E-10
U237	6.750E+00	d	2.1E-11	8.3E-12	6.7E-14	1.2E-19	1.2E-19
U238	4.470E+09	yr	5.8E-12	5.8E-12	5.8E-12	5.8E-12	5.8E-12
U240	1.410E+01	h	2.2E-19	2.2E-19	2.2E-19	2.2E-19	2.2E-19
Np235	3.961E+02	d	2.0E-26				
Np237	2.140E+06	yr	5.0E-09	5.0E-09	5.0E-09	5.1E-09	5.1E-09

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Table 7: Calculated Radionuclide Activities for Al Calcine in Ci/g as a Function of Decay Time (Continued)

Nuclide (Actinides and Daughters)	Half-Life		2016	2035	Decay Time Since 2016 (yr)		
					1E2	5E2	1E3
Np238	2.117E+00	d	9.1E-14	8.3E-14	5.3E-14	8.5E-15	8.7E-16
Np239	2.355E+00	d	1.9E-11	1.9E-11	1.9E-11	1.8E-11	1.7E-11
Np240M	7.400E+00	m	2.2E-19	2.2E-19	2.2E-19	2.2E-19	2.2E-19
Pu236	2.851E+00	yr	5.0E-15	4.9E-15	4.9E-15	4.9E-15	4.9E-15
Pu238	8.775E+01	yr	1.9E-06	1.6E-06	7.3E-07	3.1E-08	6.0E-10
Pu239	2.413E+04	yr	2.4E-07	2.4E-07	2.4E-07	2.4E-07	2.3E-07
Pu240	6.569E+03	yr	9.6E-08	9.6E-08	9.4E-08	9.1E-08	8.6E-08
Pu241	1.440E+01	yr	8.4E-07	3.4E-07	2.7E-09	4.9E-15	4.7E-15
Pu242	3.758E+05	yr	7.2E-12	7.2E-12	7.2E-12	7.2E-12	7.2E-12
Pu243	4.956E+00	h	4.3E-23	4.3E-23	4.3E-23	4.3E-23	4.3E-23
Pu244	8.260E+07	yr	2.2E-19	2.2E-19	2.2E-19	2.2E-19	2.2E-19
Am241	4.322E+02	yr	5.4E-07	5.4E-07	4.7E-07	2.5E-07	1.1E-07
Am242M	1.520E+02	yr	1.8E-11	1.7E-11	1.1E-11	1.7E-12	1.7E-13
Am242	1.602E+01	h	1.8E-11	1.7E-11	1.0E-11	1.7E-12	1.7E-13
Am243	7.380E+03	yr	1.9E-11	1.9E-11	1.9E-11	1.8E-11	1.7E-11
Cm242	1.628E+02	d	1.5E-11	1.4E-11	8.7E-12	1.4E-12	1.4E-13
Cm243	2.850E+01	yr	9.7E-13	6.1E-13	5.4E-14	3.2E-18	1.7E-23
Cm244	1.811E+01	yr	3.0E-11	1.4E-11	3.1E-13	7.1E-20	3.4E-28
Cm245	8.500E+03	yr	5.1E-15	5.1E-15	5.1E-15	4.9E-15	4.7E-15
Cm246	4.750E+03	yr	1.2E-16	1.2E-16	1.2E-16	1.1E-16	1.0E-16
Cm247	1.560E+07	yr	4.3E-23	4.3E-23	4.3E-23	4.3E-23	4.3E-23
Cm248	3.390E+05	yr	1.3E-23	1.3E-23	1.3E-23	1.3E-23	1.3E-23
Cf249	3.506E+02	yr	2.6E-23	2.5E-23	2.1E-23	9.4E-24	3.5E-24
Cf250	1.308E+01	yr	2.2E-24	8.1E-25	4.1E-27	2.5E-36	
Cf251	9.000E+02	yr	7.0E-26	6.9E-26	6.4E-26		
Cf252	2.639E+00	yr	5.5E-29				
(Fission Products)							
H 3	1.228E+01	yr	2.3E-06	7.8E-07	2.8E-09	5.0E-19	3.3E-31
Be 10	1.600E+06	yr	3.7E-13	3.7E-13	3.7E-13	3.7E-13	3.7E-13
C 14	5.730E+03	yr	1.5E-11	1.5E-11	1.4E-11	1.4E-11	1.3E-11
Se 79	6.500E+04	yr	5.3E-08	5.3E-08	5.3E-08	5.3E-08	5.3E-08
Sr 90	2.912E+01	yr	3.2E-03	2.1E-03	1.9E-04	1.4E-08	9.4E-14
Y 90	6.410E+01	h	3.2E-03	2.1E-03	1.9E-04	1.4E-08	9.4E-14
Zr 93	1.530E+06	yr	2.7E-07	2.7E-07	2.7E-07	2.7E-07	2.7E-07
Nb 93M	1.360E+01	yr	2.5E-07	2.6E-07	2.6E-07	2.6E-07	2.6E-07
Nb 94	2.030E+04	yr	2.9E-12	2.9E-12	2.8E-12	2.8E-12	2.8E-12
Tc 98	4.200E+06	yr	8.4E-14	8.4E-14	8.4E-14	8.4E-14	8.4E-14
Tc 99	2.130E+05	yr	1.8E-06	1.8E-06	1.8E-06	1.8E-06	1.8E-06
Rh102	2.900E+00	yr	1.3E-14	1.4E-16	5.7E-27		
Ru106	3.682E+02	d	2.6E-19				
Rh106	2.992E+01	s	2.6E-19				
Pd107	6.500E+06	yr	2.0E-09	2.0E-09	2.0E-09	2.0E-09	2.0E-09
Ag108	2.370E+00	m	1.3E-15	1.2E-15	6.7E-16	7.6E-17	4.9E-18
Ag108M	1.270E+02	yr	1.4E-14	1.3E-14	7.6E-15	8.5E-16	5.6E-17
Ag109M	3.960E+01	s	1.5E-26				
Cd109	4.640E+02	d	1.5E-26				
Ag110	2.457E+01	s	2.6E-32				
Ag110M	2.499E+02	d	2.0E-30				
Cd113M	1.360E+01	yr	1.1E-07	4.3E-08	3.7E-10	2.1E-18	
In115	5.100E+15	yr	1.7E-18	1.7E-18	1.7E-18	1.7E-18	1.7E-18
Sn119M	2.930E+02	d	8.0E-31	2.4E-39			
Sn121M	5.000E+01	yr	5.2E-09	4.0E-09	9.9E-10	3.9E-12	3.8E-15
Te123	1.000E+13	yr	3.2E-21	3.2E-21	3.2E-21	3.2E-21	3.2E-21
Sb125	2.770E+00	yr	5.3E-10	4.5E-12	6.1E-23		
Te125M	5.800E+01	d	1.3E-10	1.1E-12	1.5E-23		
Sn126	1.000E+05	yr	4.7E-08	4.7E-08	4.7E-08	4.7E-08	4.7E-08

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Table 7: Calculated Radionuclide Activities for Al Calcine in Ci/g as a Function of Decay Time (Continued)

Nuclide	Half-Life		2016	2035	Decay Time Since 2016 (yr)		
					1E2	5E2	1E3
(Fission Products Continued)							
Sb126	1.240E+01	d	6.6E-09	6.6E-09	6.6E-09	6.6E-09	6.6E-09
Sb126M	1.900E+01	m	4.7E-08	4.7E-08	4.7E-08	4.7E-08	4.7E-08
I129	1.570E+07	yr	3.0E-09	3.0E-09	3.0E-09	3.0E-09	3.0E-09
Cs134	2.062E+00	yr	1.8E-11	3.1E-14			
Cs135	2.300E+06	yr	4.6E-08	4.6E-08	4.6E-08	4.6E-08	4.6E-08
Cs137	3.000E+01	yr	3.5E-03	2.2E-03	2.2E-04	2.2E-08	2.1E-13
Ba137M	2.552E+00	m	3.3E-03	2.1E-03	2.1E-04	2.0E-08	2.0E-13
La138	1.350E+11	yr	2.7E-17	2.7E-17	2.7E-17	2.7E-17	2.7E-17
Ce142	1.050E+11	yr	3.7E-12	3.7E-12	3.7E-12	3.7E-12	3.7E-12
Ce144	2.843E+02	d	4.5E-23				
Pr144	1.728E+01	m	4.5E-23				
Pr144M	7.200E+00	m	5.4E-25	2.4E-32			
Nd144	2.100E+15	yr	1.8E-16	1.8E-16	1.8E-16	1.8E-16	1.8E-16
Pm146	2.020E+03	d	6.3E-11	5.8E-12	1.9E-17		
Sm146	1.030E+08	yr	3.2E-15	3.2E-15	3.2E-15	3.2E-15	3.2E-15
Pm147	2.623E+00	yr	1.3E-08	8.5E-11	2.8E-22		
Sm147	1.070E+11	yr	1.2E-12	1.2E-12	1.2E-12	1.2E-12	1.2E-12
Sm148	8.000E+15	yr	1.3E-18	1.3E-18	1.3E-18	1.3E-18	1.3E-18
Sm149	1.000E+15	yr	5.4E-19	5.4E-19	5.4E-19	5.4E-19	5.4E-19
Eu150	3.600E+01	yr	1.6E-13	1.1E-13	1.6E-14	7.4E-18	4.9E-22
Sm151	9.000E+01	yr	7.1E-05	6.1E-05	2.8E-05	1.3E-06	2.8E-08
Eu152	1.360E+01	yr	3.0E-08	1.1E-08	7.0E-11	9.8E-20	
Gd152	1.080E+14	yr	4.1E-20	4.2E-20	4.2E-20	4.2E-20	4.2E-20
Gd153	2.416E+02	d	1.3E-32				
Eu154	8.600E+00	yr	1.6E-06	3.5E-07	1.1E-10	1.1E-24	
Eu155	4.960E+00	yr	9.7E-08	6.8E-09	5.8E-15		
Ho166M	1.200E+03	yr	8.9E-13	8.8E-13	8.3E-13	6.6E-13	4.9E-13
Tm171	1.920E+00	yr	7.3E-24	7.7E-27	1.6E-42		
Total			1.3E-02	8.6E-03	8.5E-04	4.6E-06	3.0E-06

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Table 8: Calculated Gamma-Ray Photon Spectrum for Al Calcine as a Function of Decay Time

			Photons/s/g Calcine					
Photon Group Energy (MeV)			Decay after 2035					
Lower	Upper	Average	2016	2035	100yr	500yr	1000yr	
0.00E-0	>2.00E-2	1.00E-02	9.4E+07	6.0E+07	5.6E+06	1.0E+04	8.1E+03	
2.00E-2	>3.00E-2	2.50E-02	2.0E+07	1.2E+07	1.2E+06	1.8E+03	1.6E+03	
3.00E-2	>4.50E-2	3.75E-02	2.1E+07	1.3E+07	1.3E+06	5.6E+02	4.3E+02	
4.50E-2	>7.00E-2	5.75E-02	1.8E+07	1.1E+07	1.1E+06	4.2E+03	2.2E+03	
7.00E-2	>1.00E-1	8.50E-02	1.1E+07	6.8E+06	6.4E+05	1.1E+03	1.1E+03	
1.00E-1	>1.50E-1	1.25E-01	6.9E+06	4.4E+06	4.1E+05	1.4E+02	1.1E+02	
1.50E-1	>3.00E-1	2.25E-01	9.1E+06	5.8E+06	5.4E+05	1.4E+02	1.0E+02	
3.00E-1	>4.50E-1	3.75E-01	3.9E+06	2.5E+06	2.3E+05	2.0E+03	2.0E+03	
4.50E-1	>7.00E-1	5.75E-01	1.3E+08	8.2E+07	8.2E+06	5.0E+03	4.2E+03	
7.00E-1	>1.00E+0	8.50E-01	6.6E+05	4.1E+05	3.7E+04	2.2E+02	2.1E+02	
1.00E+0	>1.50E+0	1.25E+00	2.4E+05	1.4E+05	1.2E+04	5.4E+01	5.4E+01	
1.50E+0	>2.00E+0	1.75E+00	1.7E+04	1.0E+04	9.5E+02	1.2E+00	2.1E+00	
2.00E+0	>2.50E+0	2.25E+00	1.8E+00	1.2E+00	2.1E-01	3.6E-01	6.6E-01	
2.50E+0	>3.00E+0	2.75E+00	9.3E-03	8.0E-03	4.7E-03	6.4E-03	1.2E-02	
3.00E+0	>4.00E+0	3.50E+00	2.0E-04	2.3E-04	4.2E-04	1.2E-03	2.2E-03	
4.00E+0	>6.00E+0	5.00E+00	4.3E-05	4.0E-05	3.1E-05	2.2E-05	2.0E-05	
6.00E+0	>8.00E+0	7.00E+00	4.7E-06	4.4E-06	3.4E-06	2.5E-06	2.3E-06	
8.00E+0	>1.10E+1	9.50E+00	5.2E-07	4.8E-07	3.8E-07	2.8E-07	2.6E-07	

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Attachment A

Attachment A: ORIGEN2 Input and Output for Calculating the Radionuclide Inventory in Ci for a Pseudo MTR Element as a Function of Decay Time

Origen2 Input

```

-1
-1
-1
RDA      ORIGEN2, VERSION 2.1 (8-1-91) MTR
BAS      ONE MTR ELEMENT
CUT      -1
LIP      0 0 0
LIB      0 1 2 3 204 908 909 9 50 0 4 0
TIT      ONE CYCLE FOR ONE MTR ELEMENT
INP      -1 1 -1 -1 1 1
MOV      -1 1 0 1.0
HED      1
BUP
IRP      50.0 1.626 1 2 3 2
IRP      100.0 1.626 2 3 3 0
IRP      200.0 1.626 3 4 3 0
IRP      300.0 1.626 4 5 3 0
IRP      400.0 1.626 5 6 3 0
IRP      417.0 1.626 6 7 3 0
BUP
OPTL     8 8 8 8 8 8 5 8 8 8 8 8 8 8 8 8 8 8 8 8
OPTA     8 8 8 8 5 8 5 8 8 8 8 8 8 8 8 8 8 8 8 8
OPTF     8 8 8 8 5 8 5 8 8 8 8 8 8 8 8 8 8 8 8 8
MOV      7 1 0 1.0
DEC      22.0 1 2 5 4
DEC      23.0 2 3 5 0
DEC      24.0 3 4 5 0
DEC      25.0 4 5 5 0
DEC      26.0 5 6 5 0
DEC      27.0 6 7 5 0
DEC      28.0 7 8 5 0
DEC      29.0 8 9 5 0
OUT      -9 1 -1 0
OUT      9 1 -1 0
END
2 922340 2.317 922350 200. 922360 .4343 922380 11.53 FUEL 93.3%
0

```

**Attachment A: ORIGEN2 Input and Output for Calculating the Radionuclide Inventory in
Ci for a Pseudo MTR Element as a Function of Decay (Continued)**

```
Origen2 Input
echo off
echo **
echo **
echo **
echo **
copy a15.INP tape5.inp >nul
REM (NOT USED IN THIS CASE) copy a15.u3 tape3.inp >nul
copy \origen2\libs\decay.lib+\origen2\libs\atr.lib tape9.inp >nul
copy \origen2\libs\gxuo2brm.lib tape10.inp >nul
\origen2\code\origen2
rem combine and save files from run
copy tape12.out+tape6.out a15.u6 >nul
copy tape13.out+tape11.out a15.u11 >nul
ren tape7.out a15.pch
ren tape15.out a15.dbg
ren tape16.out a15.vxs
ren tape50.out a15.ech
rem cleanup files
del tape*.inp
del tape*.out
echo *****
echo ***** O R I G E N 2 - Version 2.1 *****
echo ***** Execution Completed *****
echo *****
echo on
```

Attachment A: ORIGEN2 Input and Output for Calculating the Radionuclide Inventory in Ci for a Pseudo MTR Element as a Function of Decay (Continued)

al5.out ORIGEN2 V2.1 (8-1-91), Run on 06/04/97 at 15:18:15										
	3336.0HR	22.0YR	23.0YR	24.0YR	25.0YR	26.0YR	27.0YR	28.0YR	29.0YR	
TL206	6.211E-25	6.211E-25	6.211E-25	6.211E-25	6.211E-25	6.211E-25	6.211E-25	6.211E-25	6.211E-25	6.211E-25
TL207	1.643E-11	4.995E-08	5.401E-08	5.807E-08	6.224E-08	6.652E-08	7.090E-08	7.538E-08	7.996E-08	8.463E-08
TL208	3.201E-08	5.874E-07	5.847E-07	5.797E-07	5.745E-07	5.694E-07	5.641E-07	5.589E-07	5.537E-07	5.485E-07
TL209	2.499E-13	2.444E-12	2.559E-12	2.674E-12	2.791E-12	2.909E-12	3.028E-12	3.147E-12	3.268E-12	3.389E-12
PB209	1.157E-11	1.131E-10	1.185E-10	1.238E-10	1.292E-10	1.347E-10	1.402E-10	1.457E-10	1.513E-10	1.568E-10
PB210	6.646E-14	2.536E-09	2.871E-09	3.232E-09	3.621E-09	4.038E-09	4.483E-09	4.958E-09	5.463E-09	5.998E-09
PB211	1.648E-11	5.009E-08	5.416E-08	5.824E-08	6.242E-08	6.671E-08	7.110E-08	7.559E-08	8.018E-08	8.487E-08
PB212	8.910E-08	1.635E-06	1.627E-06	1.613E-06	1.599E-06	1.585E-06	1.570E-06	1.556E-06	1.541E-06	1.526E-06
PB214	3.596E-12	1.290E-08	1.408E-08	1.531E-08	1.659E-08	1.792E-08	1.930E-08	2.073E-08	2.221E-08	2.374E-08
BI208	9.254E-25	9.254E-25	9.254E-25	9.254E-25	9.254E-25	9.254E-25	9.254E-25	9.254E-25	9.254E-25	9.254E-25
BI210M	6.236E-25	6.236E-25	6.236E-25	6.236E-25	6.236E-25	6.236E-25	6.236E-25	6.236E-25	6.236E-25	6.236E-25
BI210	5.792E-14	2.536E-09	2.873E-09	3.234E-09	3.623E-09	4.040E-09	4.485E-09	4.960E-09	5.466E-09	5.998E-09
BI211	1.648E-11	5.009E-08	5.416E-08	5.824E-08	6.242E-08	6.671E-08	7.110E-08	7.559E-08	8.018E-08	8.487E-08
BI212	8.910E-08	1.635E-06	1.627E-06	1.613E-06	1.599E-06	1.585E-06	1.570E-06	1.556E-06	1.541E-06	1.526E-06
BI213	1.157E-11	1.131E-10	1.185E-10	1.238E-10	1.292E-10	1.347E-10	1.402E-10	1.457E-10	1.513E-10	1.568E-10
BI214	3.596E-12	1.290E-08	1.408E-08	1.531E-08	1.659E-08	1.792E-08	1.930E-08	2.073E-08	2.221E-08	2.374E-08
PO210	9.023E-15	2.536E-09	2.688E-09	3.004E-09	3.369E-09	3.765E-09	4.189E-09	4.642E-09	5.125E-09	5.638E-09
PO211	4.614E-14	1.403E-10	1.516E-10	1.631E-10	1.748E-10	1.868E-10	1.991E-10	2.117E-10	2.245E-10	2.374E-10
PO212	5.709E-08	1.047E-06	1.043E-06	1.034E-06	1.025E-06	1.015E-06	1.006E-06	9.966E-07	9.873E-07	9.780E-07
PO213	1.132E-11	1.107E-10	1.159E-10	1.211E-10	1.264E-10	1.318E-10	1.371E-10	1.426E-10	1.480E-10	1.534E-10
PO214	1.537E-11	1.290E-08	1.408E-08	1.530E-08	1.658E-08	1.791E-08	1.929E-08	2.073E-08	2.221E-08	2.374E-08
PO215	1.648E-11	5.009E-08	5.416E-08	5.824E-08	6.242E-08	6.671E-08	7.110E-08	7.559E-08	8.018E-08	8.487E-08
PO216	8.910E-08	1.635E-06	1.627E-06	1.613E-06	1.599E-06	1.585E-06	1.570E-06	1.556E-06	1.541E-06	1.526E-06
PO218	3.597E-12	1.291E-08	1.408E-08	1.531E-08	1.659E-08	1.792E-08	1.930E-08	2.074E-08	2.222E-08	2.375E-08
AT217	1.157E-11	1.131E-10	1.185E-10	1.238E-10	1.292E-10	1.347E-10	1.402E-10	1.457E-10	1.513E-10	1.568E-10
RN219	1.648E-11	5.009E-08	5.416E-08	5.824E-08	6.242E-08	6.671E-08	7.110E-08	7.559E-08	8.018E-08	8.487E-08
RN220	8.910E-08	1.635E-06	1.627E-06	1.613E-06	1.599E-06	1.585E-06	1.570E-06	1.556E-06	1.541E-06	1.526E-06
RN222	3.597E-12	1.291E-08	1.408E-08	1.531E-08	1.659E-08	1.792E-08	1.930E-08	2.074E-08	2.222E-08	2.375E-08
FR221	1.157E-11	1.131E-10	1.185E-10	1.238E-10	1.292E-10	1.347E-10	1.402E-10	1.457E-10	1.513E-10	1.568E-10
FR223	4.688E-13	6.913E-10	7.459E-10	8.020E-10	8.596E-10	9.187E-10	9.791E-10	1.041E-09	1.104E-09	1.168E-09
RA223	1.648E-11	5.009E-08	5.416E-08	5.824E-08	6.242E-08	6.671E-08	7.110E-08	7.559E-08	8.018E-08	8.487E-08
RA224	8.910E-08	1.635E-06	1.627E-06	1.613E-06	1.599E-06	1.585E-06	1.570E-06	1.556E-06	1.541E-06	1.526E-06
RA225	1.491E-11	1.131E-10	1.185E-10	1.238E-10	1.292E-10	1.347E-10	1.402E-10	1.457E-10	1.513E-10	1.568E-10
RA226	3.835E-12	1.291E-08	1.408E-08	1.531E-08	1.659E-08	1.792E-08	1.930E-08	2.074E-08	2.222E-08	2.375E-08
RA228	6.155E-17	2.973E-13	3.172E-13	3.374E-13	3.577E-13	3.781E-13	3.987E-13	4.195E-13	4.404E-13	4.614E-13
AC225	1.157E-11	1.131E-10	1.185E-10	1.238E-10	1.292E-10	1.347E-10	1.402E-10	1.457E-10	1.513E-10	1.568E-10
AC227	3.397E-11	5.009E-08	5.405E-08	5.811E-08	6.229E-08	6.657E-08	7.095E-08	7.543E-08	8.001E-08	8.469E-08
AC228	5.221E-10	2.973E-13	3.173E-13	3.374E-13	3.577E-13	3.782E-13	3.988E-13	4.195E-13	4.404E-13	4.614E-13
TH227	2.193E-11	4.940E-08	5.341E-08	5.743E-08	6.156E-08	6.579E-08	7.012E-08	7.455E-08	7.908E-08	8.371E-08
TH228	9.527E-08	1.635E-06	1.621E-06	1.607E-06	1.593E-06	1.579E-06	1.564E-06	1.550E-06	1.535E-06	1.520E-06
TH229	6.130E-12	1.131E-10	1.185E-10	1.238E-10	1.292E-10	1.347E-10	1.402E-10	1.457E-10	1.513E-10	1.568E-10
TH230	4.550E-08	2.671E-06	2.790E-06	2.909E-06	3.029E-06	3.148E-06	3.267E-06	3.387E-06	3.506E-06	3.625E-06
TH231	1.571E-03	3.551E-04	3.551E-04	3.551E-04	3.551E-04	3.551E-04	3.551E-04	3.551E-04	3.551E-04	3.551E-04
TH232	4.471E-15	4.887E-13	5.107E-13	5.327E-13	5.547E-13	5.767E-13	5.987E-13	6.207E-13	6.427E-13	6.647E-13
TH234	3.734E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06
PA231	7.116E-09	1.725E-07	1.800E-07	1.876E-07	1.951E-07	2.026E-07	2.102E-07	2.177E-07	2.252E-07	2.327E-07
PA233	5.052E-05	9.647E-05	9.648E-05	9.648E-05	9.649E-05	9.649E-05	9.649E-05	9.650E-05	9.650E-05	9.650E-05
PA234M	4.421E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06
PA234	6.935E-07	4.915E-09	4.915E-09	4.915E-09	4.915E-09	4.915E-09	4.915E-09	4.915E-09	4.915E-09	4.915E-09
U232	1.635E-06	1.598E-06	1.583E-06	1.568E-06	1.554E-06	1.539E-06	1.524E-06	1.510E-06	1.495E-06	1.480E-06
U233	4.692E-08	5.617E-08	5.664E-08	5.710E-08	5.757E-08	5.804E-08	5.850E-08	5.897E-08	5.944E-08	5.990E-08
U234	1.325E-02	1.326E-02	1.326E-02	1.326E-02	1.326E-02	1.326E-02	1.326E-02	1.326E-02	1.326E-02	1.326E-02
U235	3.551E-04	3.551E-04	3.551E-04	3.551E-04	3.551E-04	3.551E-04	3.551E-04	3.551E-04	3.551E-04	3.551E-04
U236	4.461E-04	4.461E-04	4.461E-04	4.461E-04	4.461E-04	4.461E-04	4.461E-04	4.461E-04	4.461E-04	4.461E-04
U237	1.488E-03	4.766E-06	4.542E-06	4.329E-06	4.125E-06	3.931E-06	3.747E-06	3.571E-06	3.403E-06	3.239E-06
U238	3.781E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06
U240	4.358E-03	1.188E-14	1.188E-14	1.188E-14	1.188E-14	1.188E-14	1.188E-14	1.188E-14	1.188E-14	1.188E-14
NP235	8.506E-07	6.642E-13	3.505E-13	1.850E-13	9.761E-14	5.151E-14	2.718E-14	1.434E-14	7.569E-15	4.034E-15
NP236	3.747E-10	3.746E-10	3.746E-10	3.746E-10	3.746E-10	3.746E-10	3.746E-10	3.746E-10	3.746E-10	3.746E-10
NP237	8.356E-05	9.647E-05	9.647E-05	9.647E-05	9.648E-05	9.648E-05	9.649E-05	9.649E-05	9.649E-05	9.649E-05
NP238	8.571E+01	5.861E-09	5.835E-09	5.808E-09	5.782E-09	5.755E-09	5.729E-09	5.703E-09	5.677E-09	5.651E-09
NP239	1.747E+03	1.051E-06	1.051E-06	1.051E-06	1.051E-06	1.051E-06	1.051E-06	1.051E-06	1.051E-06	1.051E-06
NP240M	4.830E-01	1.188E-14	1.188E-14	1.188E-14	1.188E-14	1.188E-14	1.188E-14	1.188E-14	1.188E-14	1.188E-14
PU236	7.774E-06	3.824E-08	2.999E-08	2.353E-08	1.846E-08	1.448E-08	1.136E-08	8.917E-09	6.999E-09	5.299E-09
PU238	7.803E-02	7.036E-02	6.980E-02	6.925E-02	6.871E-02	6.817E-02	6.763E-02	6.710E-02	6.657E-02	6.604E-02
PU239	1.317E-02	1.363E-02	1.363E-02	1.363E-02	1.363E-02	1.363E-02	1.363E-02	1.363E-02	1.363E-02	1.363E-02
PU240	4.037E-03	4.028E-03	4.027E-03	4.027E-03	4.026E-03	4.026E-03	4.026E-03	4.025E-03	4.025E-03	4.025E-03
PU241	5.602E-01	1.943E-01	1.852E-01	1.765E-01	1.682E-01	1.603E-01	1.527E-01	1.455E-01	1.387E-01	1.320E-01
PU242	7.460E-07	7.460E-07	7.460E-07	7.460E-07	7.460E-07	7.460E-07	7.460E-07	7.460E-07	7.460E-07	7.460E-07
PU243	1.563E-01	2.370E-18	2.370E-18	2.370E-18	2.370E-18	2.370E-18	2.370E-18	2.370E-18	2.370E-18	2.370E-18
PU244	1.190E-14	1.190E-14	1.190E-14	1.190E-14	1.190E-14	1.190E-14	1.190E-14	1.190E-14	1.190E-14	1.190E-14
PU246	7.465E-12	5.567E-30	5.567E-30	5.567E-30	5.567E-30	5.567E-30	5.567E-30	5.567E-30	5.567E-30	5.567E-30
AM241	8.241E-05	1.202E-02	1.231E-02	1.258E-02	1.283E-02	1.307E-02	1.330E-02	1.352E-02	1.373E-02	1.394E-02

Attachment A: ORIGEN2 Input and Output for Calculating the Radionuclide Inventory in Ci for a Pseudo MTR Element as a Function of Decay (Continued)

al5.out ORIGEN2 V2.1 (8-1-91), Run on 06/04/97 at 15:18:15									
	3336.OHR	22.OYR	23.OYR	24.OYR	25.OYR	26.OYR	27.OYR	28.OYR	29.OYR
AM242M	1.296E-06	1.172E-06	1.167E-06	1.162E-06	1.156E-06	1.151E-06	1.146E-06	1.141E-06	1.135E-06
AM242	4.641E-02	1.166E-06	1.161E-06	1.156E-06	1.151E-06	1.145E-06	1.140E-06	1.135E-06	1.130E-06
AM243	1.041E-06	1.051E-06	1.051E-06	1.051E-06	1.051E-06	1.051E-06	1.051E-06	1.051E-06	1.051E-06
AM245	4.103E-08	2.522E-28	2.522E-28	2.522E-28	2.522E-28	2.522E-28	2.522E-28	2.522E-28	2.522E-28
AM246	7.470E-12	5.567E-30	5.567E-30	5.567E-30	5.567E-30	5.567E-30	5.567E-30	5.567E-30	5.567E-30
CM242	4.030E-03	9.646E-07	9.613E-07	9.571E-07	9.528E-07	9.485E-07	9.442E-07	9.399E-07	9.356E-07
CM243	2.174E-07	1.273E-07	1.243E-07	1.213E-07	1.184E-07	1.155E-07	1.128E-07	1.101E-07	1.074E-07
CM244	1.494E-05	6.452E-06	6.209E-06	5.976E-06	5.752E-06	5.536E-06	5.328E-06	5.128E-06	4.935E-06
CM245	2.837E-10	2.832E-10	2.832E-10	2.832E-10	2.832E-10	2.831E-10	2.831E-10	2.831E-10	2.831E-10
CM246	6.494E-12	6.473E-12	6.472E-12	6.472E-12	6.471E-12	6.470E-12	6.469E-12	6.468E-12	6.467E-12
CM247	2.370E-18	2.370E-18	2.370E-18	2.370E-18	2.370E-18	2.370E-18	2.370E-18	2.370E-18	2.370E-18
CM248	7.374E-19	7.374E-19	7.374E-19	7.374E-19	7.374E-19	7.373E-19	7.373E-19	7.373E-19	7.373E-19
CM250	2.223E-29	2.223E-29	2.223E-29	2.223E-29	2.223E-29	2.223E-29	2.223E-29	2.223E-29	2.223E-29
BK249	6.255E-16	1.739E-23	1.739E-23	1.739E-23	1.739E-23	1.739E-23	1.739E-23	1.739E-23	1.739E-23
BK250	1.867E-15	3.103E-30	3.103E-30	3.103E-30	3.103E-30	3.103E-30	3.103E-30	3.103E-30	3.103E-30
CF249	3.451E-20	1.543E-18	1.540E-18	1.537E-18	1.534E-18	1.531E-18	1.528E-18	1.525E-18	1.522E-18
CF250	2.560E-18	8.157E-19	7.725E-19	7.316E-19	6.928E-19	6.561E-19	6.213E-19	5.884E-19	5.572E-19
CF251	3.987E-21	3.919E-21	3.919E-21	3.919E-21	3.919E-21	3.919E-21	3.919E-21	3.919E-21	3.919E-21
CF252	5.116E-20	7.851E-21	7.851E-21	7.851E-21	7.851E-21	7.851E-21	7.851E-21	7.851E-21	7.851E-21
H 3	3.958E-01	1.151E-01	1.089E-01	1.029E-01	9.730E-02	9.199E-02	8.697E-02	8.222E-02	7.773E-02
BE 10	2.522E-09	2.522E-09	2.522E-09	2.522E-09	2.522E-09	2.522E-09	2.522E-09	2.522E-09	2.522E-09
C 14	1.017E-07	1.015E-07	1.015E-07	1.014E-07	1.014E-07	1.014E-07	1.014E-07	1.014E-07	1.014E-07
SE 79	3.660E-04	3.659E-04	3.659E-04	3.659E-04	3.659E-04	3.659E-04	3.659E-04	3.659E-04	3.659E-04
KR 81	1.217E-11	1.217E-11	1.217E-11	1.217E-11	1.217E-11	1.217E-11	1.217E-11	1.217E-11	1.217E-11
KR 85	1.117E+01	2.698E+00	2.529E+00	2.370E+00	2.222E+00	2.083E+00	1.952E+00	1.830E+00	1.716E+00
RB 87	2.458E-08	2.459E-08	2.459E-08	2.459E-08	2.459E-08	2.459E-08	2.459E-08	2.459E-08	2.459E-08
SR 90	8.772E+01	5.196E+01	5.074E+01	4.955E+01	4.838E+01	4.724E+01	4.613E+01	4.505E+01	4.399E+01
Y 90	8.805E+01	5.198E+01	5.075E+01	4.956E+01	4.840E+01	4.726E+01	4.615E+01	4.506E+01	4.400E+01
ZR 93	1.882E-03	1.890E-03	1.890E-03	1.890E-03	1.890E-03	1.890E-03	1.890E-03	1.890E-03	1.890E-03
NB 93M	1.759E-05	1.216E-03	1.245E-03	1.272E-03	1.298E-03	1.323E-03	1.347E-03	1.369E-03	1.390E-03
NB 94	1.969E-08	1.968E-08	1.968E-08	1.968E-08	1.967E-08	1.967E-08	1.967E-08	1.967E-08	1.967E-08
TC 98	5.780E-10	5.780E-10	5.780E-10	5.780E-10	5.780E-10	5.780E-10	5.780E-10	5.780E-10	5.780E-10
TC 99	1.208E-02	1.247E-02	1.247E-02	1.247E-02	1.247E-02	1.247E-02	1.247E-02	1.247E-02	1.247E-02
RH102	7.992E-05	4.159E-07	3.275E-07	2.579E-07	2.030E-07	1.599E-07	1.259E-07	9.912E-08	7.805E-08
RU106	1.658E+02	4.461E-05	2.243E-05	1.128E-05	5.670E-06	2.850E-06	1.433E-06	7.205E-07	3.622E-07
RH106	2.277E+02	4.461E-05	2.243E-05	1.128E-05	5.670E-06	2.850E-06	1.433E-06	7.205E-07	3.622E-07
PD107	1.358E-05	1.358E-05	1.358E-05	1.358E-05	1.358E-05	1.358E-05	1.358E-05	1.358E-05	1.358E-05
AG108	1.225E-04	1.076E-11	1.070E-11	1.064E-11	1.058E-11	1.052E-11	1.047E-11	1.041E-11	1.035E-11
AG108M	1.363E-10	1.209E-10	1.202E-10	1.195E-10	1.189E-10	1.182E-10	1.176E-10	1.170E-10	1.163E-10
AG109M	8.704E+01	2.042E-14	1.183E-14	6.855E-15	3.973E-15	2.302E-15	1.334E-15	7.730E-16	4.480E-16
CD109	3.335E-09	2.042E-14	1.183E-14	6.855E-15	3.973E-15	2.302E-15	1.334E-15	7.730E-16	4.480E-16
AG110	1.320E+01	3.122E-13	1.133E-13	4.115E-14	1.494E-14	5.424E-15	1.969E-15	7.150E-16	2.596E-16
AG110M	1.124E-01	2.347E-11	8.522E-12	3.094E-12	1.123E-12	4.078E-13	1.481E-13	5.376E-14	1.952E-14
CD113M	1.133E-02	3.990E-03	3.805E-03	3.629E-03	3.460E-03	3.300E-03	3.147E-03	3.001E-03	2.861E-03
IN115	1.101E-14	1.185E-14	1.185E-14	1.185E-14	1.185E-14	1.185E-14	1.185E-14	1.185E-14	1.185E-14
SN119M	1.400E-01	1.878E-11	6.684E-12	2.379E-12	8.464E-13	3.012E-13	1.072E-13	3.814E-14	1.357E-14
SN121M	7.922E-05	5.839E-05	5.758E-05	5.679E-05	5.601E-05	5.524E-05	5.448E-05	5.372E-05	5.298E-05
SN123	5.088E+00	9.537E-19	7.604E-20	7.306E-20	7.020E-20	6.745E-20	6.481E-20	6.227E-20	5.983E-20
TE123	1.657E-17	2.199E-17	2.199E-17	2.199E-17	2.199E-17	2.199E-17	2.199E-17	2.199E-17	2.199E-17
TE123M	1.655E-04	1.015E-24	1.015E-24	1.015E-24	1.015E-24	1.015E-24	1.015E-24	1.015E-24	1.015E-24
SB125	5.931E+00	2.514E-02	1.958E-02	1.524E-02	1.187E-02	9.241E-03	7.195E-03	5.602E-03	4.362E-03
TE125M	6.933E-01	6.135E-03	4.777E-03	3.719E-03	2.896E-03	2.255E-03	1.755E-03	1.367E-03	1.064E-03
SN126	3.255E-04	3.254E-04	3.254E-04	3.254E-04	3.254E-04	3.254E-04	3.254E-04	3.254E-04	3.254E-04
SB126	1.868E+00	4.556E-05	4.556E-05	4.556E-05	4.556E-05	4.556E-05	4.556E-05	4.556E-05	4.556E-05
SB126M	8.760E-01	3.254E-04	3.254E-04	3.254E-04	3.254E-04	3.254E-04	3.254E-04	3.254E-04	3.254E-04
I129	1.937E-05	2.038E-05	2.038E-05	2.038E-05	2.038E-05	2.038E-05	2.038E-05	2.038E-05	2.038E-05
CS134	2.855E+01	1.754E-02	1.253E-02	8.952E-03	6.396E-03	4.570E-03	3.265E-03	2.333E-03	1.667E-03
CS135	3.137E-04	3.183E-04	3.183E-04	3.183E-04	3.183E-04	3.183E-04	3.183E-04	3.183E-04	3.183E-04
CS137	9.109E+01	5.479E+01	5.354E+01	5.232E+01	5.112E+01	4.995E+01	4.881E+01	4.770E+01	4.661E+01
BAL37M	8.661E+01	5.183E+01	5.065E+01	4.949E+01	4.836E+01	4.726E+01	4.618E+01	4.512E+01	4.409E+01
LA138	1.836E-13	1.836E-13	1.836E-13	1.836E-13	1.836E-13	1.836E-13	1.836E-13	1.836E-13	1.836E-13
CE142	2.517E-08	2.519E-08	2.519E-08	2.519E-08	2.519E-08	2.519E-08	2.519E-08	2.519E-08	2.519E-08
CE144	2.645E+03	8.182E-06	3.358E-06	1.378E-06	5.655E-07	2.321E-07	9.525E-08	3.909E-08	1.604E-08
PR144	2.710E+03	8.182E-06	3.358E-06	1.378E-06	5.655E-07	2.321E-07	9.525E-08	3.909E-08	1.604E-08
PR144M	3.180E+01	9.818E-08	4.029E-08	1.654E-08	6.786E-09	2.785E-09	1.143E-09	4.691E-10	1.925E-10
ND144	2.287E-13	1.210E-12	1.210E-12	1.210E-12	1.210E-12	1.210E-12	1.210E-12	1.210E-12	1.210E-12
PM146	6.158E-04	3.849E-05	3.393E-05	2.991E-05	2.637E-05	2.325E-05	2.050E-05	1.807E-05	1.593E-05
SM146	3.843E-12	2.063E-11	2.076E-11	2.088E-11	2.098E-11	2.107E-11	2.115E-11	2.122E-11	2.128E-11
PM147	2.892E+02	9.984E-01	7.666E-01	5.886E-01	4.519E-01	3.470E-01	2.664E-01	2.046E-01	1.571E-01
SM147	3.309E-10	8.490E-09	8.495E-09	8.500E-09	8.503E-09	8.506E-09	8.508E-09	8.509E-09	8.510E-09
SM148	7.365E-15	9.005E-15	9.005E-15	9.005E-15	9.005E-15	9.005E-15	9.005E-15	9.005E-15	9.005E-15
SM149	2.403E-15	3.731E-15	3.731E-15	3.731E-15	3.731E-15	3.731E-15	3.731E-15	3.731E-15	3.731E-15
EU150	3.400E-09	2.226E-09	2.183E-09	2.142E-09	2.101E-09	2.061E-09	2.022E-09	1.983E-09	1.945E-09

Attachment A: ORIGEN2 Input and Output for Calculating the Radionuclide Inventory in Ci for a Pseudo MTR Element as a Function of Decay (Continued)

al5.out

ORIGEN2 V2.1 (8-1-91), Run on 06/04/97 at 15:18:15

	3336.0HR	22.0YR	23.0YR	24.0YR	25.0YR	26.0YR	27.0YR	28.0YR	29.0YR
SM151	7.337E-01	6.412E-01	6.363E-01	6.314E-01	6.265E-01	6.217E-01	6.170E-01	6.122E-01	6.075E-01
EU152	3.924E-03	1.279E-03	1.215E-03	1.155E-03	1.097E-03	1.043E-03	9.910E-04	9.418E-04	8.950E-04
GD152	1.509E-16	2.452E-16	2.474E-16	2.495E-16	2.515E-16	2.534E-16	2.553E-16	2.570E-16	2.586E-16
GD153	4.611E-03	4.664E-13	1.639E-13	5.757E-14	2.022E-14	7.104E-15	2.496E-15	8.768E-16	3.080E-16
EU154	1.168E+00	1.983E-01	1.829E-01	1.687E-01	1.557E-01	1.436E-01	1.325E-01	1.222E-01	1.128E-01
EU155	2.081E+00	9.615E-02	8.360E-02	7.270E-02	6.322E-02	5.497E-02	4.780E-02	4.156E-02	3.614E-02
HO166M	6.295E-09	6.216E-09	6.212E-09	6.209E-09	6.205E-09	6.202E-09	6.198E-09	6.194E-09	6.191E-09
TM170	1.951E-08	3.011E-27	3.011E-27	3.011E-27	3.011E-27	3.011E-27	3.011E-27	3.011E-27	3.011E-27
TM171	4.638E-11	1.648E-14	1.149E-14	8.006E-15	5.580E-15	3.889E-15	2.711E-15	1.889E-15	1.317E-15

**Attachment A: ORIGEN2 Input and Output for Calculating the Radionuclide Inventory in
Ci for a Pseudo MTR Element as a Function of Decay (Continued)**

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Attachment A: ORIGEN2 Input and Output for Calculating the Radionuclide Inventory in Ci for a Pseudo MTR Element as a Function of Decay (Continued)

Origen2 Input

```

-1
-1
-1
RDA      ORIGIN2, VERSION 2.1 (8-1-91) MTR
BAS      ONE MTR ELEMENT
CUT      -1
LIP      0 0 0
LIB      0 1 2 3 204 908 909 9 50 0 4 0
TIT      ONE CYCLE FOR ONE MTR ELEMENT
INP      -1 1 -1 -1 1 1
MOV      -1 1 0 1.0
HED      1
ELEMENT
BUP
IRP      50.0 1.626 1 2 3 2
IRP      100.0 1.626 2 3 3 0
IRP      200.0 1.626 3 4 3 0
IRP      300.0 1.626 4 5 3 0
IRP      400.0 1.626 5 6 3 0
IRP      417.0 1.626 6 7 3 0
BUP
OPTL     8 8 8 8 8 8 5 8 8 8 8 8 8 8 8 8 8 8 8 8
OPTA     8 8 8 8 5 8 5 8 8 8 8 8 8 8 8 8 8 8 8 8
OPTF     8 8 8 8 5 8 5 8 8 8 8 8 8 8 8 8 8 8 8 8
MOV      7 1 0 1.0
DEC      22.0 1 2 5 4
DEC      30.0 2 3 5 0
DEC      31.0 3 4 5 0
DEC      32.0 4 5 5 0
DEC      33.0 5 6 5 0
DEC      34.0 6 7 5 0
DEC      35.0 7 8 5 0
DEC      36.0 8 9 5 0
OUT      -9 1 -1 0
OUT      9 1 -1 0
END
2 922340 2.317 922350 200. 922360 .4343 922380 11.53 FUEL 93.3%
0

```

Attachment A: ORIGEN2 Input and Output for Calculating the Radionuclide Inventory in Ci for a Pseudo MTR Element as a Function of Decay (Continued)

```

Origen2 Input
echo off
echo **
echo **
echo **
echo **
copy al6.INP tape5.inp >nul
REM (NOT USED IN THIS CASE) copy al6.u3 tape3.inp >nul
copy \origen2\libs\decay.lib+\origen2\libs\atr.lib tape9.inp >nul
copy \origen2\libs\gxuo2brm.lib tape10.inp >nul
\origen2\code\origen2
rem combine and save files from run
copy tape12.out+tape6.out al6.u6 >nul
copy tape13.out+tape11.out al6.u11 >nul
ren tape7.out al6.pch
ren tape15.out al6.dbg
ren tape16.out al6.vxs
ren tape50.out al6.ech
rem cleanup files
del tape*.inp
del tape*.out
echo *****
echo ***** O R I G E N 2 - Version 2.1 *****
echo ***** Execution Completed *****
echo *****
echo on

```

Attachment A: ORIGEN2 Input and Output for Calculating the Radionuclide Inventory in Ci for a Pseudo MTR Element as a Function of Decay (Continued)

al6.out										
ORIGEN2 V2.1 (8-1-91), Run on 06/04/97	at 15:30:33									
	3336.0HR	22.0YR	30.0YR	31.0YR	32.0YR	33.0YR	34.0YR	35.0YR	36.0YR	
TL206	6.211E-25	6.211E-25	6.211E-25	6.211E-25	6.211E-25	6.211E-25	6.211E-25	6.211E-25	6.211E-25	
TL207	1.643E-11	4.995E-08	8.451E-08	8.935E-08	9.419E-08	9.911E-08	1.041E-07	1.092E-07	1.144E-07	
TL208	3.201E-08	5.874E-07	5.466E-07	5.433E-07	5.382E-07	5.330E-07	5.280E-07	5.229E-07	5.179E-07	
TL209	2.499E-13	2.444E-12	3.386E-12	3.508E-12	3.630E-12	3.754E-12	3.879E-12	4.004E-12	4.130E-12	
PB209	1.157E-11	1.131E-10	1.568E-10	1.624E-10	1.681E-10	1.738E-10	1.796E-10	1.854E-10	1.912E-10	
PB210	6.646E-14	2.536E-09	5.998E-09	6.565E-09	7.164E-09	7.795E-09	8.460E-09	9.158E-09	9.890E-09	
PB211	1.648E-11	5.009E-08	8.474E-08	8.960E-08	9.445E-08	9.939E-08	1.044E-07	1.095E-07	1.147E-07	
PB212	8.910E-08	1.635E-06	1.521E-06	1.512E-06	1.498E-06	1.484E-06	1.469E-06	1.455E-06	1.442E-06	
PB214	3.596E-12	1.290E-08	2.375E-08	2.533E-08	2.697E-08	2.866E-08	3.040E-08	3.219E-08	3.403E-08	
BI208	9.254E-25	9.254E-25	9.254E-25	9.254E-25	9.254E-25	9.254E-25	9.254E-25	9.254E-25	9.254E-25	
BI210M	6.236E-25	6.236E-25	6.236E-25	6.236E-25	6.236E-25	6.236E-25	6.236E-25	6.236E-25	6.236E-25	
BI210	5.792E-14	2.536E-09	6.000E-09	6.569E-09	7.168E-09	7.800E-09	8.464E-09	9.163E-09	9.895E-09	
BI211	1.648E-11	5.009E-08	8.474E-08	8.960E-08	9.445E-08	9.939E-08	1.044E-07	1.095E-07	1.147E-07	
BI212	8.910E-08	1.635E-06	1.521E-06	1.512E-06	1.498E-06	1.484E-06	1.469E-06	1.455E-06	1.442E-06	
BI213	1.157E-11	1.131E-10	1.568E-10	1.624E-10	1.681E-10	1.738E-10	1.796E-10	1.854E-10	1.912E-10	
BI214	3.596E-12	1.290E-08	2.375E-08	2.533E-08	2.697E-08	2.866E-08	3.040E-08	3.219E-08	3.403E-08	
PO210	9.023E-15	2.536E-09	6.000E-09	6.239E-09	6.764E-09	7.362E-09	7.999E-09	8.671E-09	9.375E-09	
PO211	4.614E-14	1.403E-10	2.373E-10	2.509E-10	2.645E-10	2.783E-10	2.923E-10	3.066E-10	3.211E-10	
PO212	5.709E-08	1.047E-06	9.747E-07	9.688E-07	9.596E-07	9.505E-07	9.415E-07	9.325E-07	9.236E-07	
PO213	1.132E-11	1.107E-10	1.534E-10	1.589E-10	1.644E-10	1.700E-10	1.757E-10	1.814E-10	1.871E-10	
PO214	1.537E-11	1.290E-08	2.374E-08	2.533E-08	2.697E-08	2.865E-08	3.039E-08	3.218E-08	3.402E-08	
PO215	1.648E-11	5.009E-08	8.474E-08	8.960E-08	9.445E-08	9.939E-08	1.044E-07	1.095E-07	1.147E-07	
PO216	8.910E-08	1.635E-06	1.521E-06	1.512E-06	1.498E-06	1.484E-06	1.469E-06	1.455E-06	1.442E-06	
PO218	3.597E-12	1.291E-08	2.375E-08	2.534E-08	2.698E-08	2.866E-08	3.040E-08	3.219E-08	3.403E-08	
AT217	1.157E-11	1.131E-10	1.568E-10	1.624E-10	1.681E-10	1.738E-10	1.796E-10	1.854E-10	1.912E-10	
RN219	1.648E-11	5.009E-08	8.474E-08	8.960E-08	9.445E-08	9.939E-08	1.044E-07	1.095E-07	1.147E-07	
RN220	8.910E-08	1.635E-06	1.521E-06	1.512E-06	1.498E-06	1.484E-06	1.469E-06	1.455E-06	1.442E-06	
RN222	3.597E-12	1.291E-08	2.375E-08	2.534E-08	2.698E-08	2.866E-08	3.040E-08	3.219E-08	3.403E-08	
FR221	1.157E-11	1.131E-10	1.568E-10	1.624E-10	1.681E-10	1.738E-10	1.796E-10	1.854E-10	1.912E-10	
FR223	4.688E-13	6.913E-10	1.168E-09	1.234E-09	1.301E-09	1.369E-09	1.438E-09	1.508E-09	1.579E-09	
RA223	1.648E-11	5.009E-08	8.474E-08	8.960E-08	9.445E-08	9.939E-08	1.044E-07	1.095E-07	1.147E-07	
RA224	8.910E-08	1.635E-06	1.521E-06	1.512E-06	1.498E-06	1.484E-06	1.469E-06	1.455E-06	1.442E-06	
RA225	1.491E-11	1.131E-10	1.568E-10	1.624E-10	1.681E-10	1.738E-10	1.796E-10	1.854E-10	1.912E-10	
RA226	3.835E-12	1.291E-08	2.375E-08	2.534E-08	2.698E-08	2.866E-08	3.040E-08	3.219E-08	3.403E-08	
RA228	6.155E-17	2.973E-13	4.614E-13	4.825E-13	5.036E-13	5.249E-13	5.462E-13	5.676E-13	5.891E-13	
AC225	1.157E-11	1.131E-10	1.568E-10	1.624E-10	1.681E-10	1.738E-10	1.796E-10	1.854E-10	1.912E-10	
AC227	3.397E-11	5.009E-08	8.465E-08	8.941E-08	9.425E-08	9.917E-08	1.042E-07	1.093E-07	1.144E-07	
AC228	5.221E-10	2.973E-13	4.614E-13	4.825E-13	5.037E-13	5.249E-13	5.463E-13	5.677E-13	5.891E-13	
TH227	2.193E-11	4.940E-08	8.358E-08	8.837E-08	9.315E-08	9.802E-08	1.030E-07	1.080E-07	1.131E-07	
TH228	9.527E-08	1.635E-06	1.521E-06	1.507E-06	1.492E-06	1.478E-06	1.464E-06	1.450E-06	1.436E-06	
TH229	6.130E-12	1.131E-10	1.568E-10	1.624E-10	1.681E-10	1.738E-10	1.796E-10	1.854E-10	1.912E-10	
TH230	4.550E-08	2.671E-06	3.625E-06	3.745E-06	3.864E-06	3.983E-06	4.103E-06	4.222E-06	4.341E-06	
TH231	1.571E-03	3.551E-04	3.551E-04	3.551E-04	3.551E-04	3.551E-04	3.551E-04	3.551E-04	3.551E-04	
TH232	4.471E-15	4.887E-13	6.648E-13	6.868E-13	7.088E-13	7.308E-13	7.528E-13	7.748E-13	7.968E-13	
TH234	3.734E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06	
PA231	7.116E-09	1.725E-07	2.326E-07	2.401E-07	2.476E-07	2.552E-07	2.627E-07	2.703E-07	2.778E-07	
PA233	5.052E-05	9.647E-05	9.650E-05	9.651E-05	9.652E-05	9.652E-05	9.653E-05	9.653E-05	9.654E-05	
PA234M	4.421E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06	
PA234	6.935E-07	4.915E-09	4.915E-09	4.915E-09	4.915E-09	4.915E-09	4.915E-09	4.915E-09	4.915E-09	
U232	1.635E-06	1.598E-06	1.481E-06	1.467E-06	1.453E-06	1.439E-06	1.425E-06	1.412E-06	1.398E-06	
U233	4.692E-08	5.617E-08	5.954E-08	6.001E-08	6.048E-08	6.094E-08	6.141E-08	6.188E-08	6.234E-08	
U234	1.325E-02	1.326E-02	1.326E-02	1.326E-02	1.326E-02	1.326E-02	1.326E-02	1.326E-02	1.326E-02	
U235	3.551E-04	3.551E-04	3.551E-04	3.551E-04	3.551E-04	3.551E-04	3.551E-04	3.551E-04	3.551E-04	
U236	4.461E-04	4.461E-04	4.461E-04	4.461E-04	4.461E-04	4.461E-04	4.461E-04	4.461E-04	4.461E-04	
U237	1.488E+03	4.766E-06	3.243E-06	3.090E-06	2.945E-06	2.807E-06	2.675E-06	2.549E-06	2.429E-06	
U238	3.781E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06	3.781E-06	
U240	4.358E-03	1.188E-14	1.188E-14	1.188E-14	1.188E-14	1.188E-14	1.188E-14	1.188E-14	1.188E-14	
NP235	8.506E-07	6.642E-13	3.995E-15	2.108E-15	1.112E-15	5.870E-16	3.098E-16	1.634E-16	8.624E-17	
NP236	3.747E-10	3.746E-10	3.746E-10	3.746E-10	3.746E-10	3.746E-10	3.746E-10	3.746E-10	3.746E-10	
NP237	8.356E-05	9.647E-05	9.650E-05	9.650E-05	9.651E-05	9.652E-05	9.652E-05	9.653E-05	9.653E-05	
NP238	8.571E+01	5.861E-09	5.651E-09	5.626E-09	5.600E-09	5.575E-09	5.549E-09	5.524E-09	5.499E-09	
NP239	1.747E+03	1.051E-06	1.050E-06	1.050E-06	1.050E-06	1.050E-06	1.050E-06	1.050E-06	1.050E-06	
NP240M	4.830E-01	1.188E-14	1.188E-14	1.188E-14	1.188E-14	1.188E-14	1.188E-14	1.188E-14	1.188E-14	
PU236	7.774E-06	3.824E-08	5.496E-09	4.317E-09	3.393E-09	2.668E-09	2.099E-09	1.653E-09	1.304E-09	
PU238	7.803E-02	7.036E-02	6.605E-02	6.553E-02	6.501E-02	6.450E-02	6.399E-02	6.349E-02	6.299E-02	
PU239	1.317E-02	1.363E-02	1.363E-02	1.363E-02	1.363E-02	1.363E-02	1.363E-02	1.363E-02	1.363E-02	
PU240	4.037E-03	4.028E-03	4.024E-03	4.024E-03	4.023E-03	4.023E-03	4.023E-03	4.022E-03	4.022E-03	
PU241	5.602E-01	1.943E-01	1.322E-01	1.260E-01	1.201E-01	1.144E-01	1.090E-01	1.039E-01	9.903E-02	
PU242	7.460E-07	7.460E-07	7.460E-07	7.460E-07	7.460E-07	7.460E-07	7.460E-07	7.460E-07	7.460E-07	
PU243	1.563E-01	2.370E-18	2.370E-18	2.370E-18	2.370E-18	2.370E-18	2.370E-18	2.370E-18	2.370E-18	
PU244	1.190E-14	1.190E-14	1.190E-14	1.190E-14	1.190E-14	1.190E-14	1.190E-14	1.190E-14	1.190E-14	
PU246	7.465E-12	5.567E-30	5.567E-30	5.567E-30	5.567E-30	5.567E-30	5.567E-30	5.567E-30	5.567E-30	
AM241	8.241E-05	1.202E-02	1.392E-02	1.411E-02	1.428E-02	1.445E-02	1.460E-02	1.475E-02	1.489E-02	
AM242M	1.296E-06	1.172E-06	1.130E-06	1.125E-06	1.120E-06	1.115E-06	1.110E-06	1.105E-06	1.100E-06	
AM242	4.641E-02	1.166E-06	1.125E-06	1.119E-06	1.114E-06	1.109E-06	1.104E-06	1.099E-06	1.094E-06	

Attachment A: ORIGEN2 Input and Output for Calculating the Radionuclide Inventory in Ci for a Pseudo MTR Element as a Function of Decay (Continued)

al6.out	ORIGEN2 V2.1 (8-1-91), Run on 06/04/97 at 15:30:33									
	3336.0HR	22.0YR	30.0YR	31.0YR	32.0YR	33.0YR	34.0YR	35.0YR	36.0YR	
AM243	1.041E-06	1.051E-06	1.050E-06	1.050E-06	1.050E-06	1.050E-06	1.050E-06	1.050E-06	1.050E-06	
AM245	4.103E-08	2.522E-28	2.521E-28	2.522E-28	2.522E-28	2.522E-28	2.522E-28	2.522E-28	2.522E-28	
AM246	7.470E-12	5.567E-30	5.567E-30	5.567E-30	5.567E-30	5.567E-30	5.567E-30	5.567E-30	5.567E-30	
CM242	4.030E-03	9.646E-07	9.301E-07	9.268E-07	9.228E-07	9.187E-07	9.145E-07	9.104E-07	9.062E-07	
CM243	2.174E-07	1.273E-07	1.048E-07	1.023E-07	9.985E-08	9.745E-08	9.511E-08	9.282E-08	9.059E-08	
CM244	1.494E-05	6.452E-06	4.750E-06	4.572E-06	4.400E-06	4.235E-06	4.076E-06	3.923E-06	3.775E-06	
CM245	2.837E-10	2.832E-10	2.830E-10	2.830E-10	2.830E-10	2.830E-10	2.829E-10	2.829E-10	2.829E-10	
CM246	6.494E-12	6.473E-12	6.466E-12	6.465E-12	6.464E-12	6.463E-12	6.462E-12	6.461E-12	6.460E-12	
CM247	2.370E-18	2.370E-18	2.370E-18	2.370E-18	2.370E-18	2.370E-18	2.370E-18	2.370E-18	2.370E-18	
CM248	7.374E-19	7.374E-19	7.373E-19	7.373E-19	7.373E-19	7.373E-19	7.373E-19	7.373E-19	7.373E-19	
CM250	2.223E-29	2.223E-29	2.223E-29	2.223E-29	2.223E-29	2.223E-29	2.223E-29	2.223E-29	2.223E-29	
BK249	6.255E-16	1.739E-23	1.739E-23	1.739E-23	1.739E-23	1.739E-23	1.739E-23	1.739E-23	1.739E-23	
BK250	1.867E-15	3.103E-30	3.103E-30	3.103E-30	3.103E-30	3.103E-30	3.103E-30	3.103E-30	3.103E-30	
CF249	3.451E-20	1.543E-18	1.519E-18	1.516E-18	1.513E-18	1.510E-18	1.507E-18	1.504E-18	1.501E-18	
CF250	2.560E-18	8.157E-19	5.329E-19	5.046E-19	4.779E-19	4.526E-19	4.286E-19	4.059E-19	3.844E-19	
CF251	3.987E-21	3.919E-21	3.919E-21	3.919E-21	3.919E-21	3.919E-21	3.919E-21	3.919E-21	3.919E-21	
CF252	5.116E-20	7.851E-21	8.693E-21	8.693E-21	8.693E-21	8.693E-21	8.693E-21	8.693E-21	8.693E-21	
H 3	3.958E-01	1.151E-01	7.349E-02	6.948E-02	6.568E-02	6.210E-02	5.871E-02	5.550E-02	5.247E-02	
BE 10	2.522E-09	2.522E-09	2.522E-09	2.522E-09	2.522E-09	2.522E-09	2.522E-09	2.522E-09	2.522E-09	
C 14	1.017E-07	1.015E-07	1.014E-07	1.014E-07	1.013E-07	1.013E-07	1.013E-07	1.013E-07	1.013E-07	
SE 79	3.660E-04	3.659E-04	3.659E-04	3.659E-04	3.659E-04	3.659E-04	3.659E-04	3.659E-04	3.659E-04	
KR 81	1.217E-11	1.217E-11	1.217E-11	1.217E-11	1.217E-11	1.217E-11	1.217E-11	1.217E-11	1.217E-11	
KR 85	1.117E+01	2.698E+00	1.608E+00	1.507E+00	1.413E+00	1.325E+00	1.242E+00	1.164E+00	1.091E+00	
RB 87	2.458E-08	2.459E-08	2.459E-08	2.459E-08	2.459E-08	2.459E-08	2.459E-08	2.459E-08	2.459E-08	
SR 90	8.772E+01	5.196E+01	4.295E+01	4.194E+01	4.096E+01	3.999E+01	3.905E+01	3.813E+01	3.724E+01	
Y 90	8.805E+01	5.198E+01	4.297E+01	4.195E+01	4.097E+01	4.000E+01	3.906E+01	3.814E+01	3.725E+01	
ZR 93	1.882E-03	1.890E-03	1.890E-03	1.890E-03	1.890E-03	1.890E-03	1.890E-03	1.890E-03	1.890E-03	
NB 93M	1.759E-05	1.216E-03	1.410E-03	1.429E-03	1.448E-03	1.465E-03	1.481E-03	1.497E-03	1.512E-03	
NB 94	1.969E-08	1.968E-08	1.967E-08	1.967E-08	1.967E-08	1.967E-08	1.967E-08	1.967E-08	1.967E-08	
TC 98	5.780E-10	5.780E-10	5.780E-10	5.780E-10	5.780E-10	5.780E-10	5.780E-10	5.780E-10	5.780E-10	
TC 99	1.208E-02	1.247E-02	1.247E-02	1.247E-02	1.247E-02	1.247E-02	1.247E-02	1.247E-02	1.247E-02	
RH102	7.992E-05	4.159E-07	6.145E-08	4.839E-08	3.810E-08	3.000E-08	2.362E-08	1.860E-08	1.465E-08	
RU106	1.658E+02	4.461E-05	1.820E-07	9.151E-08	4.601E-08	2.313E-08	1.163E-08	5.846E-09	2.939E-09	
RH106	2.277E+02	4.461E-05	1.821E-07	9.151E-08	4.601E-08	2.313E-08	1.163E-08	5.846E-09	2.939E-09	
PD107	1.358E-05	1.358E-05	1.358E-05	1.358E-05	1.358E-05	1.358E-05	1.358E-05	1.358E-05	1.358E-05	
AG108	1.225E-04	1.076E-11	1.030E-11	1.024E-11	1.018E-11	1.013E-11	1.007E-11	1.002E-11	9.965E-12	
AG108M	1.363E-10	1.209E-10	1.157E-10	1.151E-10	1.144E-10	1.138E-10	1.132E-10	1.126E-10	1.120E-10	
AG109M	8.704E+01	2.042E-14	2.596E-16	1.504E-16	8.717E-17	5.051E-17	2.929E-17	1.698E-17	9.846E-18	
CD109	3.335E-09	2.042E-14	2.596E-16	1.504E-16	8.716E-17	5.051E-17	2.929E-17	1.698E-17	9.846E-18	
AG110	1.320E+01	3.122E-13	9.426E-17	3.422E-17	1.243E-17	4.511E-18	1.638E-18	5.949E-19	2.161E-19	
AG110M	1.124E-01	2.347E-11	7.087E-15	2.573E-15	9.342E-16	3.392E-16	1.231E-16	4.473E-17	1.625E-17	
CD113M	1.133E-02	3.990E-03	2.729E-03	2.602E-03	2.481E-03	2.366E-03	2.256E-03	2.152E-03	2.052E-03	
IN115	1.101E-14	1.185E-14	1.185E-14	1.185E-14	1.185E-14	1.185E-14	1.185E-14	1.185E-14	1.185E-14	
SN119M	1.400E-01	1.878E-11	4.829E-15	1.719E-15	6.116E-16	2.176E-16	7.743E-17	2.757E-17	9.770E-18	
SN121M	7.922E-05	5.839E-05	5.225E-05	5.153E-05	5.083E-05	5.012E-05	4.943E-05	4.875E-05	4.808E-05	
SN123	5.088E+00	9.537E-19	1.477E-25	1.477E-25	1.477E-25	1.477E-25	1.477E-25	1.477E-25	1.477E-25	
TE123	1.657E-17	2.199E-17	2.199E-17	2.199E-17	2.199E-17	2.199E-17	2.199E-17	2.199E-17	2.199E-17	
TE123M	1.655E-04	1.015E-24	4.536E-32	4.536E-32	4.536E-32	4.536E-32	4.536E-32	4.536E-32	4.536E-32	
SBI25	5.931E+00	2.514E-02	3.396E-03	2.644E-03	2.059E-03	1.603E-03	1.248E-03	9.718E-04	7.566E-04	
TE125M	6.933E-01	6.135E-03	8.286E-04	6.452E-04	5.023E-04	3.911E-04	3.045E-04	2.371E-04	1.846E-04	
SN126	3.255E-04	3.254E-04	3.254E-04	3.254E-04	3.254E-04	3.254E-04	3.254E-04	3.254E-04	3.254E-04	
SBI26	1.868E+00	4.556E-05	4.556E-05	4.556E-05	4.556E-05	4.556E-05	4.556E-05	4.556E-05	4.556E-05	
SBI26M	8.760E-01	3.254E-04	3.254E-04	3.254E-04	3.254E-04	3.254E-04	3.254E-04	3.254E-04	3.254E-04	
I129	1.937E-05	2.038E-05	2.038E-05	2.038E-05	2.038E-05	2.038E-05	2.038E-05	2.038E-05	2.038E-05	
CS134	2.855E+01	1.754E-02	1.191E-03	8.511E-04	6.081E-04	4.345E-04	3.104E-04	2.218E-04	1.585E-04	
CS135	3.137E-04	3.183E-04	3.183E-04	3.183E-04	3.183E-04	3.183E-04	3.183E-04	3.183E-04	3.183E-04	
CS137	9.109E+01	5.479E+01	4.554E+01	4.450E+01	4.349E+01	4.249E+01	4.152E+01	4.058E+01	3.965E+01	
BA137M	8.661E+01	5.183E+01	4.308E+01	4.210E+01	4.114E+01	4.020E+01	3.928E+01	3.838E+01	3.751E+01	
LA138	1.836E-13	1.836E-13	1.836E-13	1.836E-13	1.836E-13	1.836E-13	1.836E-13	1.836E-13	1.836E-13	
CE142	2.517E-08	2.519E-08	2.519E-08	2.519E-08	2.519E-08	2.519E-08	2.519E-08	2.519E-08	2.519E-08	
CE144	2.645E+03	8.182E-06	6.584E-09	2.702E-09	1.109E-09	4.551E-10	1.868E-10	7.664E-11	3.145E-11	
PR144	2.710E+03	8.182E-06	6.584E-09	2.702E-09	1.109E-09	4.551E-10	1.868E-10	7.664E-11	3.145E-11	
PR144M	3.180E+01	9.818E-08	7.900E-11	3.242E-11	1.331E-11	5.461E-12	2.241E-12	9.197E-13	3.774E-13	
ND144	2.287E-13	1.210E-12	1.210E-12	1.210E-12	1.210E-12	1.210E-12	1.210E-12	1.210E-12	1.210E-12	
PM146	6.158E-04	3.849E-05	1.404E-05	1.238E-05	1.091E-05	9.622E-06	8.483E-06	7.478E-06	6.593E-06	
SM146	3.843E-12	2.063E-11	2.134E-11	2.139E-11	2.143E-11	2.147E-11	2.150E-11	2.153E-11	2.155E-11	
PM147	2.892E+02	9.984E-01	1.206E-01	9.259E-02	7.109E-02	5.459E-02	4.191E-02	3.218E-02	2.471E-02	
SM147	3.309E-10	8.490E-09	8.511E-09	8.512E-09	8.512E-09	8.513E-09	8.513E-09	8.513E-09	8.514E-09	
SM148	7.365E-15	9.005E-15	9.005E-15	9.005E-15	9.005E-15	9.005E-15	9.005E-15	9.005E-15	9.005E-15	
SM149	2.403E-15	3.731E-15	3.731E-15	3.731E-15	3.731E-15	3.731E-15	3.731E-15	3.731E-15	3.731E-15	
EU150	3.400E-09	2.226E-09	1.908E-09	1.872E-09	1.836E-09	1.801E-09	1.767E-09	1.733E-09	1.700E-09	
SM151	7.337E-01	6.412E-01	6.029E-01	5.982E-01	5.937E-01	5.891E-01	5.846E-01	5.801E-01	5.756E-01	
EU152	3.924E-03	1.279E-03	8.505E-04	8.082E-04	7.681E-04	7.299E-04	6.936E-04	6.592E-04	6.264E-04	
GD152	1.509E-16	2.452E-16	2.602E-16	2.617E-16	2.631E-16	2.644E-16	2.657E-16	2.669E-16	2.681E-16	
GD153	4.611E-03	4.664E-13	1.082E-16	3.804E-17	1.337E-17	4.677E-18	1.684E-18	6.067E-19	1.882E-19	

**Attachment A: ORIGEN2 Input and Output for Calculating the Radionuclide Inventory in
Ci for a Pseudo MTR Element as a Function of Decay (Continued)**

```

a16.out
ORIGEN2 V2.1 (8-1-91), Run on 06/04/97   at 15:30:33
      3336.0HR      22.0YR      30.0YR      31.0YR      32.0YR      33.0YR      34.0YR      35.0YR      36.0YR
EU154      1.168E+00  1.983E-01  1.040E-01  9.599E-02  8.856E-02  8.170E-02  7.537E-02  6.954E-02  6.415E-02
EU155      2.081E+00  9.615E-02  3.143E-02  2.733E-02  2.376E-02  2.066E-02  1.797E-02  1.562E-02  1.359E-02
HO166M      6.295E-09  6.216E-09  6.187E-09  6.184E-09  6.180E-09  6.177E-09  6.173E-09  6.169E-09  6.166E-09
TM170      1.951E-08  3.011E-27  4.347E-34  4.347E-34  4.347E-34  4.347E-34  4.347E-34  4.347E-34  4.347E-34
TM171      4.638E-11  1.648E-14  9.177E-16  6.396E-16  4.458E-16  3.107E-16  2.166E-16  1.509E-16  1.052E-16
  
```

Attachment B

Attachment B: Source Listing for FORTRAN Program REDUCE1

```
PROGRAM REDUCE1
C
C----- WRITTEN BY D.R. WENZEL
C
C          TO REDUCE ORIGEN2 OUTPUT
C
      CHARACTER * 1 ORGLINE(132), DCYTME(9)
      CHARACTER * 3 PBRK, PBREAK
      CHARACTER * 5 SUM, TOTAL
      CHARACTER * 7 BEGIN, START
      CHARACTER * 9 RUN
      CHARACTER * 12 DESC
      CHARACTER * 132 BUFFER
C
      EQUIVALENCE (DCYTME,ORGLINE(23)), (PBRK,ORGLINE(1)),
+                (SUM,ORGLINE(2)), (BEGIN,ORGLINE(23))
C
      DATA PBREAK /'1  '/
      DATA TOTAL /'TOTAL'/
      DATA START /'7 NUCLID'/
C
C----- DETERMINE RUN NAME
C
      CALL GETCL(RUN)
C
C----- OPEN INPUT AND OUTPUT FILES
C
      OPEN(3,FILE ='REDUCE.IN', STATUS='OLD',FORM='FORMATTED',
+        ERR = 900)
      OPEN(6,FILE ='REDUCE.OUT', STATUS='UNKNOWN', ERR = 920)
+
C
      PRINT *, 'Working -- have patience.'
C
      IFLAG = 0
      WRITE(6,600) RUN
600   FORMAT(A9)
      READ(3,300) ORGLINE
300   FORMAT(132A1)
      READ(3,300) ORGLINE
      WRITE(6,300) ORGLINE
C
C----- SEARCH FOR BEGINNING OF DESIRED DATA
C
      30  READ(3,300,END=999) ORGLINE
          IF(BEGIN .NE. START) GO TO 30
C
C----- BEGIN SEARCHING FOR SELECTED RADIONUCLIDES
C
      READ(3,300,END=999) ORGLINE
      READ(3,300,END=999) ORGLINE
      IF(IFLAG .EQ. 0) THEN
        WRITE(6,300) ORGLINE
C          WRITE(6,310) DCYTME
C 310   FORMAT(16X,9A1)
        IFLAG = 1
```


Attachment B: Source Listing for FORTRAN Program REDUCE1 (Continued)

```
      ENDIF
C
  40  READ(3,300,END=999) ORGLINE
      IF(PBRK .EQ. PBREAK) GO TO 50
      IF(SUM .EQ. TOTAL) GO TO 60
      WRITE(BUFFER,300) ORGLINE
      READ(BUFFER,400) DESC, VALUE
  400  FORMAT(A12,10X,E9.4)
      IF(VALUE .LE. 0.) GO TO 40
      WRITE(6,300) ORGLINE
      GO TO 40
C
C----- SKIP LINES OF PAGE BREAK
C
  50  DO 55 I=1,8
      READ(3,300,END=999) ORGLINE
  55  CONTINUE
C
      GO TO 40
C
C----- WRITE BLANK LINE FOLLOWING A TOTAL AND THEN SEARCH FOR
C      MORE OUTPUT
C
  60  WRITE(6,420)
  420  FORMAT(' ')
      GO TO 30
C
C----- ERROR STATEMENTS
C
  900  WRITE(6,9000)
  9000 FORMAT(2X,'ERROR IN OPENING FILE 3')
      GO TO 999
C
  920  WRITE(6,9020)
  9020 FORMAT(2X,'ERROR IN OPENING FILE 6')
      GO TO 999
C
C----- PROGRAM END
C
  999  CONTINUE
      END
```

Attachment C

Attachment C: Source Listing for FORTRAN Program REDUCE86

```

PROGRAM REDUCE86
C
C----- WRITTEN BY D.R. WENZEL
C
C           To calculate activity in Ci for calcine bin set 1
C
      CHARACTER * 1 ORGLINE1(111), ORGLINE2(111)
      CHARACTER * 9 RUN
      CHARACTER * 12 DESC1, DESC2
      CHARACTER * 111 BUFFER1, BUFFER2
      REAL      * 4 VALUE1(9), VALUE2(9)
      REAL      * 4 AL1(9), AL2(9)
      REAL      * 4 RED1(9), RED2(9)
C
C-----Following data statements assume fuel 2 years old when
C           processed
C
C      AGE OF MTR FUEL   1      2      3      4      5      6      7      8
C      PROCESSING YEAR      86      85      84      83      82      81      80
C
C      AGE OF MTR FUEL      9      10     11     12     13     14     15
C      PROCESSING YEAR      79      78      77      76      75      74      73
C
C      AGE OF FUEL        16      17      18      19      20      21      22
C      PROCESSING YEAR      72      71      70      69      68      67      66
C
C      AGE OF FUEL        23      24      25      26      27      28      29
C      PROCESSING YEAR      65      64      63      62      61      60      59
C      DATA AL1 /0.,    0.,    0.,    0., 795.,    0., 45., 420., 91./
C      DATA RED1 /1.,    1.,    1.,    1., 1.,    1., 1., 1., 1./
C
C      AGE OF FUEL        30      31      32      33      34      35      36
C      PROCESSING YEAR      58      57      56      55      54      53      52
C      DATA AL2 /0.,    0., 292.,    0.,    0.,    0.,    0.,    0./
C      DATA RED2 /1.,    1.,    1.,    1.,    1.,    1.,    1.,    1./
C
C----- DETERMINE RUN NAME
C
C      CALL GETCL(RUN)
C
C----- OPEN INPUT AND OUTPUT FILES
C
      OPEN(1,FILE ='AL5.OUT', STATUS='OLD',FORM='FORMATTED',
+      ERR = 900)
      OPEN(2,FILE ='AL6.OUT', STATUS='OLD',FORM='FORMATTED',
+      ERR = 900)
      OPEN(6,FILE ='REDUCE86.OUT', STATUS='UNKNOWN', ERR = 920)
C
C----- Normalize to Berreth's Cs-137 data in WINCO-1050
C
      CORMTR = 22.17
      WRITE(6,600) RUN
600  FORMAT(A9)
C
C----- READ PAST FIRST LINE
C

```

Attachment C: Source Listing for FORTRAN Program REDUCE86

```
      READ(1,300) ORGLINE1
      READ(2,300) ORGLINE2
300   FORMAT(111A1)
C
C----- READ PAST SECOND LINE
C
      READ(1,300) ORGLINE1
      READ(2,300) ORGLINE2
C
C----- READ PAST THIRD LINE
C
      READ(1,300) ORGLINE1
      READ(2,300) ORGLINE2
C
C----- START DATA SUMMATION PROCESS
C
40   READ(1,300,END=999) ORGLINE1
      READ(2,300,END=999) ORGLINE2
      WRITE(BUFFER1,300) ORGLINE1
      WRITE(BUFFER2,300) ORGLINE2
      READ(BUFFER1,400) DESC1, (VALUE1(I),I=1,9)
400  FORMAT(A12,9X,9(1X,E9.4))
      READ(BUFFER2,400) DESC2, (VALUE2(I),I=1,9)
C
C----- CHECK TO BE SURE LISTS ARE IN THE SAME ORDER
C
      NUM = 2
      IF(DESC2 .NE. DESC1) GO TO 930
      SUM = 0.
      DO 45, J=1,7
        K = 10 - J
        SUM = SUM * RED2(K)
        SUM = SUM + VALUE2(K) * AL2(K) * CORMTR
45   CONTINUE
C
      DO 46, J=1,7
        K = 10 - J
        SUM = SUM * RED1(K)
        SUM = SUM + VALUE1(K) * AL1(K) * CORMTR
46   CONTINUE
C
      WRITE(6,401) DESC1,SUM
401  FORMAT(A12,1PE10.3)
      GO TO 40
C
C----- ERROR STATEMENTS
C
900  WRITE(6,9000)
9000 FORMAT(2X,'ERROR IN OPENING FILE ')
      GO TO 999
C
920  WRITE(6,9020)
9020 FORMAT(2X,'ERROR IN OPENING FILE 6')
      GO TO 999
C
```

Attachment C: Source Listing for FORTRAN Program REDUCE86

```
930  WRITE(6,9030)  DESC1,DESC2,NUM
9030  FORMAT(2X,2(2X,A2),5X,I1)
940  WRITE(6,9040)
9040  FORMAT(2X,'ERROR DETECTED IN THE ORDER OF THE RADIONUCLIDES')
C
C----- PROGRAM END
C
999  CONTINUE
      END
```

**Attachment C: Source Listing and Output for FORTRAN Program REDUCE86
(Continued)**

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Attachment D

Attachment D: Output from FORTRAN Program REDUCE86

Radionuclide	Calculated Ci	Radionuclide	Calculated Ci	Radionuclide	Calculated Ci
TL206	2.137E-20	U236	1.535E+01	TC 99	4.291E+02
TL207	2.571E-03	U237	1.245E-01	RH102	3.957E-03
TL208	1.927E-02	U238	1.301E-01	RU106	5.492E-02
TL209	1.076E-07	U240	4.088E-10	RH106	5.492E-02
PB209	4.980E-06	NP235	1.006E-09	PD107	4.673E-01
PB210	1.695E-04	NP236	1.289E-05	AG108	3.585E-07
PB211	2.578E-03	NP237	3.320E+00	AG108M	4.028E-06
PB212	5.363E-02	NP238	1.964E-04	AG109M	4.649E-11
PB214	7.073E-04	NP239	3.616E-02	CD109	4.649E-11
BI208	3.184E-20	NP240M	4.088E-10	AG110	9.895E-11
BI210M	2.146E-20	PU236	3.572E-04	AG110M	7.440E-09
BI210	1.696E-04	PU238	2.313E+03	CD113M	1.046E+02
BI211	2.578E-03	PU239	4.690E+02	IN115	4.077E-10
BI212	5.363E-02	PU240	1.385E+02	SN119M	5.484E-09
BI213	4.980E-06	PU241	5.078E+03	SN121M	1.854E+00
BI214	7.073E-04	PU242	2.567E-02	SN123	1.808E-15
PO210	1.591E-04	PU243	8.155E-14	TE123	7.566E-13
PO211	7.218E-06	PU244	4.095E-10	TE123M	2.835E-20
PO212	3.435E-02	PU246	1.915E-25	SB125	2.262E+02
PO213	4.872E-06	AM241	4.630E+02	TE125M	5.519E+01
PO214	7.071E-04	AM242M	3.928E-02	SN126	1.120E+01
PO215	2.578E-03	AM242	3.908E-02	SB126	1.568E+00
PO216	5.363E-02	AM243	3.616E-02	SB126M	1.120E+01
PO218	7.075E-04	AM245	8.678E-24	I129	7.012E-01
AT217	4.980E-06	AM246	1.915E-25	CS134	1.039E+02
RN219	2.578E-03	CM242	3.237E-02	CS135	1.095E+01
RN220	5.363E-02	CM243	3.808E-03	CS137	1.650E+06
RN222	7.075E-04	CM244	1.782E-01	BA137M	1.561E+06
FR221	4.980E-06	CM245	9.740E-06	LA138	6.317E-09
FR223	3.550E-05	CM246	2.226E-07	CE142	8.667E-04
RA223	2.578E-03	CM247	8.155E-14	CE144	4.297E-03
RA224	5.363E-02	CM248	2.537E-14	PR144	4.297E-03
RA225	4.980E-06	CM250	7.649E-25	PR144M	5.156E-05
RA226	7.075E-04	BK249	5.984E-19	ND144	4.163E-08
RA228	1.431E-08	BK250	1.068E-25	PM146	6.563E-01
AC225	4.980E-06	CF249	5.249E-14	SM146	7.291E-07
AC227	2.572E-03	CF250	2.061E-14	PM147	8.382E+03
AC228	1.431E-08	CF251	1.348E-16	SM147	2.928E-04
TH227	2.542E-03	CF252	2.756E-16	SM148	3.098E-10
TH228	5.343E-02			SM149	1.284E-10
TH229	4.980E-06	H 3	2.877E+03	EU150	6.853E-05
TH230	1.158E-01	BE 10	8.678E-05	SM151	2.110E+04
TH231	1.222E+01	C 14	3.489E-03	EU152	3.289E+01
TH232	2.121E-08	SE 79	1.259E+01	GD152	8.825E-12
TH234	1.301E-01	KR 81	4.187E-07	GD153	1.292E-10
PA231	7.439E-03	KR 85	6.427E+04	EU154	4.325E+03
PA233	3.320E+00	RB 87	8.461E-04	EU155	1.524E+03
PA234M	1.301E-01	SR 90	1.559E+06	HO166M	2.132E-04
PA234	1.691E-04	Y 90	1.559E+06	TM170	8.411E-23
U232	5.205E-02	ZR 93	6.503E+01	TM171	8.683E-11
U233	2.024E-03	NB 93M	4.688E+01		
U234	4.562E+02	NB 94	6.768E-04		
U235	1.222E+01	TC 98	1.989E-05		

Attachment E

Attachment E: ORIGEN2 Output for Calculating the Radionuclide Inventory in Grams for a Pseudo MTR Element as a Function of Decay Time

gm5.out

ORIGEN2 V2.1 (8-1-91), Run on 06/04/97 at 15:18:15

	3336.OHR	22.OYR	23.OYR	24.OYR	25.OYR	26.OYR	27.OYR	28.OYR	29.OYR
HE 4	1.262E-07	1.990E-05	2.079E-05	2.167E-05	2.255E-05	2.343E-05	2.430E-05	2.518E-05	2.605E-05
TL206	2.850E-33	2.850E-33	2.850E-33	2.850E-33	2.850E-33	2.850E-33	2.850E-33	2.850E-33	2.850E-33
TL207	8.625E-20	2.622E-16	2.835E-16	3.048E-16	3.267E-16	3.492E-16	3.722E-16	3.957E-16	4.197E-16
TL208	1.087E-16	1.994E-15	1.985E-15	1.968E-15	1.950E-15	1.933E-15	1.915E-15	1.897E-15	1.880E-15
TL209	6.107E-22	5.973E-21	6.254E-21	6.537E-21	6.823E-21	7.110E-21	7.400E-21	7.693E-21	7.987E-21
PB206	2.810E-19	5.748E-12	6.795E-12	7.944E-12	9.233E-12	1.068E-11	1.228E-11	1.407E-11	1.605E-11
PB207	6.173E-16	1.618E-10	1.826E-10	2.050E-10	2.291E-10	2.549E-10	2.824E-10	3.117E-10	3.429E-10
PB208	4.455E-12	1.359E-08	1.425E-08	1.490E-08	1.555E-08	1.619E-08	1.683E-08	1.746E-08	1.808E-08
PB209	2.546E-18	2.489E-17	2.606E-17	2.724E-17	2.843E-17	2.963E-17	3.083E-17	3.205E-17	3.328E-17
PB210	8.702E-16	3.321E-11	3.759E-11	4.232E-11	4.741E-11	5.287E-11	5.870E-11	6.491E-11	7.152E-11
PB211	6.672E-19	2.028E-15	2.193E-15	2.358E-15	2.528E-15	2.701E-15	2.879E-15	3.061E-15	3.247E-15
PB212	6.410E-14	1.176E-12	1.171E-12	1.161E-12	1.150E-12	1.140E-12	1.130E-12	1.119E-12	1.109E-12
PB214	1.096E-19	3.934E-16	4.293E-16	4.667E-16	5.057E-16	5.463E-16	5.884E-16	6.321E-16	6.773E-16
BI208	1.981E-22	1.981E-22	1.981E-22	1.981E-22	1.981E-22	1.981E-22	1.981E-22	1.981E-22	1.981E-22
BI209	4.740E-16	5.160E-13	5.628E-13	6.118E-13	6.629E-13	7.163E-13	7.718E-13	8.296E-13	8.896E-13
BI210M	1.099E-21	1.099E-21	1.099E-21	1.099E-21	1.099E-21	1.099E-21	1.099E-21	1.099E-21	1.099E-21
BI210	4.666E-19	2.043E-14	2.314E-14	2.606E-14	2.919E-14	3.255E-14	3.614E-14	3.996E-14	4.403E-14
BI211	3.937E-20	1.197E-16	1.294E-16	1.391E-16	1.491E-16	1.594E-16	1.699E-16	1.806E-16	1.916E-16
BI212	6.080E-15	1.116E-13	1.110E-13	1.101E-13	1.091E-13	1.081E-13	1.071E-13	1.062E-13	1.052E-13
BI213	5.979E-19	5.848E-18	6.123E-18	6.400E-18	6.680E-18	6.961E-18	7.245E-18	7.531E-18	7.820E-18
BI214	8.142E-20	2.921E-16	3.188E-16	3.466E-16	3.755E-16	4.056E-16	4.369E-16	4.693E-16	5.029E-16
PO210	2.008E-18	5.644E-13	5.981E-13	6.685E-13	7.497E-13	8.377E-13	9.322E-13	1.033E-12	1.140E-12
PO211	4.830E-25	1.468E-21	1.588E-21	1.707E-21	1.830E-21	1.955E-21	2.084E-21	2.216E-21	2.350E-21
PO212	3.217E-25	5.902E-24	5.875E-24	5.825E-24	5.773E-24	5.721E-24	5.669E-24	5.616E-24	5.564E-24
PO213	8.971E-28	8.774E-27	9.186E-27	9.602E-27	1.002E-26	1.044E-26	1.087E-26	1.130E-26	1.173E-26
PO214	4.788E-26	4.019E-23	4.385E-23	4.768E-23	5.166E-23	5.580E-23	6.011E-23	6.457E-23	6.919E-23
PO215	5.587E-25	1.699E-21	1.836E-21	1.975E-21	2.117E-21	2.262E-21	2.411E-21	2.563E-21	2.719E-21
PO216	2.558E-19	4.693E-18	4.671E-18	4.631E-18	4.590E-18	4.549E-18	4.507E-18	4.465E-18	4.424E-18
PO218	1.271E-20	4.562E-17	4.978E-17	5.412E-17	5.864E-17	6.334E-17	6.823E-17	7.329E-17	7.854E-17
AT217	7.184E-24	7.026E-23	7.356E-23	7.689E-23	8.025E-23	8.363E-23	8.704E-23	9.048E-23	9.395E-23
RN219	1.266E-21	3.849E-18	4.162E-18	4.475E-18	4.796E-18	5.126E-18	5.463E-18	5.808E-18	6.161E-18
RN220	9.657E-17	1.772E-15	1.764E-15	1.748E-15	1.733E-15	1.717E-15	1.702E-15	1.686E-15	1.670E-15
RN222	2.337E-17	8.387E-14	9.152E-14	9.950E-14	1.078E-13	1.165E-13	1.254E-13	1.348E-13	1.444E-13
FR221	6.523E-20	6.380E-19	6.680E-19	6.982E-19	7.287E-19	7.595E-19	7.904E-19	8.217E-19	8.531E-19
FR223	1.212E-20	1.787E-17	1.928E-17	2.073E-17	2.221E-17	2.374E-17	2.530E-17	2.690E-17	2.854E-17
RA223	3.216E-16	9.778E-13	1.057E-12	1.137E-12	1.218E-12	1.302E-12	1.388E-12	1.476E-12	1.565E-12
RA224	5.591E-13	1.026E-11	1.021E-11	1.012E-11	1.003E-11	9.944E-12	9.853E-12	9.762E-12	9.671E-12
RA225	3.801E-16	2.885E-15	3.020E-15	3.157E-15	3.295E-15	3.434E-15	3.574E-15	3.715E-15	3.857E-15
RA226	3.787E-12	1.305E-08	1.424E-08	1.548E-08	1.677E-08	1.812E-08	1.951E-08	2.096E-08	2.246E-08
RA228	2.629E-19	1.270E-15	1.355E-15	1.441E-15	1.528E-15	1.615E-15	1.703E-15	1.792E-15	1.881E-15
AC225	1.992E-16	1.949E-15	2.040E-15	2.133E-15	2.226E-15	2.320E-15	2.414E-15	2.510E-15	2.606E-15
AC227	4.695E-13	6.923E-10	7.469E-10	8.031E-10	8.608E-10	9.199E-10	9.805E-10	1.042E-09	1.106E-09
AC228	2.328E-16	1.326E-19	1.414E-19	1.504E-19	1.595E-19	1.686E-19	1.778E-19	1.870E-19	1.964E-19
TH227	7.131E-16	1.607E-12	1.737E-12	1.868E-12	2.002E-12	2.140E-12	2.281E-12	2.425E-12	2.572E-12
TH228	1.162E-10	1.994E-09	1.977E-09	1.960E-09	1.943E-09	1.925E-09	1.908E-09	1.890E-09	1.872E-09
TH229	2.881E-11	5.316E-10	5.566E-10	5.818E-10	6.072E-10	6.328E-10	6.586E-10	6.847E-10	7.109E-10
TH230	2.253E-06	1.322E-04	1.382E-04	1.441E-04	1.500E-04	1.559E-04	1.618E-04	1.677E-04	1.736E-04
TH231	2.954E-09	6.677E-10	6.677E-10	6.677E-10	6.677E-10	6.677E-10	6.677E-10	6.677E-10	6.677E-10
TH232	4.075E-08	4.454E-06	4.655E-06	4.855E-06	5.056E-06	5.256E-06	5.457E-06	5.658E-06	5.858E-06
TH234	1.612E-10	1.632E-10	1.632E-10	1.632E-10	1.632E-10	1.632E-10	1.632E-10	1.632E-10	1.632E-10
PA231	1.506E-07	3.650E-06	3.810E-06	3.969E-06	4.129E-06	4.288E-06	4.448E-06	4.607E-06	4.767E-06
PA233	2.433E-09	4.646E-09	4.647E-09	4.647E-09	4.647E-09	4.647E-09	4.647E-09	4.648E-09	4.648E-09
PA234M	6.434E-15	5.503E-15	5.503E-15	5.503E-15	5.503E-15	5.503E-15	5.503E-15	5.503E-15	5.503E-15
PA234	3.468E-13	2.458E-15	2.458E-15	2.458E-15	2.458E-15	2.458E-15	2.458E-15	2.458E-15	2.458E-15
U232	7.635E-08	7.465E-08	7.395E-08	7.325E-08	7.256E-08	7.187E-08	7.119E-08	7.051E-08	6.984E-08
U233	4.845E-06	5.800E-06	5.848E-06	5.897E-06	5.945E-06	5.993E-06	6.041E-06	6.089E-06	6.138E-06
U234	2.120E+00	2.121E+00	2.121E+00	2.121E+00	2.121E+00	2.121E+00	2.121E+00	2.121E+00	2.121E+00
U235	1.642E+02	1.642E+02	1.642E+02	1.642E+02	1.642E+02	1.642E+02	1.642E+02	1.642E+02	1.642E+02
U236	6.893E+00	6.893E+00	6.893E+00	6.893E+00	6.893E+00	6.893E+00	6.893E+00	6.893E+00	6.893E+00
U237	1.823E-02	5.837E-11	5.562E-11	5.301E-11	5.052E-11	4.814E-11	4.588E-11	4.373E-11	4.167E-11
U238	1.124E+01	1.124E+01	1.124E+01	1.124E+01	1.124E+01	1.124E+01	1.124E+01	1.124E+01	1.124E+01
U240	4.704E-09	1.282E-20	1.282E-20	1.282E-20	1.282E-20	1.282E-20	1.282E-20	1.282E-20	1.282E-20
NP235	6.061E-10	4.733E-16	2.497E-16	1.318E-16	6.955E-17	3.670E-17	1.937E-17	1.022E-17	5.393E-18
NP236	2.843E-08	2.843E-08	2.843E-08	2.843E-08	2.843E-08	2.843E-08	2.843E-08	2.843E-08	2.843E-08
NP237	1.185E-01	1.368E-01	1.368E-01	1.368E-01	1.368E-01	1.368E-01	1.368E-01	1.368E-01	1.368E-01
NP238	3.306E-04	2.261E-14	2.250E-14	2.240E-14	2.230E-14	2.220E-14	2.210E-14	2.200E-14	2.190E-14
NP239	7.530E-03	4.530E-12	4.530E-12	4.529E-12	4.529E-12	4.529E-12	4.528E-12	4.528E-12	4.527E-12
NP240M	4.560E-09	1.122E-22	1.122E-22	1.122E-22	1.122E-22	1.122E-22	1.122E-22	1.122E-22	1.122E-22
PU236	1.462E-08	7.193E-11	5.642E-11	4.426E-11	3.472E-11	2.724E-11	2.137E-11	1.677E-11	1.317E-11
PU238	4.556E-03	4.108E-03	4.076E-03	4.044E-03	4.012E-03	3.980E-03	3.949E-03	3.918E-03	3.887E-03
PU239	2.118E-01	2.192E-01	2.192E-01	2.192E-01	2.192E-01	2.192E-01	2.192E-01	2.192E-01	2.192E-01
PU240	1.771E-02	1.767E-02	1.767E-02	1.767E-02	1.766E-02	1.766E-02	1.766E-02	1.766E-02	1.766E-02
PU241	5.436E-03	1.885E-03	1.797E-03	1.712E-03	1.632E-03	1.555E-03	1.482E-03	1.412E-03	1.346E-03
PU242	1.953E-04	1.953E-04	1.953E-04	1.953E-04	1.953E-04	1.953E-04	1.953E-04	1.953E-04	1.953E-04
PU243	6.004E-08	9.104E-25	9.104E-25	9.104E-25	9.104E-25	9.104E-25	9.104E-25	9.104E-25	9.104E-25
PU244	6.704E-10	6.705E-10	6.705E-10	6.705E-10	6.705E-10	6.705E-10	6.705E-10	6.705E-10	6.705E-10

**Attachment E: ORIGEN2 Output for Calculating the Radionuclide Inventory in
Grams for a Pseudo MTR Element as a Function of Decay Time
(Continued)**

gm5.out ORIGEN2 V2.1 (8-1-91), Run on 06/04/97 at 15:18:15										
	3336.OHR	22.OYR	23.OYR	24.OYR	25.OYR	26.OYR	27.OYR	28.OYR	29.OYR	
PU246	1.525E-16	1.138E-34	1.138E-34	1.138E-34	1.138E-34	1.138E-34	1.138E-34	1.138E-34	1.138E-34	
AM241	2.400E-05	3.501E-03	3.584E-03	3.663E-03	3.737E-03	3.808E-03	3.875E-03	3.938E-03	3.998E-03	
AM242M	1.333E-07	1.206E-07	1.200E-07	1.195E-07	1.189E-07	1.184E-07	1.179E-07	1.173E-07	1.168E-07	
AM242	5.739E-08	1.442E-12	1.436E-12	1.429E-12	1.423E-12	1.416E-12	1.410E-12	1.403E-12	1.397E-12	
AM243	5.222E-06	5.272E-06	5.271E-06	5.271E-06	5.270E-06	5.270E-06	5.269E-06	5.269E-06	5.268E-06	
AM245	6.636E-15	4.079E-35	4.079E-35	4.079E-35	4.079E-35	4.079E-35	4.079E-35	4.079E-35	4.079E-35	
AM246	2.442E-19	1.820E-37	1.820E-37	1.820E-37	1.820E-37	1.820E-37	1.820E-37	1.820E-37	1.820E-37	
CM242	1.218E-06	2.916E-10	2.906E-10	2.894E-10	2.881E-10	2.868E-10	2.855E-10	2.842E-10	2.829E-10	
CM243	4.211E-09	2.466E-09	2.407E-09	2.349E-09	2.292E-09	2.237E-09	2.184E-09	2.131E-09	2.080E-09	
CM244	1.846E-07	7.971E-08	7.672E-08	7.384E-08	7.106E-08	6.839E-08	6.583E-08	6.335E-08	6.098E-08	
CM245	1.652E-09	1.649E-09	1.649E-09	1.649E-09	1.648E-09	1.648E-09	1.648E-09	1.648E-09	1.648E-09	
CM246	2.113E-11	2.107E-11	2.106E-11	2.106E-11	2.106E-11	2.105E-11	2.105E-11	2.105E-11	2.104E-11	
CM247	2.553E-14	2.553E-14	2.553E-14	2.553E-14	2.553E-14	2.553E-14	2.553E-14	2.553E-14	2.553E-14	
CM248	1.734E-16	1.734E-16	1.734E-16	1.734E-16	1.734E-16	1.734E-16	1.734E-16	1.734E-16	1.734E-16	
CM250	2.703E-28	2.703E-28	2.703E-28	2.703E-28	2.703E-28	2.703E-28	2.703E-28	2.703E-28	2.703E-28	
BK249	3.816E-19	1.061E-26	1.061E-26	1.061E-26	1.061E-26	1.061E-26	1.061E-26	1.061E-26	1.061E-26	
BK250	4.798E-22	7.973E-37	7.973E-37	7.973E-37	7.973E-37	7.973E-37	7.973E-37	7.973E-37	7.973E-37	
CF249	8.422E-21	3.765E-19	3.758E-19	3.750E-19	3.743E-19	3.735E-19	3.728E-19	3.721E-19	3.713E-19	
CF250	2.341E-20	7.459E-21	7.064E-21	6.689E-21	6.335E-21	5.999E-21	5.681E-21	5.380E-21	5.095E-21	
CF251	2.513E-21	2.470E-21	2.470E-21	2.470E-21	2.470E-21	2.470E-21	2.470E-21	2.470E-21	2.470E-21	
CF252	9.509E-23	1.459E-23	1.459E-23	1.459E-23	1.459E-23	1.459E-23	1.459E-23	1.459E-23	1.459E-23	
SF250	2.974E-14	3.999E-12	4.167E-12	4.335E-12	4.501E-12	4.667E-12	4.833E-12	4.998E-12	5.162E-12	
H 3	4.100E-05	1.193E-05	1.128E-05	1.066E-05	1.008E-05	9.528E-06	9.008E-06	8.516E-06	8.052E-06	
LI 6	3.238E-07	3.238E-07	3.238E-07	3.238E-07	3.238E-07	3.238E-07	3.238E-07	3.238E-07	3.238E-07	
LI 7	8.778E-09	8.778E-09	8.778E-09	8.778E-09	8.778E-09	8.778E-09	8.778E-09	8.778E-09	8.778E-09	
BE 9	1.692E-08	1.692E-08	1.692E-08	1.692E-08	1.692E-08	1.692E-08	1.692E-08	1.692E-08	1.692E-08	
BE 10	1.128E-07	1.128E-07	1.128E-07	1.128E-07	1.128E-07	1.128E-07	1.128E-07	1.128E-07	1.128E-07	
C 14	2.282E-08	2.276E-08	2.275E-08	2.275E-08	2.275E-08	2.275E-08	2.274E-08	2.274E-08	2.274E-08	
ZN 66	4.487E-11	4.487E-11	4.487E-11	4.487E-11	4.487E-11	4.487E-11	4.487E-11	4.487E-11	4.487E-11	
ZN 67	1.986E-12	1.986E-12	1.986E-12	1.986E-12	1.986E-12	1.986E-12	1.986E-12	1.986E-12	1.986E-12	
ZN 68	3.916E-15	3.916E-15	3.916E-15	3.916E-15	3.916E-15	3.916E-15	3.916E-15	3.916E-15	3.916E-15	
GA 69	8.088E-19	8.109E-19	8.109E-19	8.109E-19	8.109E-19	8.109E-19	8.109E-19	8.109E-19	8.109E-19	
GE 70	3.553E-22	3.556E-22	3.556E-22	3.556E-22	3.556E-22	3.556E-22	3.556E-22	3.556E-22	3.556E-22	
GA 71	5.136E-10	5.136E-10	5.136E-10	5.136E-10	5.136E-10	5.136E-10	5.136E-10	5.136E-10	5.136E-10	
GE 72	6.323E-06	6.489E-06	6.489E-06	6.489E-06	6.489E-06	6.489E-06	6.489E-06	6.489E-06	6.489E-06	
GE 73	2.262E-05	2.267E-05	2.267E-05	2.267E-05	2.267E-05	2.267E-05	2.267E-05	2.267E-05	2.267E-05	
GE 74	5.954E-05	5.955E-05	5.955E-05	5.955E-05	5.955E-05	5.955E-05	5.955E-05	5.955E-05	5.955E-05	
AS 75	1.456E-04	1.457E-04	1.457E-04	1.457E-04	1.457E-04	1.457E-04	1.457E-04	1.457E-04	1.457E-04	
GE 76	4.375E-04	4.375E-04	4.375E-04	4.375E-04	4.375E-04	4.375E-04	4.375E-04	4.375E-04	4.375E-04	
SE 76	6.144E-07	6.292E-07	6.292E-07	6.292E-07	6.292E-07	6.292E-07	6.292E-07	6.292E-07	6.292E-07	
SE 77	9.636E-04	9.814E-04	9.814E-04	9.814E-04	9.814E-04	9.814E-04	9.814E-04	9.814E-04	9.814E-04	
SE 78	2.033E-03	2.036E-03	2.036E-03	2.036E-03	2.036E-03	2.036E-03	2.036E-03	2.036E-03	2.036E-03	
SE 79	5.252E-03	5.251E-03	5.251E-03	5.251E-03	5.251E-03	5.251E-03	5.251E-03	5.251E-03	5.251E-03	
BR 79	1.093E-08	1.244E-06	1.300E-06	1.356E-06	1.412E-06	1.468E-06	1.524E-06	1.580E-06	1.636E-06	
SE 80	1.263E-02	1.263E-02	1.263E-02	1.263E-02	1.263E-02	1.263E-02	1.263E-02	1.263E-02	1.263E-02	
KR 80	6.242E-08	6.247E-08	6.247E-08	6.247E-08	6.247E-08	6.247E-08	6.247E-08	6.247E-08	6.247E-08	
BR 81	2.161E-02	2.162E-02	2.162E-02	2.162E-02	2.162E-02	2.162E-02	2.162E-02	2.162E-02	2.162E-02	
KR 81	5.783E-10	5.783E-10	5.783E-10	5.783E-10	5.783E-10	5.783E-10	5.783E-10	5.783E-10	5.783E-10	
SE 82	3.420E-02	3.420E-02	3.420E-02	3.420E-02	3.420E-02	3.420E-02	3.420E-02	3.420E-02	3.420E-02	
KR 82	8.338E-05	8.585E-05	8.585E-05	8.585E-05	8.585E-05	8.585E-05	8.585E-05	8.585E-05	8.585E-05	
KR 83	5.387E-02	5.397E-02	5.397E-02	5.397E-02	5.397E-02	5.397E-02	5.397E-02	5.397E-02	5.397E-02	
KR 84	1.106E-01	1.106E-01	1.106E-01	1.106E-01	1.106E-01	1.106E-01	1.106E-01	1.106E-01	1.106E-01	
KR 85	2.845E-02	6.873E-03	6.442E-03	6.039E-03	5.661E-03	5.306E-03	4.974E-03	4.663E-03	4.371E-03	
RB 85	1.071E-01	1.289E-01	1.293E-01	1.297E-01	1.301E-01	1.305E-01	1.308E-01	1.311E-01	1.314E-01	
KR 86	2.170E-01	2.170E-01	2.170E-01	2.170E-01	2.170E-01	2.170E-01	2.170E-01	2.170E-01	2.170E-01	
SR 86	3.972E-05	5.697E-05	5.697E-05	5.697E-05	5.697E-05	5.697E-05	5.697E-05	5.697E-05	5.697E-05	
RB 87	2.808E-01	2.809E-01	2.809E-01	2.809E-01	2.809E-01	2.809E-01	2.809E-01	2.809E-01	2.809E-01	
SR 87	4.039E-07	4.042E-07	4.042E-07	4.042E-07	4.042E-07	4.042E-07	4.042E-07	4.042E-07	4.042E-07	
SR 88	4.041E-01	4.046E-01	4.046E-01	4.046E-01	4.046E-01	4.046E-01	4.046E-01	4.046E-01	4.046E-01	
Y 89	2.962E-01	5.340E-01	5.340E-01	5.340E-01	5.340E-01	5.340E-01	5.340E-01	5.340E-01	5.340E-01	
SR 90	6.428E-01	3.808E-01	3.718E-01	3.631E-01	3.546E-01	3.462E-01	3.381E-01	3.301E-01	3.224E-01	
Y 90	1.618E-04	9.549E-05	9.325E-05	9.105E-05	8.891E-05	8.682E-05	8.478E-05	8.279E-05	8.084E-05	
ZR 90	3.811E-03	2.659E-01	2.749E-01	2.836E-01	2.922E-01	3.005E-01	3.087E-01	3.166E-01	3.244E-01	
ZR 91	3.394E-01	6.671E-01	6.671E-01	6.671E-01	6.671E-01	6.671E-01	6.671E-01	6.671E-01	6.671E-01	
ZR 92	6.906E-01	6.924E-01	6.924E-01	6.924E-01	6.924E-01	6.924E-01	6.924E-01	6.924E-01	6.924E-01	
ZR 93	7.486E-01	7.519E-01	7.519E-01	7.519E-01	7.519E-01	7.519E-01	7.519E-01	7.519E-01	7.519E-01	
NB 93	4.713E-09	3.261E-06	3.499E-06	3.743E-06	3.992E-06	4.245E-06	4.503E-06	4.765E-06	5.030E-06	
NB 93M	6.222E-08	4.301E-06	4.403E-06	4.500E-06	4.592E-06	4.679E-06	4.762E-06	4.841E-06	4.916E-06	
ZR 94	7.366E-01	7.367E-01	7.367E-01	7.367E-01	7.367E-01	7.367E-01	7.367E-01	7.367E-01	7.367E-01	
NB 94	1.051E-07	1.050E-07	1.050E-07	1.050E-07	1.050E-07	1.050E-07	1.050E-07	1.050E-07	1.050E-07	
MO 95	2.049E-01	7.624E-01	7.624E-01	7.624E-01	7.624E-01	7.624E-01	7.624E-01	7.624E-01	7.624E-01	
ZR 96	7.578E-01	7.578E-01	7.578E-01	7.578E-01	7.578E-01	7.578E-01	7.578E-01	7.578E-01	7.578E-01	
MO 96	1.361E-03	1.367E-03	1.367E-03	1.367E-03	1.367E-03	1.367E-03	1.367E-03	1.367E-03	1.367E-03	

Attachment E: ORIGEN2 Output for Calculating the Radionuclide Inventory in Grams for a Pseudo MTR Element as a Function of Decay Time (Continued)

gm5.out ORIGEN2 V2.1 (8-1-91), Run on 06/04/97 at 15:18:15										
	3336.0HR	22.0YR	23.0YR	24.0YR	25.0YR	26.0YR	27.0YR	28.0YR	29.0YR	
MO 97	7.095E-01	7.151E-01	7.151E-01	7.151E-01	7.151E-01	7.151E-01	7.151E-01	7.151E-01	7.151E-01	7.151E-01
MO 98	7.193E-01	7.193E-01	7.193E-01	7.193E-01	7.193E-01	7.193E-01	7.193E-01	7.193E-01	7.193E-01	7.193E-01
TC 98	6.650E-07	6.649E-07	6.649E-07	6.649E-07	6.649E-07	6.649E-07	6.649E-07	6.649E-07	6.649E-07	6.649E-07
TC 99	7.123E-01	7.352E-01	7.351E-01	7.351E-01	7.351E-01	7.351E-01	7.351E-01	7.351E-01	7.351E-01	7.351E-01
RU 99	4.389E-07	5.307E-05	5.546E-05	5.785E-05	6.025E-05	6.264E-05	6.503E-05	6.742E-05	6.982E-05	6.982E-05
MO100	7.895E-01	7.895E-01	7.895E-01	7.895E-01	7.895E-01	7.895E-01	7.895E-01	7.895E-01	7.895E-01	7.895E-01
RU100	1.530E-02	1.530E-02	1.530E-02	1.530E-02	1.530E-02	1.530E-02	1.530E-02	1.530E-02	1.530E-02	1.530E-02
RU101	6.406E-01	6.407E-01	6.407E-01	6.407E-01	6.407E-01	6.407E-01	6.407E-01	6.407E-01	6.407E-01	6.407E-01
RU102	5.458E-01	5.459E-01	5.459E-01	5.459E-01	5.459E-01	5.459E-01	5.459E-01	5.459E-01	5.459E-01	5.459E-01
RH102	6.610E-08	3.440E-10	2.708E-10	2.133E-10	1.679E-10	1.322E-10	1.041E-10	8.198E-11	6.455E-11	6.455E-11
RH103	2.412E-01	3.927E-01	3.927E-01	3.927E-01	3.927E-01	3.927E-01	3.927E-01	3.927E-01	3.927E-01	3.927E-01
RU104	2.483E-01	2.483E-01	2.483E-01	2.483E-01	2.483E-01	2.483E-01	2.483E-01	2.483E-01	2.483E-01	2.483E-01
PD104	1.463E-02	1.463E-02	1.463E-02	1.463E-02	1.463E-02	1.463E-02	1.463E-02	1.463E-02	1.463E-02	1.463E-02
PD105	1.281E-01	1.303E-01	1.303E-01	1.303E-01	1.303E-01	1.303E-01	1.303E-01	1.303E-01	1.303E-01	1.303E-01
RU106	4.953E-02	1.333E-08	6.701E-09	3.369E-09	1.694E-09	8.516E-10	4.281E-10	2.152E-10	1.082E-10	1.082E-10
RH106	6.393E-08	1.253E-14	6.299E-15	3.167E-15	1.592E-15	8.004E-16	4.024E-16	2.023E-16	1.017E-16	1.017E-16
PD106	1.428E-02	6.382E-02	6.382E-02	6.382E-02	6.382E-02	6.382E-02	6.382E-02	6.382E-02	6.382E-02	6.382E-02
PD107	2.639E-02	2.640E-02	2.640E-02	2.640E-02	2.640E-02	2.640E-02	2.640E-02	2.640E-02	2.640E-02	2.640E-02
AG107	5.299E-10	6.249E-08	6.531E-08	6.813E-08	7.094E-08	7.376E-08	7.658E-08	7.939E-08	8.221E-08	8.221E-08
PD108	1.282E-02	1.282E-02	1.282E-02	1.282E-02	1.282E-02	1.282E-02	1.282E-02	1.282E-02	1.282E-02	1.282E-02
AG108	1.666E-13	1.464E-20	1.456E-20	1.448E-20	1.440E-20	1.432E-20	1.424E-20	1.416E-20	1.409E-20	1.409E-20
AG108M	5.226E-12	4.635E-12	4.610E-12	4.585E-12	4.560E-12	4.535E-12	4.510E-12	4.486E-12	4.461E-12	4.461E-12
CD108	4.509E-09	4.509E-09	4.509E-09	4.509E-09	4.509E-09	4.509E-09	4.509E-09	4.509E-09	4.509E-09	4.509E-09
AG109	5.992E-03	6.033E-03	6.033E-03	6.033E-03	6.033E-03	6.033E-03	6.033E-03	6.033E-03	6.033E-03	6.033E-03
AG109M	3.329E-08	7.808E-24	4.524E-24	2.622E-24	1.519E-24	8.804E-25	5.102E-25	2.956E-25	1.713E-25	1.713E-25
CD109	1.291E-12	7.904E-18	4.580E-18	2.654E-18	1.538E-18	8.913E-19	5.165E-19	2.993E-19	1.734E-19	1.734E-19
PD110	4.627E-03	4.627E-03	4.627E-03	4.627E-03	4.627E-03	4.627E-03	4.627E-03	4.627E-03	4.627E-03	4.627E-03
AG110	3.164E-09	7.484E-23	2.717E-23	9.866E-24	3.582E-24	1.301E-24	4.722E-25	1.714E-25	6.224E-26	6.224E-26
AG110M	2.365E-05	4.939E-15	1.793E-15	6.510E-16	2.364E-16	8.582E-17	3.116E-17	1.131E-17	4.107E-18	4.107E-18
CD110	5.074E-04	5.310E-04	5.310E-04	5.310E-04	5.310E-04	5.310E-04	5.310E-04	5.310E-04	5.310E-04	5.310E-04
CD111	3.420E-03	3.710E-03	3.710E-03	3.710E-03	3.710E-03	3.710E-03	3.710E-03	3.710E-03	3.710E-03	3.710E-03
CD112	2.711E-03	2.738E-03	2.738E-03	2.738E-03	2.738E-03	2.738E-03	2.738E-03	2.738E-03	2.738E-03	2.738E-03
CD113	2.130E-04	2.184E-04	2.184E-04	2.184E-04	2.184E-04	2.184E-04	2.184E-04	2.184E-04	2.184E-04	2.184E-04
CD113M	5.224E-05	1.839E-05	1.754E-05	1.673E-05	1.595E-05	1.521E-05	1.450E-05	1.383E-05	1.319E-05	1.319E-05
IN113	4.660E-07	3.435E-05	3.520E-05	3.602E-05	3.679E-05	3.753E-05	3.824E-05	3.891E-05	3.955E-05	3.955E-05
CD114	4.871E-03	4.871E-03	4.871E-03	4.871E-03	4.871E-03	4.871E-03	4.871E-03	4.871E-03	4.871E-03	4.871E-03
SN114	3.050E-09	4.198E-09	4.198E-09	4.198E-09	4.198E-09	4.198E-09	4.198E-09	4.198E-09	4.198E-09	4.198E-09
IN115	1.768E-03	1.905E-03	1.905E-03	1.905E-03	1.905E-03	1.905E-03	1.905E-03	1.905E-03	1.905E-03	1.905E-03
SN115	7.652E-05	7.849E-05	7.849E-05	7.849E-05	7.849E-05	7.849E-05	7.849E-05	7.849E-05	7.849E-05	7.849E-05
CD116	2.463E-03	2.463E-03	2.463E-03	2.463E-03	2.463E-03	2.463E-03	2.463E-03	2.463E-03	2.463E-03	2.463E-03
SN116	3.659E-04	3.661E-04	3.661E-04	3.661E-04	3.661E-04	3.661E-04	3.661E-04	3.661E-04	3.661E-04	3.661E-04
SN117	2.418E-03	2.423E-03	2.423E-03	2.423E-03	2.423E-03	2.423E-03	2.423E-03	2.423E-03	2.423E-03	2.423E-03
SN118	2.695E-03	2.696E-03	2.696E-03	2.696E-03	2.696E-03	2.696E-03	2.696E-03	2.696E-03	2.696E-03	2.696E-03
SN119	2.550E-03	2.582E-03	2.582E-03	2.582E-03	2.582E-03	2.582E-03	2.582E-03	2.582E-03	2.582E-03	2.582E-03
SN119M	3.124E-05	4.193E-15	1.492E-15	5.309E-16	1.889E-16	6.723E-17	2.392E-17	8.513E-18	3.029E-18	3.029E-18
SN120	2.703E-03	2.703E-03	2.703E-03	2.703E-03	2.703E-03	2.703E-03	2.703E-03	2.703E-03	2.703E-03	2.703E-03
SN121M	1.339E-06	9.871E-07	9.735E-07	9.601E-07	9.469E-07	9.339E-07	9.210E-07	9.083E-07	8.958E-07	8.958E-07
SB121	2.804E-03	2.837E-03	2.837E-03	2.837E-03	2.837E-03	2.837E-03	2.837E-03	2.837E-03	2.837E-03	2.837E-03
SN122	3.032E-03	3.032E-03	3.032E-03	3.032E-03	3.032E-03	3.032E-03	3.032E-03	3.032E-03	3.032E-03	3.032E-03
TE122	2.702E-05	2.865E-05	2.865E-05	2.865E-05	2.865E-05	2.865E-05	2.865E-05	2.865E-05	2.865E-05	2.865E-05
SN123	6.188E-04	1.160E-22	9.248E-24	8.885E-24	8.537E-24	8.203E-24	7.882E-24	7.573E-24	7.277E-24	7.277E-24
SB123	2.985E-03	3.605E-03	3.605E-03	3.605E-03	3.605E-03	3.605E-03	3.605E-03	3.605E-03	3.605E-03	3.605E-03
TE123	5.698E-08	7.563E-08	7.563E-08	7.563E-08	7.563E-08	7.563E-08	7.563E-08	7.563E-08	7.563E-08	7.563E-08
TE123M	1.865E-08	1.144E-28	1.144E-28	1.144E-28	1.144E-28	1.144E-28	1.144E-28	1.144E-28	1.144E-28	1.144E-28
SN124	4.754E-03	4.754E-03	4.754E-03	4.754E-03	4.754E-03	4.754E-03	4.754E-03	4.754E-03	4.754E-03	4.754E-03
TE124	1.114E-05	2.966E-05	2.966E-05	2.966E-05	2.966E-05	2.966E-05	2.966E-05	2.966E-05	2.966E-05	2.966E-05
SB125	5.742E-03	2.434E-05	1.895E-05	1.476E-05	1.149E-05	8.946E-06	6.965E-06	5.423E-06	4.223E-06	4.223E-06
TE125	2.303E-04	6.231E-03	6.237E-03	6.241E-03	6.244E-03	6.247E-03	6.249E-03	6.250E-03	6.252E-03	6.252E-03
TE125M	3.848E-05	3.405E-07	2.651E-07	2.064E-07	1.607E-07	1.251E-07	9.742E-08	7.585E-08	5.906E-08	5.906E-08
SN126	1.147E-02	1.147E-02	1.147E-02	1.147E-02	1.147E-02	1.147E-02	1.147E-02	1.147E-02	1.147E-02	1.147E-02
SB126	2.234E-05	5.447E-10	5.447E-10	5.447E-10	5.447E-10	5.447E-10	5.447E-10	5.447E-10	5.447E-10	5.447E-10
SB126M	1.115E-08	4.142E-12	4.142E-12	4.142E-12	4.142E-12	4.141E-12	4.141E-12	4.141E-12	4.141E-12	4.141E-12
TE126	2.170E-04	2.411E-04	2.412E-04	2.413E-04	2.413E-04	2.414E-04	2.415E-04	2.416E-04	2.417E-04	2.417E-04
I127	2.231E-02	2.571E-02	2.571E-02	2.571E-02	2.571E-02	2.571E-02	2.571E-02	2.571E-02	2.571E-02	2.571E-02
TE128	6.415E-02	6.419E-02	6.419E-02	6.419E-02	6.419E-02	6.419E-02	6.419E-02	6.419E-02	6.419E-02	6.419E-02
XE128	1.848E-04	1.849E-04	1.849E-04	1.849E-04	1.849E-04	1.849E-04	1.849E-04	1.849E-04	1.849E-04	1.849E-04
I129	1.097E-01	1.154E-01	1.154E-01	1.154E-01	1.154E-01	1.154E-01	1.154E-01	1.154E-01	1.154E-01	1.154E-01
XE129	1.802E-06	1.943E-06	1.948E-06	1.953E-06	1.958E-06	1.964E-06	1.969E-06	1.974E-06	1.979E-06	1.979E-06
TE130	2.465E-01	2.466E-01	2.466E-01	2.466E-01	2.466E-01	2.466E-01	2.466E-01	2.466E-01	2.466E-01	2.466E-01
XE130	6.580E-04	6.649E-04	6.649E-04	6.649E-04	6.649E-04	6.649E-04	6.649E-04	6.649E-04	6.649E-04	6.649E-04
XE131	4.117E-01	4.524E-01	4.524E-01	4.524E-01	4.524E-01	4.524E-01	4.524E-01	4.524E-01	4.524E-01	4.524E-01
XE132	7.123E-01	7.368E-01	7.368E-01	7.368E-01	7.368E-01	7.368E-01	7.368E-01	7.368E-01	7.368E-01	7.368E-01
BA132	2.023E-08	2.345E-08	2.345E-08	2.345E-08	2.345E-08	2.345E-08	2.345E-08	2.345E-08	2.345E-08	2.345E-08
CS133	1.040E+00	1.109E+00	1.109E+00	1.109E+00	1.109E+00	1.109E+00	1.109E+00	1.109E+00	1.109E+00	1.109E+00

Attachment E: ORIGEN2 Output for Calculating the Radionuclide Inventory in Grams for a Pseudo MTR Element as a Function of Decay Time (Continued)

gm5.out
ORIGEN2 V2.1 (8-1-91), Run on 06/04/97 at 15:18:15

	3336.0HR	22.0YR	23.0YR	24.0YR	25.0YR	26.0YR	27.0YR	28.0YR	29.0YR
XE134	1.295E+00	1.295E+00	1.295E+00	1.295E+00	1.295E+00	1.295E+00	1.295E+00	1.295E+00	1.295E+00
CS134	2.206E-02	1.355E-05	9.679E-06	6.916E-06	4.941E-06	3.531E-06	2.523E-06	1.803E-06	1.288E-06
BA134	8.820E-04	2.293E-02	2.294E-02	2.294E-02	2.294E-02	2.294E-02	2.294E-02	2.294E-02	2.294E-02
CS135	2.723E-01	2.764E-01	2.764E-01	2.764E-01	2.764E-01	2.764E-01	2.764E-01	2.764E-01	2.764E-01
BA135	8.349E-07	2.670E-06	2.754E-06	2.837E-06	2.920E-06	3.003E-06	3.087E-06	3.170E-06	3.253E-06
XE136	1.934E+00	1.934E+00	1.934E+00	1.934E+00	1.934E+00	1.934E+00	1.934E+00	1.934E+00	1.934E+00
BA136	1.826E-03	2.231E-03	2.231E-03	2.231E-03	2.231E-03	2.231E-03	2.231E-03	2.231E-03	2.231E-03
CS137	1.047E+00	6.296E-01	6.152E-01	6.012E-01	5.875E-01	5.740E-01	5.609E-01	5.481E-01	5.356E-01
BA137	4.704E-03	4.218E-01	4.362E-01	4.503E-01	4.640E-01	4.774E-01	4.905E-01	5.033E-01	5.159E-01
BA137M	1.610E-07	9.632E-08	9.412E-08	9.197E-08	8.987E-08	8.782E-08	8.582E-08	8.386E-08	8.194E-08
BA138	1.177E+00	1.177E+00	1.177E+00	1.177E+00	1.177E+00	1.177E+00	1.177E+00	1.177E+00	1.177E+00
LA138	9.562E-06	9.562E-06	9.562E-06	9.562E-06	9.562E-06	9.562E-06	9.562E-06	9.562E-06	9.562E-06
LA139	1.123E+00	1.123E+00	1.123E+00	1.123E+00	1.123E+00	1.123E+00	1.123E+00	1.123E+00	1.123E+00
CE140	9.563E-01	1.119E+00	1.119E+00	1.119E+00	1.119E+00	1.119E+00	1.119E+00	1.119E+00	1.119E+00
PR141	7.067E-01	1.039E+00	1.039E+00	1.039E+00	1.039E+00	1.039E+00	1.039E+00	1.039E+00	1.039E+00
CE142	1.049E+00	1.049E+00	1.049E+00	1.049E+00	1.049E+00	1.049E+00	1.049E+00	1.049E+00	1.049E+00
ND142	1.509E-03	1.542E-03	1.542E-03	1.542E-03	1.542E-03	1.542E-03	1.542E-03	1.542E-03	1.542E-03
ND143	8.638E-01	1.023E+00	1.023E+00	1.023E+00	1.023E+00	1.023E+00	1.023E+00	1.023E+00	1.023E+00
CE144	8.288E-01	2.564E-09	1.052E-09	4.318E-10	1.772E-10	7.273E-11	2.985E-11	1.225E-11	5.027E-12
PR144	3.586E-05	1.083E-13	4.443E-14	1.823E-14	7.483E-15	3.071E-15	1.260E-15	5.172E-16	2.123E-16
PR144M	1.753E-07	5.412E-16	2.221E-16	9.114E-17	3.740E-17	1.535E-17	6.300E-18	2.585E-18	1.061E-18
ND144	1.932E-01	1.022E+00	1.022E+00	1.022E+00	1.022E+00	1.022E+00	1.022E+00	1.022E+00	1.022E+00
ND145	6.966E-01	6.985E-01	6.985E-01	6.985E-01	6.985E-01	6.985E-01	6.985E-01	6.985E-01	6.985E-01
ND146	5.570E-01	5.572E-01	5.572E-01	5.572E-01	5.572E-01	5.572E-01	5.572E-01	5.572E-01	5.572E-01
PM146	1.383E-06	8.641E-08	7.618E-08	6.716E-08	5.921E-08	5.220E-08	4.602E-08	4.057E-08	3.576E-08
SM146	1.098E-07	5.894E-07	5.932E-07	5.965E-07	5.995E-07	6.021E-07	6.044E-07	6.064E-07	6.082E-07
PM147	3.119E-01	1.077E-03	8.266E-04	6.347E-04	4.873E-04	3.742E-04	2.873E-04	2.206E-04	1.694E-04
SM147	1.455E-02	3.734E-01	3.737E-01	3.738E-01	3.740E-01	3.741E-01	3.742E-01	3.743E-01	3.743E-01
ND148	3.166E-01	3.166E-01	3.166E-01	3.166E-01	3.166E-01	3.166E-01	3.166E-01	3.166E-01	3.166E-01
SM148	2.439E-02	2.982E-02	2.982E-02	2.982E-02	2.982E-02	2.982E-02	2.982E-02	2.982E-02	2.982E-02
SM149	1.000E-02	1.554E-02	1.554E-02	1.554E-02	1.554E-02	1.554E-02	1.554E-02	1.554E-02	1.554E-02
ND150	1.223E-01	1.223E-01	1.223E-01	1.223E-01	1.223E-01	1.223E-01	1.223E-01	1.223E-01	1.223E-01
SM150	2.055E-01	2.055E-01	2.055E-01	2.055E-01	2.055E-01	2.055E-01	2.055E-01	2.055E-01	2.055E-01
EU150	5.133E-11	3.361E-11	3.297E-11	3.234E-11	3.172E-11	3.112E-11	3.052E-11	2.994E-11	2.937E-11
SM151	2.788E-02	2.436E-02	2.418E-02	2.399E-02	2.381E-02	2.362E-02	2.344E-02	2.326E-02	2.308E-02
EU151	2.711E-05	4.526E-03	4.713E-03	4.898E-03	5.082E-03	5.265E-03	5.446E-03	5.626E-03	5.804E-03
SM152	9.239E-02	9.241E-02	9.241E-02	9.241E-02	9.241E-02	9.241E-02	9.241E-02	9.241E-02	9.241E-02
EU152	2.268E-05	7.391E-06	7.023E-06	6.674E-06	6.343E-06	6.028E-06	5.728E-06	5.444E-06	5.173E-06
GD152	6.926E-06	1.125E-05	1.135E-05	1.145E-05	1.154E-05	1.163E-05	1.172E-05	1.179E-05	1.187E-05
EU153	4.183E-02	4.320E-02	4.320E-02	4.320E-02	4.320E-02	4.320E-02	4.320E-02	4.320E-02	4.320E-02
GD153	1.307E-06	1.322E-16	4.645E-17	1.632E-17	5.732E-18	2.014E-18	7.075E-19	2.485E-19	8.730E-20
SM154	1.514E-02	1.514E-02	1.514E-02	1.514E-02	1.514E-02	1.514E-02	1.514E-02	1.514E-02	1.514E-02
EU154	4.324E-03	7.342E-04	6.773E-04	6.249E-04	5.765E-04	5.319E-04	4.907E-04	4.527E-04	4.176E-04
GD154	4.121E-05	3.631E-03	3.688E-03	3.740E-03	3.789E-03	3.833E-03	3.874E-03	3.912E-03	3.947E-03
EU155	4.472E-03	2.066E-04	1.797E-04	1.562E-04	1.359E-04	1.181E-04	1.027E-04	8.933E-05	7.768E-05
GD155	2.082E-05	4.288E-03	4.315E-03	4.338E-03	4.358E-03	4.376E-03	4.392E-03	4.405E-03	4.417E-03
GD156	4.911E-03	6.162E-03	6.162E-03	6.162E-03	6.162E-03	6.162E-03	6.162E-03	6.162E-03	6.162E-03
GD157	3.933E-05	5.183E-05	5.183E-05	5.183E-05	5.183E-05	5.183E-05	5.183E-05	5.183E-05	5.183E-05
GD158	2.523E-03	2.524E-03	2.524E-03	2.524E-03	2.524E-03	2.524E-03	2.524E-03	2.524E-03	2.524E-03
TB159	2.709E-04	2.734E-04	2.734E-04	2.734E-04	2.734E-04	2.734E-04	2.734E-04	2.734E-04	2.734E-04
GD160	1.090E-04	1.090E-04	1.090E-04	1.090E-04	1.090E-04	1.090E-04	1.090E-04	1.090E-04	1.090E-04
DY160	2.146E-06	6.898E-06	6.898E-06	6.898E-06	6.898E-06	6.898E-06	6.898E-06	6.898E-06	6.898E-06
DY161	2.576E-05	2.815E-05	2.815E-05	2.815E-05	2.815E-05	2.815E-05	2.815E-05	2.815E-05	2.815E-05
DY162	1.577E-05	1.577E-05	1.577E-05	1.577E-05	1.577E-05	1.577E-05	1.577E-05	1.577E-05	1.577E-05
DY163	6.842E-06	6.842E-06	6.842E-06	6.842E-06	6.842E-06	6.842E-06	6.842E-06	6.842E-06	6.842E-06
DY164	1.944E-06	1.944E-06	1.944E-06	1.944E-06	1.944E-06	1.944E-06	1.944E-06	1.944E-06	1.944E-06
HO165	1.509E-06	1.512E-06	1.512E-06	1.512E-06	1.512E-06	1.512E-06	1.512E-06	1.512E-06	1.512E-06
HO166M	3.506E-09	3.462E-09	3.460E-09	3.458E-09	3.456E-09	3.454E-09	3.452E-09	3.450E-09	3.448E-09
ER166	5.444E-07	5.712E-07	5.712E-07	5.712E-07	5.713E-07	5.713E-07	5.713E-07	5.713E-07	5.713E-07
ER167	2.023E-07	2.023E-07	2.023E-07	2.023E-07	2.023E-07	2.023E-07	2.023E-07	2.023E-07	2.023E-07
ER168	8.774E-08	8.774E-08	8.774E-08	8.774E-08	8.774E-08	8.774E-08	8.774E-08	8.774E-08	8.774E-08
TM169	8.453E-11	1.133E-10	1.133E-10	1.133E-10	1.133E-10	1.133E-10	1.133E-10	1.133E-10	1.133E-10
ER170	6.625E-16	5.429E-15	5.429E-15	5.429E-15	5.429E-15	5.429E-15	5.429E-15	5.429E-15	5.429E-15
TM170	3.264E-12	5.039E-31	5.039E-31	5.039E-31	5.039E-31	5.039E-31	5.039E-31	5.039E-31	5.039E-31
YB170	4.512E-13	3.711E-12	3.711E-12	3.711E-12	3.711E-12	3.711E-12	3.711E-12	3.711E-12	3.711E-12
TM171	4.258E-14	1.513E-17	1.055E-17	7.350E-18	5.123E-18	3.570E-18	2.488E-18	1.734E-18	1.209E-18
YB171	3.090E-15	4.565E-14	4.566E-14	4.566E-14	4.566E-14	4.566E-14	4.567E-14	4.567E-14	4.567E-14
YB172	9.393E-17	1.071E-16	1.071E-16	1.071E-16	1.071E-16	1.071E-16	1.071E-16	1.071E-16	1.071E-16

Attachment E: ORIGEN2 Output for Calculating the Radionuclide Inventory in Grams for a Pseudo MTR Element as a Function of Decay Time (Continued)

gm6.out ORIGEN2 V2.1 (8-1-91), Run on 06/04/97 at 15:30:33										
	3336.0HR	22.0YR	30.0YR	31.0YR	32.0YR	33.0YR	34.0YR	35.0YR	36.0YR	
HE 4	1.262E-07	1.990E-05	2.692E-05	2.778E-05	2.864E-05	2.951E-05	3.036E-05	3.122E-05	3.207E-05	
TL206	2.850E-33	2.850E-33	2.850E-33	2.850E-33	2.850E-33	2.850E-33	2.850E-33	2.850E-33	2.850E-33	
TL207	8.625E-20	2.622E-16	4.436E-16	4.690E-16	4.944E-16	5.202E-16	5.465E-16	5.732E-16	6.003E-16	
TL208	1.087E-16	1.994E-15	1.856E-15	1.844E-15	1.827E-15	1.809E-15	1.792E-15	1.775E-15	1.758E-15	
TL209	6.107E-22	5.973E-21	8.277E-21	8.574E-21	8.874E-21	9.176E-21	9.480E-21	9.787E-21	1.010E-20	
PB206	2.810E-19	5.748E-12	1.864E-11	2.110E-11	2.372E-11	2.658E-11	2.969E-11	3.306E-11	3.671E-11	
PB207	6.173E-16	1.618E-10	3.758E-10	4.107E-10	4.475E-10	4.862E-10	5.270E-10	5.698E-10	6.146E-10	
PB208	4.455E-12	1.359E-08	1.869E-08	1.930E-08	1.991E-08	2.051E-08	2.111E-08	2.170E-08	2.228E-08	
PB209	2.546E-18	2.489E-17	3.449E-17	3.573E-17	3.698E-17	3.823E-17	3.950E-17	4.078E-17	4.207E-17	
PB210	8.702E-16	3.321E-11	7.854E-11	8.596E-11	9.380E-11	1.021E-10	1.108E-10	1.199E-10	1.295E-10	
PB211	6.672E-19	2.028E-15	3.432E-15	3.628E-15	3.825E-15	4.025E-15	4.228E-15	4.434E-15	4.644E-15	
PB212	6.410E-14	1.176E-12	1.094E-12	1.088E-12	1.078E-12	1.067E-12	1.057E-12	1.047E-12	1.037E-12	
PB214	1.096E-19	3.934E-16	7.241E-16	7.724E-16	8.223E-16	8.738E-16	9.268E-16	9.813E-16	1.037E-15	
BI208	1.981E-22	1.981E-22	1.981E-22	1.981E-22	1.981E-22	1.981E-22	1.981E-22	1.981E-22	1.981E-22	
BI209	4.740E-16	5.160E-13	9.518E-13	1.016E-12	1.083E-12	1.152E-12	1.224E-12	1.298E-12	1.374E-12	
BI210M	1.099E-21	1.099E-21	1.099E-21	1.099E-21	1.099E-21	1.099E-21	1.099E-21	1.099E-21	1.099E-21	
BI210	4.666E-19	2.043E-14	4.834E-14	5.292E-14	5.775E-14	6.284E-14	6.819E-14	7.382E-14	7.972E-14	
BI211	3.937E-20	1.197E-16	2.025E-16	2.141E-16	2.257E-16	2.375E-16	2.494E-16	2.616E-16	2.740E-16	
BI212	6.080E-15	1.116E-13	1.038E-13	1.032E-13	1.022E-13	1.012E-13	1.003E-13	9.932E-14	9.837E-14	
BI213	5.979E-19	5.848E-18	8.103E-18	8.395E-18	8.688E-18	8.984E-18	9.282E-18	9.582E-18	9.884E-18	
BI214	8.142E-20	2.921E-16	5.377E-16	5.735E-16	6.106E-16	6.488E-16	6.882E-16	7.287E-16	7.703E-16	
PO210	2.008E-18	5.644E-13	1.335E-12	1.388E-12	1.505E-12	1.638E-12	1.780E-12	1.929E-12	2.086E-12	
PO211	4.830E-25	1.468E-21	2.484E-21	2.626E-21	2.769E-21	2.913E-21	3.061E-21	3.210E-21	3.362E-21	
PO212	3.217E-25	5.902E-24	5.493E-24	5.459E-24	5.408E-24	5.356E-24	5.305E-24	5.255E-24	5.204E-24	
PO213	8.971E-28	8.774E-27	1.216E-26	1.259E-26	1.303E-26	1.348E-26	1.393E-26	1.438E-26	1.483E-26	
PO214	4.788E-26	4.019E-23	7.397E-23	7.891E-23	8.400E-23	8.926E-23	9.467E-23	1.002E-22	1.060E-22	
PO215	5.587E-25	1.699E-21	2.873E-21	3.038E-21	3.203E-21	3.370E-21	3.540E-21	3.713E-21	3.889E-21	
PO216	2.558E-19	4.693E-18	4.367E-18	4.341E-18	4.300E-18	4.259E-18	4.218E-18	4.178E-18	4.138E-18	
PO218	1.271E-20	4.562E-17	8.396E-17	8.957E-17	9.535E-17	1.013E-16	1.075E-16	1.138E-16	1.203E-16	
AT217	7.184E-24	7.026E-23	9.736E-23	1.009E-22	1.044E-22	1.079E-22	1.115E-22	1.151E-22	1.187E-22	
RN219	1.266E-21	3.849E-18	6.512E-18	6.885E-18	7.257E-18	7.637E-18	8.022E-18	8.414E-18	8.812E-18	
RN220	9.657E-17	1.772E-15	1.649E-15	1.639E-15	1.623E-15	1.608E-15	1.593E-15	1.577E-15	1.562E-15	
RN222	2.337E-17	8.387E-14	1.544E-13	1.647E-13	1.753E-13	1.863E-13	1.976E-13	2.092E-13	2.212E-13	
FR221	6.523E-20	6.380E-19	8.841E-19	9.158E-19	9.478E-19	9.801E-19	1.013E-18	1.045E-18	1.078E-18	
FR223	1.212E-20	1.787E-17	3.019E-17	3.189E-17	3.361E-17	3.537E-17	3.716E-17	3.897E-17	4.081E-17	
RA223	3.216E-16	9.778E-13	1.654E-12	1.749E-12	1.844E-12	1.940E-12	2.038E-12	2.137E-12	2.238E-12	
RA224	5.591E-13	1.026E-11	9.547E-12	9.489E-12	9.399E-12	9.310E-12	9.221E-12	9.133E-12	9.046E-12	
RA225	3.801E-16	2.885E-15	3.997E-15	4.141E-15	4.286E-15	4.431E-15	4.578E-15	4.726E-15	4.876E-15	
RA226	3.878E-12	1.305E-08	2.401E-08	2.562E-08	2.727E-08	2.898E-08	3.074E-08	3.255E-08	3.441E-08	
RA228	2.629E-19	1.270E-15	1.971E-15	2.061E-15	2.151E-15	2.242E-15	2.333E-15	2.425E-15	2.516E-15	
AC225	1.992E-16	1.949E-15	2.700E-15	2.797E-15	2.895E-15	2.994E-15	3.093E-15	3.193E-15	3.294E-15	
AC227	4.695E-13	6.923E-10	1.170E-09	1.236E-09	1.302E-09	1.371E-09	1.440E-09	1.510E-09	1.581E-09	
AC228	2.328E-16	1.326E-19	2.057E-19	2.151E-19	2.246E-19	2.340E-19	2.436E-19	2.531E-19	2.627E-19	
TH227	7.131E-16	1.607E-12	2.718E-12	2.874E-12	3.029E-12	3.188E-12	3.349E-12	3.512E-12	3.678E-12	
TH228	1.162E-10	1.994E-09	1.855E-09	1.837E-09	1.820E-09	1.803E-09	1.785E-09	1.768E-09	1.752E-09	
TH229	2.881E-11	5.316E-10	7.367E-10	7.631E-10	7.898E-10	8.167E-10	8.438E-10	8.711E-10	8.985E-10	
TH230	2.253E-06	1.322E-04	1.795E-04	1.854E-04	1.913E-04	1.972E-04	2.032E-04	2.091E-04	2.150E-04	
TH231	2.954E-09	6.677E-10	6.677E-10	6.677E-10	6.677E-10	6.677E-10	6.677E-10	6.677E-10	6.677E-10	
TH232	4.075E-08	4.454E-06	6.059E-06	6.259E-06	6.460E-06	6.661E-06	6.861E-06	7.062E-06	7.262E-06	
TH234	1.612E-10	1.632E-10	1.632E-10	1.632E-10	1.632E-10	1.632E-10	1.632E-10	1.632E-10	1.632E-10	
PA231	1.506E-07	3.650E-06	4.922E-06	5.081E-06	5.241E-06	5.400E-06	5.560E-06	5.719E-06	5.879E-06	
PA233	2.433E-09	4.646E-09	4.648E-09	4.648E-09	4.648E-09	4.649E-09	4.649E-09	4.649E-09	4.649E-09	
PA234M	6.434E-15	5.503E-15	5.503E-15	5.503E-15	5.503E-15	5.503E-15	5.503E-15	5.503E-15	5.503E-15	
PA234	3.468E-13	2.458E-15	2.458E-15	2.458E-15	2.458E-15	2.458E-15	2.458E-15	2.458E-15	2.458E-15	
U232	7.635E-08	7.465E-08	6.917E-08	6.851E-08	6.786E-08	6.721E-08	6.657E-08	6.593E-08	6.530E-08	
U233	4.845E-06	5.800E-06	6.149E-06	6.197E-06	6.245E-06	6.293E-06	6.341E-06	6.390E-06	6.438E-06	
U234	2.120E+00	2.121E+00	2.121E+00	2.121E+00	2.121E+00	2.121E+00	2.121E+00	2.121E+00	2.121E+00	
U235	1.642E+02	1.642E+02	1.642E+02	1.642E+02	1.642E+02	1.642E+02	1.642E+02	1.642E+02	1.642E+02	
U236	6.893E+00	6.893E+00	6.893E+00	6.893E+00	6.893E+00	6.893E+00	6.893E+00	6.893E+00	6.893E+00	
U237	1.823E-02	5.837E-11	3.971E-11	3.785E-11	3.607E-11	3.437E-11	3.276E-11	3.122E-11	2.975E-11	
U238	1.124E+01	1.124E+01	1.124E+01	1.124E+01	1.124E+01	1.124E+01	1.124E+01	1.124E+01	1.124E+01	
U240	4.704E-09	1.282E-20	1.282E-20	1.282E-20	1.282E-20	1.282E-20	1.282E-20	1.282E-20	1.282E-20	
NP235	6.061E-10	4.733E-16	2.846E-18	1.502E-18	7.926E-19	4.183E-19	2.207E-19	1.165E-19	6.144E-20	
NP236	2.843E-08	2.843E-08	2.843E-08	2.843E-08	2.843E-08	2.842E-08	2.842E-08	2.842E-08	2.842E-08	
NP237	1.185E-01	1.368E-01	1.368E-01	1.368E-01	1.369E-01	1.369E-01	1.369E-01	1.369E-01	1.369E-01	
NP238	3.306E-04	2.261E-14	2.180E-14	2.170E-14	2.160E-14	2.150E-14	2.140E-14	2.131E-14	2.121E-14	
NP239	7.530E-03	4.530E-12	4.527E-12	4.526E-12	4.526E-12	4.526E-12	4.525E-12	4.525E-12	4.524E-12	
NP240M	4.560E-09	1.122E-22	1.122E-22	1.122E-22	1.122E-22	1.122E-22	1.122E-22	1.122E-22	1.122E-22	
PU236	1.462E-08	7.193E-11	1.034E-11	8.122E-12	6.383E-12	5.019E-12	3.949E-12	3.111E-12	2.453E-12	
PU238	4.556E-03	4.108E-03	3.856E-03	3.826E-03	3.796E-03	3.766E-03	3.737E-03	3.707E-03	3.678E-03	
PU239	2.118E-01	2.192E-01	2.192E-01	2.192E-01	2.192E-01	2.192E-01	2.192E-01	2.192E-01	2.191E-01	
PU240	1.771E-02	1.767E-02	1.765E-02	1.765E-02	1.765E-02	1.765E-02	1.765E-02	1.764E-02	1.764E-02	
PU241	5.436E-03	1.885E-03	1.283E-03	1.222E-03	1.155E-03	1.110E-03	1.058E-03	1.008E-03	9.608E-04	
PU242	1.953E-04	1.953E-04	1.953E-04	1.953E-04	1.953E-04	1.953E-04	1.953E-04	1.953E-04	1.953E-04	

Attachment E: ORIGEN2 Output for Calculating the Radionuclide Inventory in Grams for a Pseudo MTR Element as a Function of Decay Time (Continued)

gm6.out ORIGEN2 V2.1 (8-1-91), Run on 06/04/97 at 15:30:33										
	3336.0HR	22.0YR	30.0YR	31.0YR	32.0YR	33.0YR	34.0YR	35.0YR	36.0YR	
PU243	6.004E-08	9.104E-25	9.104E-25	9.104E-25	9.104E-25	9.104E-25	9.104E-25	9.104E-25	9.104E-25	9.104E-25
PU244	6.704E-10	6.705E-10	6.705E-10	6.705E-10	6.705E-10	6.705E-10	6.705E-10	6.705E-10	6.705E-10	6.705E-10
PU246	1.525E-16	1.138E-34	1.138E-34	1.138E-34	1.138E-34	1.138E-34	1.138E-34	1.138E-34	1.138E-34	1.138E-34
AM241	2.400E-05	3.501E-03	4.055E-03	4.109E-03	4.160E-03	4.208E-03	4.253E-03	4.296E-03	4.336E-03	4.336E-03
AM242M	1.333E-07	1.206E-07	1.163E-07	1.157E-07	1.152E-07	1.147E-07	1.141E-07	1.136E-07	1.131E-07	1.131E-07
AM242	5.739E-08	1.442E-12	1.391E-12	1.384E-12	1.378E-12	1.372E-12	1.365E-12	1.359E-12	1.353E-12	1.353E-12
AM243	5.222E-06	5.272E-06	5.268E-06	5.267E-06	5.267E-06	5.266E-06	5.266E-06	5.265E-06	5.265E-06	5.265E-06
AM245	6.636E-15	4.079E-35	4.078E-35	4.079E-35	4.079E-35	4.079E-35	4.079E-35	4.079E-35	4.079E-35	4.079E-35
AM246	2.442E-19	1.820E-37	1.820E-37	1.820E-37	1.820E-37	1.820E-37	1.820E-37	1.820E-37	1.820E-37	1.820E-37
CM242	1.218E-06	2.916E-10	2.812E-10	2.802E-10	2.790E-10	2.777E-10	2.765E-10	2.752E-10	2.740E-10	2.740E-10
CM243	4.211E-09	2.466E-09	2.030E-09	1.981E-09	1.934E-09	1.887E-09	1.842E-09	1.797E-09	1.754E-09	1.754E-09
CM244	1.846E-07	7.971E-08	5.869E-08	5.648E-08	5.436E-08	5.232E-08	5.036E-08	4.846E-08	4.664E-08	4.664E-08
CM245	1.652E-09	1.649E-09	1.648E-09	1.648E-09	1.648E-09	1.647E-09	1.647E-09	1.647E-09	1.647E-09	1.647E-09
CM246	2.113E-11	2.107E-11	2.104E-11	2.104E-11	2.103E-11	2.103E-11	2.103E-11	2.103E-11	2.103E-11	2.103E-11
CM247	2.553E-14	2.553E-14	2.553E-14	2.553E-14	2.553E-14	2.553E-14	2.553E-14	2.553E-14	2.553E-14	2.553E-14
CM248	1.734E-16	1.734E-16	1.734E-16	1.734E-16	1.734E-16	1.734E-16	1.734E-16	1.734E-16	1.734E-16	1.734E-16
CM250	2.703E-28	2.703E-28	2.703E-28	2.703E-28	2.703E-28	2.703E-28	2.703E-28	2.703E-28	2.703E-28	2.703E-28
BK249	3.816E-19	1.061E-26	1.061E-26	1.061E-26	1.061E-26	1.061E-26	1.061E-26	1.061E-26	1.061E-26	1.061E-26
BK250	4.798E-22	7.973E-37	7.973E-37	7.973E-37	7.973E-37	7.973E-37	7.973E-37	7.973E-37	7.973E-37	7.973E-37
CF249	8.422E-21	3.765E-19	3.706E-19	3.699E-19	3.691E-19	3.684E-19	3.677E-19	3.669E-19	3.662E-19	3.662E-19
CF250	2.341E-20	7.459E-21	4.872E-21	4.614E-21	4.370E-21	4.138E-21	3.919E-21	3.711E-21	3.515E-21	3.515E-21
CF251	2.513E-21	2.470E-21	2.470E-21	2.470E-21	2.470E-21	2.470E-21	2.470E-21	2.470E-21	2.470E-21	2.470E-21
CF252	9.509E-23	1.459E-23	1.616E-23	1.616E-23	1.616E-23	1.616E-23	1.616E-23	1.616E-23	1.616E-23	1.616E-23
SF250	2.974E-14	3.999E-12	5.325E-12	5.488E-12	5.650E-12	5.812E-12	5.974E-12	6.134E-12	6.294E-12	6.294E-12
H 3	4.100E-05	1.193E-05	7.612E-06	7.197E-06	6.804E-06	6.432E-06	6.081E-06	5.749E-06	5.436E-06	5.436E-06
LI 6	3.238E-07	3.238E-07	3.238E-07	3.238E-07	3.238E-07	3.238E-07	3.238E-07	3.238E-07	3.238E-07	3.238E-07
LI 7	8.778E-09	8.778E-09	8.778E-09	8.778E-09	8.778E-09	8.778E-09	8.778E-09	8.778E-09	8.778E-09	8.778E-09
BE 9	1.692E-08	1.692E-08	1.692E-08	1.692E-08	1.692E-08	1.692E-08	1.692E-08	1.692E-08	1.692E-08	1.692E-08
BE 10	1.128E-07	1.128E-07	1.128E-07	1.128E-07	1.128E-07	1.128E-07	1.128E-07	1.128E-07	1.128E-07	1.128E-07
C 14	2.282E-08	2.276E-08	2.273E-08	2.273E-08	2.273E-08	2.273E-08	2.272E-08	2.272E-08	2.272E-08	2.272E-08
ZN 66	4.487E-11	4.487E-11	4.487E-11	4.487E-11	4.487E-11	4.487E-11	4.487E-11	4.487E-11	4.487E-11	4.487E-11
ZN 67	1.986E-12	1.986E-12	1.986E-12	1.986E-12	1.986E-12	1.986E-12	1.986E-12	1.986E-12	1.986E-12	1.986E-12
ZN 68	3.916E-15	3.916E-15	3.916E-15	3.916E-15	3.916E-15	3.916E-15	3.916E-15	3.916E-15	3.916E-15	3.916E-15
GA 69	8.088E-19	8.109E-19	8.109E-19	8.109E-19	8.109E-19	8.109E-19	8.109E-19	8.109E-19	8.109E-19	8.109E-19
GE 70	3.553E-22	3.556E-22	3.556E-22	3.556E-22	3.556E-22	3.556E-22	3.556E-22	3.556E-22	3.556E-22	3.556E-22
GA 71	5.136E-10	5.136E-10	5.136E-10	5.136E-10	5.136E-10	5.136E-10	5.136E-10	5.136E-10	5.136E-10	5.136E-10
GE 72	6.323E-06	6.489E-06	6.489E-06	6.489E-06	6.489E-06	6.489E-06	6.489E-06	6.489E-06	6.489E-06	6.489E-06
GE 73	2.262E-05	2.267E-05	2.267E-05	2.267E-05	2.267E-05	2.267E-05	2.267E-05	2.267E-05	2.267E-05	2.267E-05
GE 74	5.954E-05	5.955E-05	5.955E-05	5.955E-05	5.955E-05	5.955E-05	5.955E-05	5.955E-05	5.955E-05	5.955E-05
AS 75	1.456E-04	1.457E-04	1.457E-04	1.457E-04	1.457E-04	1.457E-04	1.457E-04	1.457E-04	1.457E-04	1.457E-04
GE 76	4.375E-04	4.375E-04	4.375E-04	4.375E-04	4.375E-04	4.375E-04	4.375E-04	4.375E-04	4.375E-04	4.375E-04
SE 76	6.144E-07	6.292E-07	6.292E-07	6.292E-07	6.292E-07	6.292E-07	6.292E-07	6.292E-07	6.292E-07	6.292E-07
SE 77	9.636E-04	9.814E-04	9.814E-04	9.814E-04	9.814E-04	9.814E-04	9.814E-04	9.814E-04	9.814E-04	9.814E-04
SE 78	2.033E-03	2.036E-03	2.036E-03	2.036E-03	2.036E-03	2.036E-03	2.036E-03	2.036E-03	2.036E-03	2.036E-03
SE 79	5.252E-03	5.251E-03	5.250E-03	5.250E-03	5.250E-03	5.250E-03	5.250E-03	5.250E-03	5.250E-03	5.250E-03
BR 79	1.093E-08	1.244E-06	1.692E-06	1.748E-06	1.804E-06	1.860E-06	1.916E-06	1.972E-06	2.028E-06	2.028E-06
SE 80	1.263E-02	1.263E-02	1.263E-02	1.263E-02	1.263E-02	1.263E-02	1.263E-02	1.263E-02	1.263E-02	1.263E-02
KR 80	6.242E-08	6.247E-08	6.247E-08	6.247E-08	6.247E-08	6.247E-08	6.247E-08	6.247E-08	6.247E-08	6.247E-08
BR 81	2.161E-02	2.162E-02	2.162E-02	2.162E-02	2.162E-02	2.162E-02	2.162E-02	2.162E-02	2.162E-02	2.162E-02
KR 81	5.783E-10	5.783E-10	5.783E-10	5.783E-10	5.783E-10	5.783E-10	5.783E-10	5.783E-10	5.783E-10	5.783E-10
SE 82	3.420E-02	3.420E-02	3.420E-02	3.420E-02	3.420E-02	3.420E-02	3.420E-02	3.420E-02	3.420E-02	3.420E-02
KR 82	8.338E-05	8.585E-05	8.585E-05	8.585E-05	8.585E-05	8.585E-05	8.585E-05	8.585E-05	8.585E-05	8.585E-05
KR 83	5.387E-02	5.397E-02	5.397E-02	5.397E-02	5.397E-02	5.397E-02	5.397E-02	5.397E-02	5.397E-02	5.397E-02
KR 84	1.106E-01	1.106E-01	1.106E-01	1.106E-01	1.106E-01	1.106E-01	1.106E-01	1.106E-01	1.106E-01	1.106E-01
KR 85	2.845E-02	6.873E-03	4.097E-03	3.841E-03	3.600E-03	3.375E-03	3.163E-03	2.965E-03	2.780E-03	2.780E-03
RB 85	1.071E-01	1.289E-01	1.317E-01	1.319E-01	1.322E-01	1.324E-01	1.326E-01	1.328E-01	1.330E-01	1.330E-01
KR 86	2.170E-01	2.170E-01	2.170E-01	2.170E-01	2.170E-01	2.170E-01	2.170E-01	2.170E-01	2.170E-01	2.170E-01
SR 86	3.972E-05	5.697E-05	5.697E-05	5.697E-05	5.697E-05	5.697E-05	5.697E-05	5.697E-05	5.697E-05	5.697E-05
RB 87	2.808E-01	2.809E-01	2.809E-01	2.809E-01	2.809E-01	2.809E-01	2.809E-01	2.809E-01	2.809E-01	2.809E-01
SR 87	4.039E-07	4.042E-07	4.042E-07	4.042E-07	4.042E-07	4.042E-07	4.042E-07	4.042E-07	4.042E-07	4.042E-07
SR 88	4.041E-01	4.046E-01	4.046E-01	4.046E-01	4.046E-01	4.046E-01	4.046E-01	4.046E-01	4.046E-01	4.046E-01
Y 89	2.962E-01	5.340E-01	5.340E-01	5.340E-01	5.340E-01	5.340E-01	5.340E-01	5.340E-01	5.340E-01	5.340E-01
SR 90	6.428E-01	3.808E-01	3.148E-01	3.074E-01	3.001E-01	2.931E-01	2.862E-01	2.795E-01	2.729E-01	2.729E-01
Y 90	1.618E-04	9.549E-05	7.894E-05	7.708E-05	7.527E-05	7.350E-05	7.177E-05	7.008E-05	6.843E-05	6.843E-05
ZR 90	3.811E-03	2.659E-01	3.320E-01	3.394E-01	3.466E-01	3.537E-01	3.606E-01	3.673E-01	3.739E-01	3.739E-01
ZR 91	3.394E-01	6.671E-01	6.671E-01	6.671E-01	6.671E-01	6.671E-01	6.671E-01	6.671E-01	6.671E-01	6.671E-01
ZR 92	6.906E-01	6.924E-01	6.924E-01	6.924E-01	6.924E-01	6.924E-01	6.924E-01	6.924E-01	6.924E-01	6.924E-01
ZR 93	7.486E-01	7.519E-01	7.519E-01	7.519E-01	7.519E-01	7.519E-01	7.519E-01	7.519E-01	7.519E-01	7.519E-01
NB 93	4.713E-09	3.261E-06	5.300E-06	5.573E-06	5.849E-06	6.129E-06	6.411E-06	6.697E-06	6.985E-06	6.985E-06
NB 93M	6.222E-08	4.301E-06	4.987E-06	5.055E-06	5.119E-06	5.180E-06	5.239E-06	5.294E-06	5.346E-06	5.346E-06
ZR 94	7.366E-01	7.367E-01	7.367E-01	7.367E-01	7.367E-01	7.367E-01	7.367E-01	7.367E-01	7.367E-01	7.367E-01
NB 94	1.051E-07	1.050E-07	1.050E-07	1.049E-07	1.049E-07	1.049E-07	1.049E-07	1.049E-07	1.049E-07	1.049E-07
MO 95	2.049E-01	7.624E-01	7.624E-01	7.624E-01	7.624E-01	7.624E-01	7.624E-01	7.624E-01	7.624E-01	7.624E-01

Attachment E: ORIGEN2 Output for Calculating the Radionuclide Inventory in Grams for a Pseudo MTR Element as a Function of Decay Time (Continued)

gm6.out ORIGEN2 V2.1 (8-1-91), Run on 06/04/97 at 15:30:33										
	3336.0HR	22.0YR	30.0YR	31.0YR	32.0YR	33.0YR	34.0YR	35.0YR	36.0YR	
ZR 96	7.578E-01	7.578E-01	7.578E-01	7.578E-01	7.578E-01	7.578E-01	7.578E-01	7.578E-01	7.578E-01	7.578E-01
MO 96	1.361E-03	1.367E-03	1.367E-03	1.367E-03	1.367E-03	1.367E-03	1.367E-03	1.367E-03	1.367E-03	1.367E-03
MO 97	7.095E-01	7.151E-01	7.151E-01	7.151E-01	7.151E-01	7.151E-01	7.151E-01	7.151E-01	7.151E-01	7.151E-01
MO 98	7.193E-01	7.193E-01	7.193E-01	7.193E-01	7.193E-01	7.193E-01	7.193E-01	7.193E-01	7.193E-01	7.193E-01
TC 98	6.650E-07	6.649E-07	6.649E-07	6.649E-07	6.649E-07	6.649E-07	6.649E-07	6.649E-07	6.649E-07	6.649E-07
TC 99	7.123E-01	7.352E-01	7.351E-01	7.351E-01	7.351E-01	7.351E-01	7.351E-01	7.351E-01	7.351E-01	7.351E-01
RU 99	4.389E-07	5.307E-05	7.221E-05	7.460E-05	7.699E-05	7.938E-05	8.178E-05	8.417E-05	8.656E-05	8.656E-05
MO100	7.895E-01	7.895E-01	7.895E-01	7.895E-01	7.895E-01	7.895E-01	7.895E-01	7.895E-01	7.895E-01	7.895E-01
RU100	1.530E-02	1.530E-02	1.530E-02	1.530E-02	1.530E-02	1.530E-02	1.530E-02	1.530E-02	1.530E-02	1.530E-02
RU101	6.406E-01	6.407E-01	6.407E-01	6.407E-01	6.407E-01	6.407E-01	6.407E-01	6.407E-01	6.407E-01	6.407E-01
RU102	5.458E-01	5.459E-01	5.459E-01	5.459E-01	5.459E-01	5.459E-01	5.459E-01	5.459E-01	5.459E-01	5.459E-01
RH102	6.610E-08	3.440E-10	5.083E-11	4.002E-11	3.151E-11	2.481E-11	1.954E-11	1.538E-11	1.211E-11	1.211E-11
RH103	2.412E-01	3.927E-01	3.927E-01	3.927E-01	3.927E-01	3.927E-01	3.927E-01	3.927E-01	3.927E-01	3.927E-01
RU104	2.483E-01	2.483E-01	2.483E-01	2.483E-01	2.483E-01	2.483E-01	2.483E-01	2.483E-01	2.483E-01	2.483E-01
PD104	1.463E-02	1.463E-02	1.463E-02	1.463E-02	1.463E-02	1.463E-02	1.463E-02	1.463E-02	1.463E-02	1.463E-02
PD105	1.281E-01	1.303E-01	1.303E-01	1.303E-01	1.303E-01	1.303E-01	1.303E-01	1.303E-01	1.303E-01	1.303E-01
RU106	4.953E-02	1.333E-08	5.438E-11	2.734E-11	1.374E-11	6.910E-12	3.474E-12	1.747E-12	8.781E-13	8.781E-13
RH106	6.393E-08	1.253E-14	5.114E-17	2.570E-17	1.292E-17	6.495E-18	3.266E-18	1.642E-18	8.254E-19	8.254E-19
PD106	1.428E-02	6.382E-02	6.382E-02	6.382E-02	6.382E-02	6.382E-02	6.382E-02	6.382E-02	6.382E-02	6.382E-02
PD107	2.639E-02	2.640E-02	2.640E-02	2.640E-02	2.640E-02	2.640E-02	2.640E-02	2.640E-02	2.640E-02	2.640E-02
AG107	5.299E-10	6.249E-08	8.503E-08	8.784E-08	9.066E-08	9.347E-08	9.629E-08	9.911E-08	1.019E-07	1.019E-07
PD108	1.282E-02	1.282E-02	1.282E-02	1.282E-02	1.282E-02	1.282E-02	1.282E-02	1.282E-02	1.282E-02	1.282E-02
AG108	1.666E-13	1.464E-20	1.401E-20	1.393E-20	1.386E-20	1.378E-20	1.371E-20	1.363E-20	1.356E-20	1.356E-20
AG108M	5.226E-12	4.635E-12	4.437E-12	4.413E-12	4.389E-12	4.365E-12	4.341E-12	4.318E-12	4.294E-12	4.294E-12
CD108	4.509E-09	4.509E-09	4.509E-09	4.509E-09	4.509E-09	4.509E-09	4.509E-09	4.509E-09	4.509E-09	4.509E-09
AG109	5.992E-03	6.033E-03	6.033E-03	6.033E-03	6.033E-03	6.033E-03	6.033E-03	6.033E-03	6.033E-03	6.033E-03
AG109M	3.329E-08	7.808E-24	9.928E-26	5.753E-26	3.334E-26	1.932E-26	1.120E-26	6.494E-27	3.766E-27	3.766E-27
CD109	1.291E-12	7.904E-18	1.005E-19	5.824E-20	3.375E-20	1.955E-20	1.134E-20	6.575E-21	3.812E-21	3.812E-21
PD110	4.627E-03	4.627E-03	4.627E-03	4.627E-03	4.627E-03	4.627E-03	4.627E-03	4.627E-03	4.627E-03	4.627E-03
AG110	3.164E-09	7.484E-23	2.260E-26	8.205E-27	2.979E-27	1.082E-27	3.927E-28	1.426E-28	5.181E-29	5.181E-29
AG110M	2.365E-05	4.939E-15	1.491E-18	5.414E-19	1.966E-19	7.137E-20	2.591E-20	9.412E-21	3.419E-21	3.419E-21
CD110	5.074E-04	5.310E-04	5.310E-04	5.310E-04	5.310E-04	5.310E-04	5.310E-04	5.310E-04	5.310E-04	5.310E-04
CD111	3.420E-03	3.710E-03	3.710E-03	3.710E-03	3.710E-03	3.710E-03	3.710E-03	3.710E-03	3.710E-03	3.710E-03
CD112	2.711E-03	2.738E-03	2.738E-03	2.738E-03	2.738E-03	2.738E-03	2.738E-03	2.738E-03	2.738E-03	2.738E-03
CD113	2.130E-04	2.184E-04	2.184E-04	2.184E-04	2.184E-04	2.184E-04	2.184E-04	2.184E-04	2.184E-04	2.184E-04
CD113M	5.224E-05	1.839E-05	1.258E-05	1.199E-05	1.144E-05	1.091E-05	1.040E-05	9.918E-06	9.458E-06	9.458E-06
IN113	4.660E-07	3.435E-05	4.016E-05	4.074E-05	4.130E-05	4.183E-05	4.234E-05	4.282E-05	4.328E-05	4.328E-05
CD114	4.871E-03	4.871E-03	4.871E-03	4.871E-03	4.871E-03	4.871E-03	4.871E-03	4.871E-03	4.871E-03	4.871E-03
SN114	3.050E-09	4.198E-09	4.198E-09	4.198E-09	4.198E-09	4.198E-09	4.198E-09	4.198E-09	4.198E-09	4.198E-09
IN115	1.768E-03	1.905E-03	1.905E-03	1.905E-03	1.905E-03	1.905E-03	1.905E-03	1.905E-03	1.905E-03	1.905E-03
SN115	7.652E-05	7.849E-05	7.849E-05	7.849E-05	7.849E-05	7.849E-05	7.849E-05	7.849E-05	7.849E-05	7.849E-05
CD116	2.463E-03	2.463E-03	2.463E-03	2.463E-03	2.463E-03	2.463E-03	2.463E-03	2.463E-03	2.463E-03	2.463E-03
SN116	3.659E-04	3.661E-04	3.661E-04	3.661E-04	3.661E-04	3.661E-04	3.661E-04	3.661E-04	3.661E-04	3.661E-04
SN117	2.418E-03	2.423E-03	2.423E-03	2.423E-03	2.423E-03	2.423E-03	2.423E-03	2.423E-03	2.423E-03	2.423E-03
SN118	2.695E-03	2.696E-03	2.696E-03	2.696E-03	2.696E-03	2.696E-03	2.696E-03	2.696E-03	2.696E-03	2.696E-03
SN119	2.550E-03	2.582E-03	2.582E-03	2.582E-03	2.582E-03	2.582E-03	2.582E-03	2.582E-03	2.582E-03	2.582E-03
SN119M	3.124E-05	4.193E-15	1.078E-18	3.836E-19	1.365E-19	4.857E-20	1.728E-20	6.154E-21	2.181E-21	2.181E-21
SN120	2.703E-03	2.703E-03	2.703E-03	2.703E-03	2.703E-03	2.703E-03	2.703E-03	2.703E-03	2.703E-03	2.703E-03
SN121M	1.339E-06	9.871E-07	8.835E-07	8.713E-07	8.593E-07	8.474E-07	8.358E-07	8.243E-07	8.129E-07	8.129E-07
SB121	2.804E-03	2.837E-03	2.837E-03	2.838E-03	2.838E-03	2.838E-03	2.838E-03	2.838E-03	2.838E-03	2.838E-03
SN122	3.032E-03	3.032E-03	3.032E-03	3.032E-03	3.032E-03	3.032E-03	3.032E-03	3.032E-03	3.032E-03	3.032E-03
TE122	2.702E-05	2.865E-05	2.865E-05	2.865E-05	2.865E-05	2.865E-05	2.865E-05	2.865E-05	2.865E-05	2.865E-05
SN123	6.188E-04	1.160E-22	1.797E-29	1.797E-29	1.797E-29	1.797E-29	1.797E-29	1.797E-29	1.797E-29	1.797E-29
SB123	2.985E-03	3.605E-03	3.605E-03	3.605E-03	3.605E-03	3.605E-03	3.605E-03	3.605E-03	3.605E-03	3.605E-03
TE123	5.698E-08	7.563E-08	7.563E-08	7.563E-08	7.563E-08	7.563E-08	7.563E-08	7.563E-08	7.563E-08	7.563E-08
TE123M	1.865E-08	1.144E-28	5.111E-36	5.111E-36	5.111E-36	5.111E-36	5.111E-36	5.111E-36	5.111E-36	5.111E-36
SN124	4.754E-03	4.754E-03	4.754E-03	4.754E-03	4.754E-03	4.754E-03	4.754E-03	4.754E-03	4.754E-03	4.754E-03
TE124	1.114E-05	2.966E-05	2.966E-05	2.966E-05	2.966E-05	2.966E-05	2.966E-05	2.966E-05	2.966E-05	2.966E-05
SB125	5.742E-03	2.434E-05	3.288E-06	2.560E-06	1.993E-06	1.552E-06	1.208E-06	9.408E-07	7.325E-07	7.325E-07
TE125	2.303E-04	6.231E-03	6.253E-03	6.253E-03	6.254E-03	6.254E-03	6.255E-03	6.255E-03	6.255E-03	6.255E-03
TE125M	3.848E-05	3.405E-07	4.599E-08	3.580E-08	2.788E-08	2.171E-08	1.690E-08	1.316E-08	1.025E-08	1.025E-08
SN126	1.147E-02	1.147E-02	1.147E-02	1.146E-02	1.146E-02	1.146E-02	1.146E-02	1.146E-02	1.146E-02	1.146E-02
SB126	2.234E-05	5.447E-10	5.447E-10	5.447E-10	5.447E-10	5.447E-10	5.447E-10	5.447E-10	5.447E-10	5.447E-10
SB126M	1.115E-08	4.142E-12	4.141E-12	4.141E-12	4.141E-12	4.141E-12	4.141E-12	4.141E-12	4.141E-12	4.141E-12
TE126	2.170E-04	2.411E-04	2.417E-04	2.418E-04	2.419E-04	2.420E-04	2.421E-04	2.421E-04	2.422E-04	2.422E-04
I127	2.231E-02	2.571E-02	2.571E-02	2.571E-02	2.571E-02	2.571E-02	2.571E-02	2.571E-02	2.571E-02	2.571E-02
TE128	6.415E-02	6.419E-02	6.419E-02	6.419E-02	6.419E-02	6.419E-02	6.419E-02	6.419E-02	6.419E-02	6.419E-02
XE128	1.848E-04	1.849E-04	1.849E-04	1.849E-04	1.849E-04	1.849E-04	1.849E-04	1.849E-04	1.849E-04	1.849E-04
I129	1.097E-01	1.154E-01	1.154E-01	1.154E-01	1.154E-01	1.154E-01	1.154E-01	1.154E-01	1.154E-01	1.154E-01
XE129	1.802E-06	1.943E-06	1.984E-06	1.989E-06	1.994E-06	1.999E-06	2.004E-06	2.009E-06	2.014E-06	2.014E-06
TE130	2.465E-01	2.466E-01	2.466E-01	2.466E-01	2.466E-01	2.466E-01	2.466E-01	2.466E-01	2.466E-01	2.466E-01
XE130	6.580E-04	6.649E-04	6.649E-04	6.649E-04	6.649E-04	6.649E-04	6.649E-04	6.649E-04	6.649E-04	6.649E-04
XE131	4.117E-01	4.524E-01	4.524E-01	4.524E-01	4.524E-01	4.524E-01	4.524E-01	4.524E-01	4.524E-01	4.524E-01
XE132	7.123E-01	7.368E-01	7.368E-01	7.368E-01	7.368E-01	7.368E-01	7.368E-01	7.368E-01	7.368E-01	7.368E-01

Attachment E: ORIGEN2 Output for Calculating the Radionuclide Inventory in Grams for a Pseudo MTR Element as a Function of Decay Time (Continued)

gm6.out
ORIGEN2 V2.1 (8-1-91), Run on 06/04/97 at 15:30:33

	3336.0HR	22.0YR	30.0YR	31.0YR	32.0YR	33.0YR	34.0YR	35.0YR	36.0YR
BA132	2.023E-08	2.345E-08	2.345E-08	2.345E-08	2.345E-08	2.345E-08	2.345E-08	2.345E-08	2.345E-08
CS133	1.040E+00	1.109E+00	1.109E+00	1.109E+00	1.109E+00	1.109E+00	1.109E+00	1.109E+00	1.109E+00
XE134	1.295E+00	1.295E+00	1.295E+00	1.295E+00	1.295E+00	1.295E+00	1.295E+00	1.295E+00	1.295E+00
CS134	2.206E-02	1.355E-05	9.202E-07	6.575E-07	4.698E-07	3.357E-07	2.398E-07	1.714E-07	1.224E-07
BA134	8.820E-04	2.293E-02	2.295E-02	2.295E-02	2.295E-02	2.295E-02	2.295E-02	2.295E-02	2.295E-02
CS135	2.723E-01	2.764E-01	2.764E-01	2.764E-01	2.764E-01	2.764E-01	2.764E-01	2.764E-01	2.764E-01
BA135	8.349E-07	2.670E-06	3.337E-06	3.420E-06	3.503E-06	3.586E-06	3.670E-06	3.753E-06	3.836E-06
XE136	1.934E+00	1.934E+00	1.934E+00	1.934E+00	1.934E+00	1.934E+00	1.934E+00	1.934E+00	1.934E+00
BA136	1.826E-03	2.231E-03	2.231E-03	2.231E-03	2.231E-03	2.231E-03	2.231E-03	2.231E-03	2.231E-03
CS137	1.047E+00	6.296E-01	5.234E-01	5.114E-01	4.997E-01	4.883E-01	4.772E-01	4.663E-01	4.556E-01
BA137	4.704E-03	4.218E-01	5.281E-01	5.400E-01	5.517E-01	5.631E-01	5.743E-01	5.852E-01	5.958E-01
BA137M	1.610E-07	9.632E-08	8.007E-08	7.824E-08	7.645E-08	7.471E-08	7.300E-08	7.133E-08	6.970E-08
BA138	1.177E+00	1.177E+00	1.177E+00	1.177E+00	1.177E+00	1.177E+00	1.177E+00	1.177E+00	1.177E+00
LA138	9.562E-06	9.562E-06	9.562E-06	9.562E-06	9.562E-06	9.562E-06	9.562E-06	9.562E-06	9.562E-06
LA139	1.123E+00	1.123E+00	1.123E+00	1.123E+00	1.123E+00	1.123E+00	1.123E+00	1.123E+00	1.123E+00
CE140	9.563E-01	1.119E+00	1.119E+00	1.119E+00	1.119E+00	1.119E+00	1.119E+00	1.119E+00	1.119E+00
PR141	7.067E-01	1.039E+00	1.039E+00	1.039E+00	1.039E+00	1.039E+00	1.039E+00	1.039E+00	1.039E+00
CE142	1.049E+00	1.049E+00	1.049E+00	1.049E+00	1.049E+00	1.049E+00	1.049E+00	1.049E+00	1.049E+00
ND142	1.509E-03	1.542E-03	1.542E-03	1.542E-03	1.542E-03	1.542E-03	1.542E-03	1.542E-03	1.542E-03
ND143	8.638E-01	1.023E+00	1.023E+00	1.023E+00	1.023E+00	1.023E+00	1.023E+00	1.023E+00	1.023E+00
CE144	8.288E-01	2.564E-09	2.063E-12	8.466E-13	3.474E-13	1.426E-13	5.852E-14	2.402E-14	9.856E-15
PR144	3.586E-05	1.083E-13	8.711E-17	3.575E-17	1.467E-17	6.021E-18	2.471E-18	1.014E-18	4.162E-19
PR144M	1.753E-07	5.412E-16	4.354E-19	1.787E-19	7.334E-20	3.010E-20	1.235E-20	5.069E-21	2.080E-21
ND144	1.932E-01	1.022E+00	1.022E+00	1.022E+00	1.022E+00	1.022E+00	1.022E+00	1.022E+00	1.022E+00
ND145	6.966E-01	6.985E-01	6.985E-01	6.985E-01	6.985E-01	6.985E-01	6.985E-01	6.985E-01	6.985E-01
ND146	5.570E-01	5.572E-01	5.572E-01	5.572E-01	5.572E-01	5.572E-01	5.572E-01	5.572E-01	5.572E-01
PM146	1.383E-06	8.641E-08	3.153E-08	2.780E-08	2.451E-08	2.160E-08	1.905E-08	1.679E-08	1.480E-08
SM146	1.098E-07	5.894E-07	6.097E-07	6.111E-07	6.123E-07	6.134E-07	6.143E-07	6.152E-07	6.159E-07
PM147	3.119E-01	1.077E-03	1.300E-04	9.984E-05	7.666E-05	5.886E-05	4.519E-05	3.470E-05	2.664E-05
SM147	1.455E-02	3.734E-01	3.743E-01	3.744E-01	3.744E-01	3.744E-01	3.744E-01	3.744E-01	3.745E-01
ND148	3.166E-01	3.166E-01	3.166E-01	3.166E-01	3.166E-01	3.166E-01	3.166E-01	3.166E-01	3.166E-01
SM148	2.439E-02	2.982E-02	2.982E-02	2.982E-02	2.982E-02	2.982E-02	2.982E-02	2.982E-02	2.982E-02
SM149	1.000E-02	1.554E-02	1.554E-02	1.554E-02	1.554E-02	1.554E-02	1.554E-02	1.554E-02	1.554E-02
ND150	1.223E-01	1.223E-01	1.223E-01	1.223E-01	1.223E-01	1.223E-01	1.223E-01	1.223E-01	1.223E-01
SM150	2.055E-01	2.055E-01	2.055E-01	2.055E-01	2.055E-01	2.055E-01	2.055E-01	2.055E-01	2.055E-01
EU150	5.133E-11	3.361E-11	2.881E-11	2.826E-11	2.772E-11	2.719E-11	2.667E-11	2.617E-11	2.567E-11
SM151	2.788E-02	2.436E-02	2.291E-02	2.273E-02	2.256E-02	2.238E-02	2.221E-02	2.204E-02	2.187E-02
EU151	2.711E-05	4.526E-03	5.981E-03	6.157E-03	6.332E-03	6.505E-03	6.676E-03	6.847E-03	7.016E-03
SM152	9.239E-02	9.241E-02	9.241E-02	9.241E-02	9.241E-02	9.241E-02	9.241E-02	9.241E-02	9.241E-02
EU152	2.268E-05	7.391E-06	4.916E-06	4.672E-06	4.400E-06	4.219E-06	4.009E-06	3.810E-06	3.621E-06
GD152	6.926E-06	1.125E-05	1.194E-05	1.201E-05	1.207E-05	1.214E-05	1.219E-05	1.225E-05	1.230E-05
EU153	4.183E-02	4.320E-02	4.320E-02	4.320E-02	4.320E-02	4.320E-02	4.320E-02	4.320E-02	4.320E-02
GD153	1.307E-06	1.322E-16	3.067E-20	1.078E-20	3.791E-21	1.326E-21	4.774E-22	1.720E-22	5.335E-23
SM154	1.514E-02	1.514E-02	1.514E-02	1.514E-02	1.514E-02	1.514E-02	1.514E-02	1.514E-02	1.514E-02
EU154	4.324E-03	7.342E-04	3.853E-04	3.555E-04	3.279E-04	3.025E-04	2.791E-04	2.575E-04	2.376E-04
GD154	4.121E-05	3.631E-03	3.980E-03	4.010E-03	4.037E-03	4.063E-03	4.086E-03	4.108E-03	4.128E-03
EU155	4.472E-03	2.066E-04	6.755E-05	5.874E-05	5.107E-05	4.441E-05	3.862E-05	3.358E-05	2.920E-05
GD155	2.082E-05	4.288E-03	4.427E-03	4.436E-03	4.443E-03	4.450E-03	4.456E-03	4.461E-03	4.465E-03
GD156	4.911E-03	6.162E-03	6.162E-03	6.162E-03	6.162E-03	6.162E-03	6.162E-03	6.162E-03	6.162E-03
GD157	3.933E-05	5.183E-05	5.183E-05	5.183E-05	5.183E-05	5.183E-05	5.183E-05	5.183E-05	5.183E-05
GD158	2.523E-03	2.524E-03	2.524E-03	2.524E-03	2.524E-03	2.524E-03	2.524E-03	2.524E-03	2.524E-03
TB159	2.709E-04	2.734E-04	2.734E-04	2.734E-04	2.734E-04	2.734E-04	2.734E-04	2.734E-04	2.734E-04
GD160	1.090E-04	1.090E-04	1.090E-04	1.090E-04	1.090E-04	1.090E-04	1.090E-04	1.090E-04	1.090E-04
DY160	2.146E-06	6.898E-06	6.898E-06	6.898E-06	6.898E-06	6.898E-06	6.898E-06	6.898E-06	6.898E-06
DY161	2.576E-05	2.815E-05	2.815E-05	2.815E-05	2.815E-05	2.815E-05	2.815E-05	2.815E-05	2.815E-05
DY162	1.577E-05	1.577E-05	1.577E-05	1.577E-05	1.577E-05	1.577E-05	1.577E-05	1.577E-05	1.577E-05
DY163	6.842E-06	6.842E-06	6.842E-06	6.842E-06	6.842E-06	6.842E-06	6.842E-06	6.842E-06	6.842E-06
DY164	1.944E-06	1.944E-06	1.944E-06	1.944E-06	1.944E-06	1.944E-06	1.944E-06	1.944E-06	1.944E-06
HO165	1.509E-06	1.512E-06	1.512E-06	1.512E-06	1.512E-06	1.512E-06	1.512E-06	1.512E-06	1.512E-06
HO166M	3.506E-09	3.462E-09	3.446E-09	3.444E-09	3.442E-09	3.440E-09	3.438E-09	3.436E-09	3.434E-09
ER166	5.444E-07	5.712E-07	5.713E-07	5.713E-07	5.713E-07	5.713E-07	5.713E-07	5.713E-07	5.713E-07
ER167	2.023E-07	2.023E-07	2.023E-07	2.023E-07	2.023E-07	2.023E-07	2.023E-07	2.023E-07	2.023E-07
ER168	8.774E-08	8.774E-08	8.774E-08	8.774E-08	8.774E-08	8.774E-08	8.774E-08	8.774E-08	8.774E-08
TM169	8.453E-11	1.133E-10	1.133E-10	1.133E-10	1.133E-10	1.133E-10	1.133E-10	1.133E-10	1.133E-10
ER170	6.625E-16	5.429E-15	5.429E-15	5.429E-15	5.429E-15	5.429E-15	5.429E-15	5.429E-15	5.429E-15
TM170	3.264E-12	5.039E-31	7.275E-38	7.275E-38	7.275E-38	7.275E-38	7.275E-38	7.275E-38	7.275E-38
YB170	4.512E-13	3.711E-12	3.711E-12	3.711E-12	3.711E-12	3.711E-12	3.711E-12	3.711E-12	3.711E-12
TM171	4.258E-14	1.513E-17	8.424E-19	5.872E-19	4.092E-19	2.852E-19	1.988E-19	1.386E-19	9.658E-20
YB171	3.090E-15	4.565E-14	4.567E-14	4.567E-14	4.567E-14	4.567E-14	4.567E-14	4.567E-14	4.567E-14
YB172	9.393E-17	1.071E-16	1.071E-16	1.071E-16	1.071E-16	1.071E-16	1.071E-16	1.071E-16	1.071E-16

Attachment F

Attachment F: Source Listing and Output for FORTRAN Program REDUCES

```

PROGRAM REDUCES
C
C----- WRITTEN BY D.R. WENZEL
C
C           To help evaluate correction factors for actinides
C
CHARACTER * 1 ORGLINE1(111), ORGLINE2(111)
CHARACTER * 9 RUN
CHARACTER * 12 DESC1, DESC2
CHARACTER * 111 BUFFER1, BUFFER2
REAL      * 4 VALUE1(9), VALUE2(9)
REAL      * 4 AL1(9), AL2(9)
REAL      * 4 RED1(9), RED2(9)
C
C-----Following data statements assume fuel 2 years old when
C           processed
C
C           AGE OF MTR FUEL      1      2      3      4      5      6      7      8
C           PROCESSING YEAR      86      85      84      83      82      81      80
C
C           AGE OF MTR FUEL           9      10      11      12      13      14      15
C           PROCESSING YEAR          79      78      77      76      75      74      73
C
C           AGE OF FUEL             16      17      18      19      20      21      22
C           PROCESSING YEAR          72      71      70      69      68      67      66
C
C           AGE OF FUEL             23      24      25      26      27      28      29
C           PROCESSING YEAR          65      64      63      62      61      60      59
C           DATA AL1 /0., 0., 0., 0., 795., 0., 45., 420., 91./
C           DATA RED1 /1., 1., 1., 1., 1., 1., 1., 1., 1./
C
C           AGE OF FUEL             30      31      32      33      34      35      36
C           PROCESSING YEAR          58      57      56      55      54      53      52
C           DATA AL2 /0., 0., 292., 505., 712., 1064., 0., 333., 0./
C           DATA AL2 /0., 0., 292., 0., 0., 0., 0., 0., 0./
C           DATA RED2 /1., 1., 1., 1., 1., 1., 1., 1., 1./
C
C----- DETERMINE RUN NAME
C
C           CALL GETCL(RUN)
C
C----- OPEN INPUT AND OUTPUT FILES
C
C           OPEN(1,FILE ='GM5.OUT', STATUS='OLD',FORM='FORMATTED',
+             ERR = 900)
C           OPEN(2,FILE ='GM6.OUT', STATUS='OLD',FORM='FORMATTED',
+             ERR = 900)
C           OPEN(6,FILE ='REDUCES.OUT', STATUS='UNKNOWN', ERR = 920)
C
C           PRINT *, 'Working -- have patience.'
C
C----- Normalize to Berreth's Cs-137 data in WINCO-1050
C
C           CORMTR = 22.17
C
C----- Normalize to Staples average Cs-137 measurement of

```

Attachment F: Source Listing and Output for FORTRAN Program REDUCES (Continued)

```

C          69 micro grams/gram
C
C          STAPLES = 3.0063E-3
C          WRITE(6,600) RUN
C 600      FORMAT(A9)
C
C----- READ PAST FIRST LINE
C
C          READ(1,300) ORGLINE1
C          READ(2,300) ORGLINE2
C 300      FORMAT(111A1)
C
C----- READ PAST SECOND LINE
C
C          READ(1,300) ORGLINE1
C          READ(2,300) ORGLINE2
C
C----- READ PAST THIRD LINE
C
C          READ(1,300) ORGLINE1
C          READ(2,300) ORGLINE2
C
C----- START DATA SUMMATION PROCESS
C
C 40      READ(1,300,END=999) ORGLINE1
C          READ(2,300,END=999) ORGLINE2
C          WRITE(BUFFER1,300) ORGLINE1
C          WRITE(BUFFER2,300) ORGLINE2
C          READ(BUFFER1,400) DESC1, (VALUE1(I),I=1,9)
C 400      FORMAT(A12,9X,9(1X,E9.4))
C          READ(BUFFER2,400) DESC2, (VALUE2(I),I=1,9)
C
C----- CHECK TO BE SURE LISTS ARE IN THE SAME ORDER
C
C          NUM = 2
C          IF(DESC2 .NE. DESC1) GO TO 930
C          SUM = 0.
C          DO 45, J=1,7
C              K = 10 - J
C              SUM = SUM * RED2(K)
C              SUM = SUM + VALUE2(K) * AL2(K) * CORMTR * STAPLES
C 45      CONTINUE
C
C          DO 46, J=1,7
C              K = 10 - J
C              SUM = SUM * RED1(K)
C              SUM = SUM + VALUE1(K) * AL1(K) * CORMTR * STAPLES
C 46      CONTINUE
C
C          WRITE(6,401) DESC1,SUM
C 401      FORMAT(A12,1PE10.3)
C          GO TO 40
C
C----- ERROR STATEMENTS
C

```

**Attachment F: Source Listing and Output for FORTRAN Program REDUCES
(Continued)**

```
900  WRITE(6,9000) 9000  FORMAT(2X,'ERROR IN OPENING FILE ')
      GO TO 999
C
920  WRITE(6,9020)
9020  FORMAT(2X,'ERROR IN OPENING FILE 6')
      GO TO 999
C
930  WRITE(6,9030) DESC1,DESC2,NUM
9030  FORMAT(2X,2(2X,A2),5X,I1)
940  WRITE(6,9040)
9040  FORMAT(2X,'ERROR DETECTED IN THE ORDER OF THE RADIONUCLIDES')
C
C----- PROGRAM END
C
999  CONTINUE
      END
```

**Attachment F: Source Listing and Output for FORTRAN Program REDUCES
(Continued)**

Nuclide	gram	Nuclide	gram	Nuclide	gram
HE 4	2.587E-03	U232	7.308E-06	GA 69	8.388E-17
TL206	2.948E-31	U233	6.282E-04	GE 70	3.678E-20
TL207	4.057E-14	U234	2.194E+02	GA 71	5.313E-08
TL208	1.966E-13	U235	1.698E+04	GE 72	6.712E-04
TL209	7.903E-19	U236	7.130E+02	GE 73	2.345E-03
PB206	1.468E-09	U237	4.585E-09	GE 74	6.160E-03
PB207	3.203E-08	U238	1.163E+03	AS 75	1.507E-02
PB208	1.792E-06	U240	1.326E-18	GE 76	4.526E-02
PB209	3.293E-15	NP235	2.155E-15	SE 76	6.508E-05
PB210	6.671E-09	NP236	2.941E-06	SE 77	1.015E-01
PB211	3.138E-13	NP237	1.415E+01	SE 78	2.106E-01
PB212	1.160E-10	NP238	2.278E-12	SE 79	5.431E-01
PB214	6.483E-14	NP239	4.684E-10	BR 79	1.623E-04
BI208	2.049E-20	NP240M	1.161E-20	SE 80	1.306E+00
BI209	8.512E-11	PU236	2.020E-09	KR 80	6.462E-06
BI210M	1.137E-19	PU238	4.059E-01	BR 81	2.236E+00
BI210	4.107E-12	PU239	2.267E+01	KR 81	5.982E-08
BI211	1.852E-14	PU240	1.827E+00	SE 82	3.538E+00
BI212	1.100E-11	PU241	1.481E-01	KR 82	8.880E-03
BI213	7.737E-16	PU242	2.020E-02	KR 83	5.583E+00
BI214	4.814E-14	PU243	9.417E-23	KR 84	1.144E+01
PO210	1.064E-10	PU244	6.936E-08	KR 85	4.922E-01
PO211	2.271E-19	PU246	1.177E-32	RB 85	1.355E+01
PO212	5.820E-22	AM241	4.055E-01	KR 86	2.245E+01
PO213	1.160E-24	AM242M	1.215E-05	SR 86	5.893E-03
PO214	6.623E-21	AM242	1.453E-10	RB 87	2.906E+01
PO215	2.628E-19	AM243	5.450E-04	SR 87	4.181E-05
PO216	4.628E-16	AM245	4.219E-33	SR 88	4.185E+01
PO218	7.518E-15	AM246	1.883E-35	Y 89	5.524E+01
AT217	9.296E-21	CM242	2.942E-08	SR 90	3.434E+01
RN219	5.955E-16	CM243	2.217E-07	Y 90	8.612E-03
RN220	1.747E-13	CM244	6.620E-06	ZR 90	3.256E+01
RN222	1.382E-11	CM245	1.705E-07	ZR 91	6.901E+01
FR221	8.441E-17	CM246	2.177E-09	ZR 92	7.162E+01
FR223	2.758E-15	CM247	2.641E-12	ZR 93	7.778E+01
RA223	1.513E-10	CM248	1.794E-14	NB 93	4.885E-04
RA224	1.012E-09	CM250	2.796E-26	NB 93M	4.984E-04
RA225	3.817E-13	BK249	1.098E-24	ZR 94	7.620E+01
RA226	2.150E-06	BK250	8.247E-35	NB 94	1.086E-05
RA228	1.837E-13	CF249	3.850E-17	MO 95	7.886E+01
AC225	2.578E-13	CF250	5.664E-19	ZR 96	7.839E+01
AC227	1.069E-07	CF251	2.555E-19	MO 96	1.414E-01
AC228	1.918E-17	CF252	1.540E-21	MO 97	7.397E+01
TH227	2.486E-10	SF250	5.136E-10	MO 98	7.440E+01
TH228	1.958E-07		0.000E+00	TC 98	6.878E-05
TH229	7.033E-08	H 3	8.959E-04	TC 99	7.604E+01
TH230	1.723E-02	LI 6	3.349E-05	RU 99	6.928E-03
TH231	6.907E-08	LI 7	9.080E-07	MO100	8.167E+01
TH232	5.813E-04	BE 9	1.750E-06	RU100	1.583E+00
TH234	1.688E-08	BE 10	1.167E-05	RU101	6.627E+01
PA231	4.734E-04	C 14	2.353E-06	RU102	5.647E+01
PA233	4.807E-07	ZN 66	4.641E-09	RH102	9.836E-09
PA234M	5.692E-13	ZN 67	2.054E-10	RH103	4.062E+01
PA234	2.543E-13	ZN 68	4.051E-13	RU104	2.568E+01

**Attachment F: Source Listing and Output for FORTRAN Program REDUCES
(Continued)**

Nuclide	gram	Nuclide	gram	Nuclide	gram
PD104	1.513E+00	I129	1.194E+01	GD156	6.374E-01
PD105	1.348E+01	XE129	2.041E-04	GD157	5.361E-03
RU106	4.933E-08	TE130	2.551E+01	GD158	2.611E-01
RH106	4.636E-14	XE130	6.878E-02	TB159	2.828E-02
PD106	6.602E+00	XE131	4.680E+01	GD160	1.127E-02
PD107	2.731E+00	XE132	7.621E+01	DY160	7.135E-04
AG107	8.157E-06	BA132	2.426E-06	DY161	2.912E-03
PD108	1.326E+00	CS133	1.147E+02	DY162	1.631E-03
AG108	1.467E-18	XE134	1.340E+02	DY163	7.077E-04
AG108M	4.645E-10	CS134	2.414E-04	DY164	2.011E-04
CD108	4.664E-07	BA134	2.373E+00	HO165	1.564E-04
AG109	6.241E-01	CS135	2.859E+01	HO166M	3.569E-07
AG109M	5.345E-23	BA135	3.262E-04	ER166	5.910E-05
CD109	5.411E-17	XE136	2.001E+02	ER167	2.093E-05
PD110	4.786E-01	BA136	2.308E-01	ER168	9.076E-06
AG110	7.135E-23	CS137	5.700E+01	TM169	1.172E-08
AG110M	4.707E-15	BA137	5.176E+01	ER170	5.616E-13
CD110	5.493E-02	BA137M	8.721E-06	TM170	4.232E-29
CD111	3.838E-01	BA138	1.217E+02	YB170	3.839E-10
CD112	2.832E-01	LA138	9.891E-04	TM171	2.396E-16
CD113	2.259E-02	LA139	1.162E+02	YB171	4.724E-12
CD113M	1.450E-03	CE140	1.157E+02	YB172	1.108E-14
IN113	4.005E-03	PR141	1.075E+02		
CD114	5.039E-01	CE142	1.085E+02		
SN114	4.342E-07	ND142	1.595E-01		
IN115	1.971E-01	ND143	1.058E+02		
SN115	8.119E-03	CE144	4.048E-09		
CD116	2.548E-01	PR144	1.709E-13		
SN116	3.787E-02	PR144M	8.543E-16		
SN117	2.506E-01	ND144	1.057E+02		
SN118	2.789E-01	ND145	7.225E+01		
SN119	2.671E-01	ND146	5.764E+01		
SN119M	3.680E-15	PM146	4.430E-06		
SN120	2.796E-01	SM146	6.264E-05		
SN121M	9.424E-05	PM147	2.717E-02		
SB121	2.935E-01	SM147	3.871E+01		
SN122	3.136E-01	ND148	3.275E+01		
TE122	2.964E-03	SM148	3.085E+00		
SN123	6.611E-22	SM149	1.607E+00		
SB123	3.729E-01	ND150	1.265E+01		
TE123	7.823E-06	SM150	2.126E+01		
TE123M	9.607E-27	EU150	3.111E-09		
SN124	4.918E-01	SM151	2.410E+00		
TE124	3.068E-03	EU151	5.781E-01		
SB125	6.583E-04	SM152	9.559E+00		
TE125	6.465E-01	EU152	5.715E-04		
TE125M	9.206E-06	GD152	1.218E-03		
SN126	1.186E+00	EU153	4.469E+00		
SB126	5.634E-08	GD153	1.101E-16		
SB126M	4.283E-10	SM154	1.566E+00		
TE126	2.499E-02	EU154	4.815E-02		
I127	2.659E+00	GD154	4.034E-01		
TE128	6.640E+00	EU155	9.843E-03		
XE128	1.913E-02	GD155	4.551E-01		

Attachment G

Attachment G: Source Listing, Input and Output for FORTRAN Program ADJUSTG

```

PROGRAM ADJUSTG
C
C----- WRITTEN BY D.R. WENZEL
C
C          To adjust the activity in gm for calcine bin set 1
C
CHARACTER * 2 ELE, SYMBOL(7)
CHARACTER * 4 AMI, NPI, NUM, PU(9), UI(8)
C
DATA SYMBOL /' U', 'NP', 'PU', 'AM', 'CM', 'BK', 'CF' /
DATA AMI /'241 ' /
DATA NPI /'237 ' /
DATA PU /'236 ', '238 ', '239 ', '240 ', '241 ', '242 ', '243 ', '244 ',
+      '246 ' /
DATA UI /'232 ', '233 ', '234 ', '235 ', '236 ', '237 ', '238 ', '240 ' /

C
C----- OPEN INPUT AND OUTPUT FILES
C
OPEN(1, FILE = 'REDUCEG.MOD', STATUS = 'OLD', FORM = 'FORMATTED',
+     ERR = 900)
OPEN(6, FILE = 'ADJUSTG.NRM', STATUS = 'UNKNOWN', ERR = 920)
C
PRINT *, 'Working -- have patience.'
C
C----- Normalize to Berreth's Cs-137 data in WINCO-1050
C
C----- READ PAST FIRST LINE
C
READ(1, 300) DUMMY
300 FORMAT(1X, A2)
C
C----- START DATA NORMALIZATION PROCESS
C
40 READ(1, 310, END = 999) ELE, NUM, ACTIVITY
310 FORMAT(1X, A2, A4, 6X, E9.3)
DO 400 I = 1, 7
  IF (ELE .EQ. SYMBOL(I)) THEN
    IF (ELE .EQ. SYMBOL(1)) THEN
      IF (NUM .EQ. UI(1)) ACTIVITY = ACTIVITY / 250.
      IF (NUM .EQ. UI(2)) ACTIVITY = ACTIVITY / 250.
      IF (NUM .EQ. UI(3)) ACTIVITY = ACTIVITY / 131.
      IF (NUM .EQ. UI(4)) ACTIVITY = ACTIVITY / 504.
      IF (NUM .EQ. UI(5)) ACTIVITY = ACTIVITY / 272.
      IF (NUM .EQ. UI(6)) ACTIVITY = ACTIVITY / 250.
      IF (NUM .EQ. UI(7)) ACTIVITY = ACTIVITY / 94.5
      IF (NUM .EQ. UI(8)) ACTIVITY = ACTIVITY / 250.
    ENDIF
  ENDIF
C
  IF (ELE .EQ. SYMBOL(2)) THEN
    IF (NUM .EQ. NPI) ACTIVITY = ACTIVITY / 2.8
  ENDIF
C
  IF (ELE .EQ. SYMBOL(3)) THEN
    IF (NUM .EQ. PU(1)) ACTIVITY = ACTIVITY / 8.

```

**Attachment G: Source Listing, Input and Output for FORTRAN Program ADJUSTG
(Continued)**

```

                IF(NUM .EQ. PU(2)) ACTIVITY = ACTIVITY / 4.1
                IF(NUM .EQ. PU(3)) ACTIVITY = ACTIVITY / 8.21
                IF(NUM .EQ. PU(4)) ACTIVITY = ACTIVITY / 6.1
                IF(NUM .EQ. PU(5)) ACTIVITY = ACTIVITY / 6.
                IF(NUM .EQ. PU(6)) ACTIVITY = ACTIVITY / 15.
                IF(NUM .EQ. PU(7)) ACTIVITY = ACTIVITY / 8.
                IF(NUM .EQ. PU(8)) ACTIVITY = ACTIVITY / 8.
                IF(NUM .EQ. PU(9)) ACTIVITY = ACTIVITY / 8.
            ENDIF
C
            IF(ELE .EQ. SYMBOL(4)) THEN
                IF(NUM .EQ. AMI) THEN
                    ACTIVITY = ACTIVITY / 4.1
                ELSE
                    ACTIVITY = ACTIVITY / 8.
                ENDIF
            ENDIF
C
C
            IF(ELE .EQ. SYMBOL(5)) THEN
                ACTIVITY = ACTIVITY / 8.
            ENDIF
C
            IF(ELE .EQ. SYMBOL(6)) THEN
                ACTIVITY = ACTIVITY / 8.
            ENDIF
C
            IF(ELE .EQ. SYMBOL(7)) THEN
                ACTIVITY = ACTIVITY / 8.
            ENDIF
C
            ENDIF
C
C
400  CONTINUE
C
        WRITE(6,600) ELE, NUM, ACTIVITY
600  FORMAT(1X,A2,A4,6X,1PE9.3)
C
        GO TO 40
C
C----- ERROR STATEMENTS
C
900  WRITE(6,9000)
9000 FORMAT(2X,'ERROR IN OPENING FILE ')
        GO TO 999
C
920  WRITE(6,9020)
9020 FORMAT(2X,'ERROR IN OPENING FILE 6')
C
C----- PROGRAM END
C
999  CONTINUE
        END

```

Attachment G: Source Listing, Input and Output for FORTRAN Program ADJUSTG (Continued)

Input File REDUCEG.MOD

Radionuclide	g	Radionuclide	g	Radionuclide	g
HE 4	8.605E-01	PA234	8.457E-11	GE 74	2.049E+00
TL207	1.349E-11	U232	9.724E-06	AS 75	5.013E+00
TL208	6.540E-11	U233	8.360E-04	GE 76	1.505E+01
TL209	2.629E-16	U234	5.571E+02	SE 76	2.165E-02
PB206	4.883E-07	U235	1.121E+04	SE 77	3.377E+01
PB207	1.066E-05	U236	8.721E+02	SE 78	7.005E+01
PB208	5.961E-04	U237	6.100E-09	SE 79	1.807E+02
PB209	1.095E-12	U238	4.092E+03	BR 79	5.400E-02
PB210	2.219E-06	U240	1.764E-18	SE 80	4.346E+02
PB211	1.044E-10	NP235	7.170E-13	KR 80	2.149E-03
PB212	3.858E-08	NP236	9.782E-04	BR 81	7.439E+02
PB214	2.157E-11	NP237	1.383E+03	KR 81	1.990E-05
BI208	6.816E-18	NP238	7.576E-10	SE 82	1.177E+03
BI209	2.831E-08	NP239	1.558E-07	KR 82	2.954E+00
BI210M	3.781E-17	NP240M	3.861E-18	KR 83	1.857E+03
BI210	1.366E-09	PU236	8.400E-08	KR 84	3.806E+03
BI211	6.160E-12	PU238	3.293E+01	KR 85	1.637E+02
BI212	3.659E-09	PU239	9.186E+02	RB 85	4.508E+03
BI213	2.574E-13	PU240	9.961E+01	KR 86	7.467E+03
BI214	1.601E-11	PU241	8.210E+00	SR 86	1.960E+00
PO210	3.540E-08	PU242	4.480E-01	RB 87	9.665E+03
PO211	7.555E-17	PU243	3.915E-21	SR 87	1.391E-02
PO212	1.936E-19	PU244	2.884E-06	SR 88	1.392E+04
PO213	3.860E-22	AM241	3.290E+01	Y 89	1.837E+04
PO214	2.203E-18	AM242M	5.050E-04	SR 90	1.142E+04
PO215	8.741E-17	AM242	6.040E-09	Y 90	2.865E+00
PO216	1.539E-13	AM243	2.266E-02	ZR 90	1.083E+04
PO218	2.501E-12	CM242	1.223E-06	ZR 91	2.295E+04
AT217	3.092E-18	CM243	9.219E-06	ZR 92	2.382E+04
RN219	1.981E-13	CM244	2.753E-04	ZR 93	2.587E+04
RN220	5.810E-11	CM245	7.087E-06	NB 93	1.625E-01
RN222	4.599E-09	CM246	9.051E-08	NB 93M	1.658E-01
FR221	2.808E-14	CM247	1.098E-10	ZR 94	2.535E+04
FR223	9.174E-13	CM248	7.457E-13	NB 94	3.612E-03
RA223	5.032E-08	CF249	1.601E-15	MO 95	2.623E+04
RA224	3.365E-07	CF250	2.355E-17	ZR 96	2.607E+04
RA225	1.270E-10	CF251	1.062E-17	MO 96	4.704E+01
RA226	7.153E-04	CF252	6.403E-20	MO 97	2.461E+04
RA228	6.111E-11	H 3	2.980E-01	MO 98	2.475E+04
AC225	8.577E-11	LI 6	1.114E-02	TC 98	2.288E-02
AC227	3.555E-05	LI 7	3.020E-04	TC 99	2.529E+04
AC228	6.379E-15	BE 9	5.822E-04	RU 99	2.304E+00
TH227	8.269E-08	BE 10	3.881E-03	MO100	2.716E+04
TH228	6.514E-05	C 14	7.825E-04	RU100	5.264E+02
TH229	2.340E-05	ZN 66	1.544E-06	RU101	2.205E+04
TH230	5.732E+00	ZN 67	6.833E-08	RU102	1.878E+04
TH231	2.297E-05	ZN 68	1.347E-10	RH102	3.272E-06
TH232	1.933E-01	GA 69	2.790E-14	RH103	1.351E+04
TH234	5.615E-06	GE 70	1.224E-17	RU104	8.543E+03
PA231	1.575E-01	GA 71	1.767E-05	PD104	5.034E+02
PA233	1.599E-04	GE 72	2.233E-01	PD105	4.483E+03
PA234M	1.893E-10	GE 73	7.800E-01	RU106	1.641E-05

Attachment G: Source Listing, Input and Output for FORTRAN Program ADJUSTG (Continued)

Input File REDUCEG.MOD (Continued)

Radionuclide	g	Radionuclide	g	Radionuclide	g
RH106	1.542E-11	TE130	8.485E+03	GD156	2.120E+02
PD106	2.196E+03	XE130	2.288E+01	GD157	1.783E+00
PD107	9.084E+02	XE131	1.557E+04	GD158	8.685E+01
AG107	2.713E-03	XE132	2.535E+04	TB159	9.407E+00
PD108	4.411E+02	BA132	8.069E-04	GD160	3.750E+00
AG108	4.879E-16	CS133	3.816E+04	DY160	2.373E-01
AG108M	1.545E-07	XE134	4.456E+04	DY161	9.686E-01
CD108	1.551E-04	CS134	8.028E-02	DY162	5.426E-01
AG109	2.076E+02	BA134	7.894E+02	DY163	2.354E-01
AG109M	1.778E-20	CS135	9.510E+03	DY164	6.689E-02
CD109	1.800E-14	BA135	1.085E-01	HO165	5.202E-02
PD110	1.592E+02	XE136	6.654E+04	HO166M	1.187E-04
AG110	2.373E-20	BA136	7.676E+01	ER166	1.966E-02
AG110M	1.566E-12	CS137	1.896E+04	ER167	6.961E-03
CD110	1.827E+01	BA137	1.722E+04	ER168	3.019E-03
CD111	1.277E+02	BA137M	2.901E-03	TM169	3.898E-06
CD112	9.421E+01	BA138	4.050E+04	ER170	1.868E-10
CD113	7.515E+00	LA138	3.290E-01	YB170	1.277E-07
CD113M	4.823E-01	LA139	3.864E+04	TM171	7.971E-14
IN113	1.332E+00	CE140	3.850E+04	YB171	1.571E-09
CD114	1.676E+02	PR141	3.575E+04	YB172	3.685E-12
SN114	1.444E-04	CE142	3.609E+04		
IN115	6.555E+01	ND142	5.306E+01		
SN115	2.701E+00	ND143	3.520E+04		
CD116	8.475E+01	CE144	1.346E-06		
SN116	1.260E+01	PR144	5.685E-11		
SN117	8.337E+01	PR144M	2.842E-13		
SN118	9.276E+01	ND144	3.516E+04		
SN119	8.884E+01	ND145	2.403E+04		
SN119M	1.224E-12	ND146	1.917E+04		
SN120	9.300E+01	PM146	1.473E-03		
SN121M	3.135E-02	SM146	2.084E-02		
SB121	9.762E+01	PM147	9.039E+00		
SN122	1.043E+02	SM147	1.288E+04		
TE122	9.858E-01	ND148	1.089E+04		
SN123	2.199E-19	SM148	1.026E+03		
SB123	1.240E+02	SM149	5.347E+02		
TE123	2.602E-03	ND150	4.208E+03		
SN124	1.636E+02	SM150	7.071E+03		
TE124	1.021E+00	EU150	1.035E-06		
SB125	2.190E-01	SM151	8.016E+02		
TE125	2.150E+02	EU151	1.923E+02		
TE125M	3.062E-03	SM152	3.180E+03		
SN126	3.946E+02	EU152	1.901E-01		
SB126	1.874E-05	GD152	4.050E-01		
SB126M	1.425E-07	EU153	1.486E+03		
TE126	8.312E+00	GD153	3.663E-14		
I127	8.846E+02	SM154	5.209E+02		
TE128	2.209E+03	EU154	1.602E+01		
XE128	6.362E+00	GD154	1.342E+02		
I129	3.971E+03	EU155	3.274E+00		
XE129	6.789E-02	GD155	1.514E+02		

Attachment G: Source Listing, Input and Output for FORTRAN Program ADJUSTG (Continued)

Output File ADJUSTG.NRM

Radionuclide	g	Radionuclide	g	Radionuclide	g
HE 4	8.605E-01	PA234	8.457E-11	GE 74	2.049E+00
TL207	1.349E-11	U232	9.724E-06	AS 75	5.013E+00
TL208	6.540E-11	U233	8.360E-04	GE 76	1.505E+01
TL209	2.629E-16	U234	5.571E+02	SE 76	2.165E-02
PB206	4.883E-07	U235	1.121E+04	SE 77	3.377E+01
PB207	1.066E-05	U236	8.721E+02	SE 78	7.005E+01
PB208	5.961E-04	U237	6.100E-09	SE 79	1.807E+02
PB209	1.095E-12	U238	4.092E+03	BR 79	5.400E-02
PB210	2.219E-06	U240	1.764E-18	SE 80	4.346E+02
PB211	1.044E-10	NP235	7.170E-13	KR 80	2.149E-03
PB212	3.858E-08	NP236	9.782E-04	BR 81	7.439E+02
PB214	2.157E-11	NP237	1.383E+03	KR 81	1.990E-05
BI208	6.816E-18	NP238	7.576E-10	SE 82	1.177E+03
BI209	2.831E-08	NP239	1.558E-07	KR 82	2.954E+00
BI210M	3.781E-17	NP240M	3.861E-18	KR 83	1.857E+03
BI210	1.366E-09	PU236	8.400E-08	KR 84	3.806E+03
BI211	6.160E-12	PU238	3.293E+01	KR 85	1.637E+02
BI212	3.659E-09	PU239	9.186E+02	RB 85	4.508E+03
BI213	2.574E-13	PU240	9.961E+01	KR 86	7.467E+03
BI214	1.601E-11	PU241	8.210E+00	SR 86	1.960E+00
PO210	3.540E-08	PU242	4.480E-01	RB 87	9.665E+03
PO211	7.555E-17	PU243	3.915E-21	SR 87	1.391E-02
PO212	1.936E-19	PU244	2.884E-06	SR 88	1.392E+04
PO213	3.860E-22	AM241	3.290E+01	Y 89	1.837E+04
PO214	2.203E-18	AM242M	5.050E-04	SR 90	1.142E+04
PO215	8.741E-17	AM242	6.040E-09	Y 90	2.865E+00
PO216	1.539E-13	AM243	2.266E-02	ZR 90	1.083E+04
PO218	2.501E-12	CM242	1.223E-06	ZR 91	2.295E+04
AT217	3.092E-18	CM243	9.219E-06	ZR 92	2.382E+04
RN219	1.981E-13	CM244	2.753E-04	ZR 93	2.587E+04
RN220	5.810E-11	CM245	7.087E-06	NB 93	1.625E-01
RN222	4.599E-09	CM246	9.051E-08	NB 93M	1.658E-01
FR221	2.808E-14	CM247	1.098E-10	ZR 94	2.535E+04
FR223	9.174E-13	CM248	7.457E-13	NB 94	3.612E-03
RA223	5.032E-08	CF249	1.601E-15	MO 95	2.623E+04
RA224	3.365E-07	CF250	2.355E-17	ZR 96	2.607E+04
RA225	1.270E-10	CF251	1.062E-17	MO 96	4.704E+01
RA226	7.153E-04	CF252	6.403E-20	MO 97	2.461E+04
RA228	6.111E-11	H 3	2.980E-01	MO 98	2.475E+04
AC225	8.577E-11	LI 6	1.114E-02	TC 98	2.288E-02
AC227	3.555E-05	LI 7	3.020E-04	TC 99	2.529E+04
AC228	6.379E-15	BE 9	5.822E-04	RU 99	2.304E+00
TH227	8.269E-08	BE 10	3.881E-03	MO100	2.716E+04
TH228	6.514E-05	C 14	7.825E-04	RU100	5.264E+02
TH229	2.340E-05	ZN 66	1.544E-06	RU101	2.205E+04
TH230	5.732E+00	ZN 67	6.833E-08	RU102	1.878E+04
TH231	2.297E-05	ZN 68	1.347E-10	RH102	3.272E-06
TH232	1.933E-01	GA 69	2.790E-14	RH103	1.351E+04
TH234	5.615E-06	GE 70	1.224E-17	RU104	8.543E+03
PA231	1.575E-01	GA 71	1.767E-05	PD104	5.034E+02
PA233	1.599E-04	GE 72	2.233E-01	PD105	4.483E+03
PA234M	1.893E-10	GE 73	7.800E-01	RU106	1.641E-05

Attachment G: Source Listing, Input and Output for FORTRAN Program ADJUSTG (Continued)

Output File ADJUSTG.NRM (Continued)

Radionuclide	g	Radionuclide	g	Radionuclide	g
RH106	1.542E-11	TE130	8.485E+03	GD156	2.120E+02
PD106	2.196E+03	XE130	2.288E+01	GD157	1.783E+00
PD107	9.084E+02	XE131	1.557E+04	GD158	8.685E+01
AG107	2.713E-03	XE132	2.535E+04	TB159	9.407E+00
PD108	4.411E+02	BA132	8.069E-04	GD160	3.750E+00
AG108	4.879E-16	CS133	3.816E+04	DY160	2.373E-01
AG108M	1.545E-07	XE134	4.456E+04	DY161	9.686E-01
CD108	1.551E-04	CS134	8.028E-02	DY162	5.426E-01
AG109	2.076E+02	BA134	7.894E+02	DY163	2.354E-01
AG109M	1.778E-20	CS135	9.510E+03	DY164	6.689E-02
CD109	1.800E-14	BA135	1.085E-01	HO165	5.202E-02
PD110	1.592E+02	XE136	6.654E+04	HO166M	1.187E-04
AG110	2.373E-20	BA136	7.676E+01	ER166	1.966E-02
AG110M	1.566E-12	CS137	1.896E+04	ER167	6.961E-03
CD110	1.827E+01	BA137	1.722E+04	ER168	3.019E-03
CD111	1.277E+02	BA137M	2.901E-03	TM169	3.898E-06
CD112	9.421E+01	BA138	4.050E+04	ER170	1.868E-10
CD113	7.515E+00	LA138	3.290E-01	YB170	1.277E-07
CD113M	4.823E-01	LA139	3.864E+04	TM171	7.971E-14
IN113	1.332E+00	CE140	3.850E+04	YB171	1.571E-09
CD114	1.676E+02	PR141	3.575E+04	YB172	3.685E-12
SN114	1.444E-04	CE142	3.609E+04		
IN115	6.555E+01	ND142	5.306E+01		
SN115	2.701E+00	ND143	3.520E+04		
CD116	8.475E+01	CE144	1.346E-06		
SN116	1.260E+01	PR144	5.685E-11		
SN117	8.337E+01	PR144M	2.842E-13		
SN118	9.276E+01	ND144	3.516E+04		
SN119	8.884E+01	ND145	2.403E+04		
SN119M	1.224E-12	ND146	1.917E+04		
SN120	9.300E+01	PM146	1.473E-03		
SN121M	3.135E-02	SM146	2.084E-02		
SB121	9.762E+01	PM147	9.039E+00		
SN122	1.043E+02	SM147	1.288E+04		
TE122	9.858E-01	ND148	1.089E+04		
SN123	2.199E-19	SM148	1.026E+03		
SB123	1.240E+02	SM149	5.347E+02		
TE123	2.602E-03	ND150	4.208E+03		
SN124	1.636E+02	SM150	7.071E+03		
TE124	1.021E+00	EU150	1.035E-06		
SB125	2.190E-01	SM151	8.016E+02		
TE125	2.150E+02	EU151	1.923E+02		
TE125M	3.062E-03	SM152	3.180E+03		
SN126	3.946E+02	EU152	1.901E-01		
SB126	1.874E-05	GD152	4.050E-01		
SB126M	1.425E-07	EU153	1.486E+03		
TE126	8.312E+00	GD153	3.663E-14		
I127	8.846E+02	SM154	5.209E+02		
TE128	2.209E+03	EU154	1.602E+01		
XE128	6.362E+00	GD154	1.342E+02		
I129	3.971E+03	EU155	3.274E+00		
XE129	6.789E-02	GD155	1.514E+02		

Attachment H

Attachment H: Input and Output for ORIGEN2 Run Decaying Al Calcine Inventory as a Function of Time after 1986

Origen2 Input

```

-1
-1
-1
RDA      ORIGEN2, VERSION 2.1 (8-1-91)
BAS      ALUNUMUM FUEL ELEMENT, 200 GRAM BOL
CUT      -1
LIP      0 0 0
LIB      0 1 2 3 204 908 909 9 50 0 4 0
TIT      MTR EQUIVALENT FUEL
PHO      101 102 103 10
INP      -1 1 -1 -1 1 1
MOV      -1 1 0 1.0
HED      1
ELEMENT
OPTL     8 8 8 8 5 8 5 8 8 8 8 8 8 8 8 8 8 8 8 8
OPTA     8 8 8 8 5 8 5 8 8 8 8 8 8 8 8 8 8 8 8 8
OPTF     8 8 8 8 5 8 5 8 8 8 8 8 8 8 8 8 8 8 8 8
DEC      30. 1 2 5 0
DEC      49. 2 3 5 0
DEC      149. 3 4 5 0
DEC      549. 4 5 5 0
DEC      1049. 5 6 5 0
OUT      -6 1 -1 0
OUT      6 1 -1 0
END
2 20040 8.605E-01 812070 1.349E-11 812080 6.540E-11 0 0.
2 812090 2.629E-16 822060 4.883E-07 822070 1.066E-05 0 0.
2 822080 5.961E-04 822090 1.095E-12 822100 2.219E-06 0 0.
2 822110 1.044E-10 822120 3.858E-08 822140 2.157E-11 0 0.
2 832080 6.816E-18 832090 2.831E-08 832101 3.781E-17 0 0.
2 832100 1.366E-09 832110 6.160E-12 832120 3.659E-09 0 0.
2 832130 2.574E-13 832140 1.601E-11 842100 3.540E-08 0 0.
2 842110 7.555E-17 842120 1.936E-19 842130 3.860E-22 0 0.
2 842140 2.203E-18 842150 8.741E-17 842160 1.539E-13 0 0.
2 842180 2.501E-12 852170 3.092E-18 862190 1.981E-13 0 0.
2 862200 5.810E-11 862220 4.599E-09 872210 2.808E-14 0 0.
2 872230 9.174E-13 882230 5.032E-08 882240 3.365E-07 0 0.
2 882250 1.270E-10 882260 7.153E-04 882280 6.111E-11 0 0.
2 892250 8.577E-11 892270 3.555E-05 892280 6.379E-15 0 0.
2 902270 8.269E-08 902280 6.514E-05 902290 2.340E-05 0 0.
2 902300 5.732E+00 902310 2.297E-05 902320 1.933E-01 0 0.
2 902340 5.615E-06 912310 1.575E-01 912330 1.599E-04 0 0.
2 912341 1.893E-10 912340 8.457E-11 922320 9.724E-06 0 0.
2 922330 8.360E-04 922340 5.571E+02 922350 1.121E+04 0 0.
2 922360 8.721E+02 922370 6.100E-09 922380 4.092E+03 0 0.
2 922400 1.764E-18 932350 7.170E-13 932360 9.782E-04 0 0.
2 932370 1.383E+03 932380 7.576E-10 932390 1.558E-07 0 0.
2 932401 3.861E-18 942360 8.400E-08 942380 3.293E+01 0 0.
2 942390 9.186E+02 942400 9.961E+01 942410 8.210E+00 0 0.
2 942420 4.480E-01 942430 3.915E-21 942440 2.884E-06 0 0.
2 952410 3.290E+01 952421 5.050E-04 952420 6.040E-09 0 0.
2 952430 2.266E-02 962420 1.223E-06 962430 9.219E-06 0 0.
2 962440 2.753E-04 962450 7.087E-06 962460 9.051E-08 0 0.
2 962470 1.098E-10 962480 7.457E-13 982490 1.601E-15 0 0.
2 982500 2.355E-17 982510 1.062E-17 982520 6.403E-20 0 0.

```


**Attachment H: Input and Output for ORIGEN2 Run Decaying Al Calcine Inventory
as a Function of Time after 1986 (Continued)**

Origen2 Input (Continued)

3	10030	2.980E-01	30060	1.114E-02	30070	3.020E-04	0	0.
3	40090	5.822E-04	40100	3.881E-03	60140	7.825E-04	0	0.
3	300660	1.544E-06	300670	6.833E-08	300680	1.347E-10	0	0.
3	310690	2.790E-14	320700	1.224E-17	310710	1.767E-05	0	0.
3	320720	2.233E-01	320730	7.800E-01	320740	2.049E+00	0	0.
3	330750	5.013E+00	320760	1.505E+01	340760	2.165E-02	0	0.
3	340770	3.377E+01	340780	7.005E+01	340790	1.807E+02	0	0.
3	350790	5.400E-02	340800	4.346E+02	360800	2.149E-03	0	0.
3	350810	7.439E+02	360810	1.990E-05	340820	1.177E+03	0	0.
3	360820	2.954E+00	360830	1.857E+03	360840	3.806E+03	0	0.
3	360850	1.637E+02	370850	4.508E+03	360860	7.467E+03	0	0.
3	380860	1.960E+00	370870	9.665E+03	380870	1.391E-02	0	0.
3	380880	1.392E+04	390890	1.837E+04	380900	1.142E+04	0	0.
3	390900	2.865E+00	400900	1.083E+04	400910	2.295E+04	0	0.
3	400920	2.382E+04	400930	2.587E+04	410930	1.625E-01	0	0.
3	410931	1.658E-01	400940	2.535E+04	410940	3.612E-03	0	0.
3	420950	2.623E+04	400960	2.607E+04	420960	4.704E+01	0	0.
3	420970	2.461E+04	420980	2.475E+04	430980	2.288E-02	0	0.
3	430990	2.529E+04	440990	2.304E+00	421000	2.716E+04	0	0.
3	441000	5.264E+02	441010	2.205E+04	441020	1.878E+04	0	0.
3	451020	3.272E-06	451030	1.351E+04	441040	8.543E+03	0	0.
3	461040	5.034E+02	461050	4.483E+03	441060	1.641E-05	0	0.
3	451060	1.542E-11	461060	2.196E+03	461070	9.084E+02	0	0.
3	471070	2.713E-03	461080	4.411E+02	471080	4.879E-16	0	0.
3	471081	1.545E-07	481080	1.551E-04	471090	2.076E+02	0	0.
3	471091	1.778E-20	481090	1.800E-14	461100	1.592E+02	0	0.
3	471100	2.373E-20	471101	1.566E-12	481100	1.827E+01	0	0.
3	481110	1.277E+02	481120	9.421E+01	481130	7.515E+00	0	0.
3	481131	4.823E-01	491130	1.332E+00	481140	1.676E+02	0	0.
3	501140	1.444E-04	491150	6.555E+01	501150	2.701E+00	0	0.
3	481160	8.475E+01	501160	1.260E+01	501170	8.337E+01	0	0.
3	501180	9.276E+01	501190	8.884E+01	501191	1.224E-12	0	0.
3	501200	9.300E+01	501211	3.135E-02	511210	9.762E+01	0	0.
3	501220	1.043E+02	521220	9.858E-01	501230	2.199E-19	0	0.
3	511230	1.240E+02	521230	2.602E-03	501240	1.636E+02	0	0.
3	521240	1.021E+00	511250	2.190E-01	521250	2.150E+02	0	0.
3	521251	3.062E-03	501260	3.946E+02	511260	1.874E-05	0	0.
3	511261	1.425E-07	521260	8.312E+00	531270	8.846E+02	0	0.
3	521280	2.209E+03	541280	6.362E+00	531290	3.971E+03	0	0.
3	541290	6.789E-02	521300	8.485E+03	541300	2.288E+01	0	0.
3	541310	1.557E+04	541320	2.535E+04	561320	8.069E-04	0	0.
3	551330	3.816E+04	541340	4.456E+04	551340	8.028E-02	0	0.
3	561340	7.894E+02	551350	9.510E+03	561350	1.085E-01	0	0.
3	541360	6.654E+04	561360	7.676E+01	551370	1.896E+04	0	0.
3	561370	1.722E+04	561371	2.901E-03	561380	4.050E+04	0	0.
3	571380	3.290E-01	571390	3.864E+04	581400	3.850E+04	0	0.
3	591410	3.575E+04	581420	3.609E+04	601420	5.306E+01	0	0.
3	601430	3.520E+04	581440	1.346E-06	591440	5.685E-11	0	0.
3	591441	2.842E-13	601440	3.516E+04	601450	2.403E+04	0	0.
3	601460	1.917E+04	611460	1.473E-03	621460	2.084E-02	0	0.
3	611470	9.039E+00	621470	1.288E+04	601480	1.089E+04	0	0.
3	621480	1.026E+03	621490	5.347E+02	601500	4.208E+03	0	0.
3	621500	7.071E+03	631500	1.035E-06	621510	8.016E+02	0	0.
3	631510	1.923E+02	621520	3.180E+03	631520	1.901E-01	0	0.

**Attachment H: Input and Output for ORIGEN2 Run Decaying Al Calcine Inventory
as a Function of Time after 1986 (Continued)**

Origen2 Input (Continued)

3	641520	4.050E-01	631530	1.486E+03	641530	3.663E-14	0	0.
3	621540	5.209E+02	631540	1.602E+01	641540	1.342E+02	0	0.
3	631550	3.274E+00	641550	1.514E+02	641560	2.120E+02	0	0.
3	641570	1.783E+00	641580	8.685E+01	651590	9.407E+00	0	0.
3	641600	3.750E+00	661600	2.373E-01	661610	9.686E-01	0	0.
3	661620	5.426E-01	661630	2.354E-01	661640	6.689E-02	0	0.
3	671650	5.202E-02	671661	1.187E-04	681660	1.966E-02	0	0.
3	681670	6.961E-03	681680	3.019E-03	691690	3.898E-06	0	0.
3	681700	1.868E-10	701700	1.277E-07	691710	7.971E-14	0	0.
3	701710	1.571E-09	701720	3.685E-12		0	0.	0
0								

**Attachment H: Input and Output for ORIGEN2 Run Decaying Al Calcine Inventory
as a Function of Time after 1986 (Continued)**

Origen2 Input (Continued)

```
echo off
echo **
echo **
echo **
echo **
copy aldecay.INP tape5.inp >nul
REM (NOT USED IN THIS CASE) copy aldecay.u3 tape3.inp >nul
copy \origen2\libs\decay.lib+\origen2\libs\atr.lib tape9.inp >nul
copy \origen2\libs\gxuo2brm.lib tape10.inp >nul
\origen2\code\origen2
rem combine and save files from run
copy tape12.out+tape6.out aldecay.u6 >nul
copy tape13.out+tape11.out aldecay.u11 >nul
ren tape7.out aldecay.pch
ren tape15.out aldecay.dbg
ren tape16.out aldecay.vxs
ren tape50.out aldecay.ech
rem cleanup files
del tape*.inp
del tape*.out
echo *****
echo ***** O R I G E N 2 - Version 2.1 *****
echo ***** Execution Completed *****
echo *****
echo on
```

**Attachment H: Input and Output for ORIGEN2 Run Decaying Al Calcine Inventory
as a Function of Time after 1986 (Continued)**

aldecay.out

ORIGEN2 V2.1 (8-1-91), Run on 10/07/97 at 11:36:25

	ELEMENT	30.0YR	49.0YR	149.0YR	549.0YR	1049.0YR
TL206	0.000E+00	2.138E-20	2.138E-20	2.138E-20	2.138E-20	2.137E-20
TL207	2.570E-03	5.560E-03	6.417E-03	7.423E-03	7.621E-03	7.796E-03
TL208	1.927E-02	5.855E-05	4.852E-05	1.879E-05	8.106E-07	4.232E-07
TL209	1.076E-07	1.117E-07	1.184E-07	2.052E-07	1.409E-06	4.794E-06
PB209	4.977E-06	5.173E-06	5.483E-06	9.500E-06	6.523E-05	2.219E-04
PB210	1.695E-04	1.017E-03	1.774E-03	6.478E-03	2.695E-02	4.922E-02
PB211	2.578E-03	5.575E-03	6.435E-03	7.443E-03	7.642E-03	7.818E-03
PB212	5.363E-02	1.629E-04	1.350E-04	5.229E-05	2.256E-06	1.178E-06
PB214	7.075E-04	2.199E-03	3.139E-03	8.043E-03	2.695E-02	4.923E-02
BI208	3.185E-20	3.185E-20	3.184E-20	3.184E-20	3.181E-20	3.178E-20
BI210M	2.146E-20	2.146E-20	2.146E-20	2.146E-20	2.146E-20	2.146E-20
BI210	1.696E-04	1.017E-03	1.774E-03	6.478E-03	2.695E-02	4.922E-02
BI211	2.578E-03	5.575E-03	6.435E-03	7.443E-03	7.642E-03	7.818E-03
BI212	5.362E-02	1.629E-04	1.350E-04	5.229E-05	2.256E-06	1.178E-06
BI213	4.980E-06	5.173E-06	5.483E-06	9.500E-06	6.523E-05	2.219E-04
BI214	7.072E-04	2.199E-03	3.139E-03	8.043E-03	2.695E-02	4.923E-02
PO210	1.591E-04	1.017E-03	1.774E-03	6.478E-03	2.695E-02	4.922E-02
PO211	7.216E-06	1.561E-05	1.802E-05	2.084E-05	2.140E-05	2.189E-05
PO212	3.436E-02	1.044E-04	8.652E-05	3.350E-05	1.445E-06	7.546E-07
PO213	4.870E-06	5.062E-06	5.365E-06	9.295E-06	6.382E-05	2.171E-04
PO214	7.072E-04	2.198E-03	3.139E-03	8.041E-03	2.695E-02	4.922E-02
PO215	2.578E-03	5.575E-03	6.435E-03	7.443E-03	7.642E-03	7.818E-03
PO216	5.361E-02	1.629E-04	1.350E-04	5.229E-05	2.256E-06	1.178E-06
PO218	7.076E-04	2.199E-03	3.140E-03	8.044E-03	2.696E-02	4.924E-02
AT217	4.979E-06	5.173E-06	5.483E-06	9.500E-06	6.523E-05	2.219E-04
RN219	2.578E-03	5.575E-03	6.435E-03	7.443E-03	7.642E-03	7.818E-03
RN220	5.361E-02	1.629E-04	1.350E-04	5.229E-05	2.256E-06	1.178E-06
RN222	7.077E-04	2.199E-03	3.140E-03	8.044E-03	2.696E-02	4.924E-02
FR221	4.979E-06	5.173E-06	5.483E-06	9.500E-06	6.523E-05	2.219E-04
FR223	3.550E-05	7.691E-05	8.871E-05	1.027E-04	1.055E-04	1.079E-04
RA223	2.578E-03	5.575E-03	6.435E-03	7.443E-03	7.642E-03	7.818E-03
RA224	5.362E-02	1.629E-04	1.350E-04	5.229E-05	2.256E-06	1.178E-06
RA225	4.981E-06	5.173E-06	5.483E-06	9.500E-06	6.523E-05	2.219E-04
RA226	7.075E-04	2.199E-03	3.140E-03	8.044E-03	2.696E-02	4.924E-02
RA228	1.431E-08	2.096E-08	2.127E-08	2.162E-08	2.274E-08	2.415E-08
AC225	4.980E-06	5.173E-06	5.483E-06	9.500E-06	6.523E-05	2.219E-04
AC227	2.572E-03	5.573E-03	6.428E-03	7.443E-03	7.643E-03	7.818E-03
AC228	1.431E-08	2.096E-08	2.128E-08	2.162E-08	2.274E-08	2.415E-08
TH227	2.543E-03	5.498E-03	6.347E-03	7.341E-03	7.537E-03	7.710E-03
TH228	5.341E-02	1.629E-04	1.350E-04	5.229E-05	2.256E-06	1.178E-06
TH229	4.980E-06	5.173E-06	5.483E-06	9.500E-06	6.523E-05	2.219E-04
TH230	1.158E-01	1.167E-01	1.173E-01	1.204E-01	1.331E-01	1.490E-01
TH231	1.222E+01	2.424E-02	2.424E-02	2.425E-02	2.427E-02	2.430E-02
TH232	2.121E-08	2.129E-08	2.134E-08	2.162E-08	2.274E-08	2.415E-08
TH234	1.301E-01	1.376E-03	1.376E-03	1.376E-03	1.376E-03	1.376E-03
PA231	7.442E-03	7.454E-03	7.461E-03	7.496E-03	7.638E-03	7.813E-03
PA233	3.320E+00	9.765E-01	9.773E-01	9.812E-01	9.917E-01	9.981E-01
PA234M	1.301E-01	1.376E-03	1.376E-03	1.376E-03	1.376E-03	1.376E-03
PA234	1.691E-04	1.789E-06	1.789E-06	1.789E-06	1.789E-06	1.789E-06
U232	2.082E-04	1.576E-04	1.315E-04	5.090E-05	2.204E-06	1.153E-06
U233	8.096E-06	1.372E-04	2.184E-04	6.464E-04	2.370E-03	4.539E-03
U234	3.482E+00	3.525E+00	3.547E+00	3.621E+00	3.677E+00	3.674E+00

**Attachment H: Input and Output for ORIGEN2 Run Decaying Al Calcine Inventory
as a Function of Time after 1986 (Continued)**

aldecal.out

ORIGEN2 V2.1 (8-1-91), Run on 10/07/97 at 11:36:25

	ELEMENT	30.0YR	49.0YR	149.0YR	549.0YR	1049.0YR
U235	2.424E-02	2.424E-02	2.424E-02	2.425E-02	2.427E-02	2.430E-02
U236	5.645E-02	5.647E-02	5.648E-02	5.654E-02	5.680E-02	5.711E-02
U237	4.981E-04	4.898E-03	1.962E-03	1.593E-05	2.864E-11	2.742E-11
U238	1.376E-03	1.376E-03	1.376E-03	1.376E-03	1.376E-03	1.376E-03
U240	1.634E-12	5.110E-11	5.110E-11	5.110E-11	5.110E-11	5.110E-11
NP235	1.006E-09	4.726E-18	2.511E-23	0.000E+00	0.000E+00	0.000E+00
NP236	1.289E-05	1.289E-05	1.289E-05	1.288E-05	1.285E-05	1.281E-05
NP237	9.753E-01	9.765E-01	9.773E-01	9.812E-01	9.917E-01	9.981E-01
NP238	1.964E-04	2.141E-05	1.963E-05	1.244E-05	2.008E-06	2.054E-07
NP239	3.615E-02	4.506E-03	4.498E-03	4.456E-03	4.292E-03	4.095E-03
NP240M	4.089E-10	5.110E-11	5.110E-11	5.110E-11	5.110E-11	5.110E-11
PU236	4.465E-05	1.190E-06	1.160E-06	1.159E-06	1.156E-06	1.153E-06
PU238	5.640E+02	4.450E+02	3.830E+02	1.738E+02	7.376E+00	1.421E-01
PU239	5.712E+01	5.707E+01	5.704E+01	5.688E+01	5.623E+01	5.542E+01
PU240	2.271E+01	2.263E+01	2.259E+01	2.235E+01	2.142E+01	2.032E+01
PU241	8.462E+02	1.996E+02	7.999E+01	6.492E-01	1.169E-06	1.119E-06
PU242	1.711E-03	1.711E-03	1.711E-03	1.711E-03	1.710E-03	1.708E-03
PU243	1.019E-14	1.019E-14	1.019E-14	1.019E-14	1.019E-14	1.019E-14
PU244	5.117E-11	5.117E-11	5.117E-11	5.117E-11	5.117E-11	5.117E-11
AM241	1.130E+02	1.286E+02	1.286E+02	1.119E+02	5.892E+01	2.643E+01
AM242M	4.910E-03	4.282E-03	3.927E-03	2.489E-03	4.017E-04	4.108E-05
AM242	4.885E-03	4.261E-03	3.907E-03	2.476E-03	3.996E-04	4.088E-05
AM243	4.519E-03	4.506E-03	4.498E-03	4.456E-03	4.292E-03	4.095E-03
CM242	4.045E-03	3.524E-03	3.231E-03	2.048E-03	3.305E-04	3.381E-05
CM243	4.761E-04	2.295E-04	1.446E-04	1.270E-05	7.567E-10	3.961E-15
CM244	2.228E-02	7.068E-03	3.416E-03	7.434E-05	1.668E-11	8.145E-20
CM245	1.217E-06	1.214E-06	1.212E-06	1.203E-06	1.164E-06	1.117E-06
CM246	2.781E-08	2.769E-08	2.761E-08	2.721E-08	2.566E-08	2.385E-08
CM247	1.019E-14	1.019E-14	1.019E-14	1.019E-14	1.019E-14	1.019E-14
CM248	3.172E-15	3.171E-15	3.171E-15	3.171E-15	3.168E-15	3.165E-15
CF249	6.561E-15	6.183E-15	5.955E-15	4.887E-15	2.215E-15	8.241E-16
CF250	2.576E-15	5.254E-16	1.920E-16	9.581E-19	5.973E-28	1.877E-39
CF251	1.685E-17	1.646E-17	1.623E-17	1.502E-17	1.103E-17	7.499E-18
CF252	3.445E-17	1.300E-20	0.000E+00	0.000E+00	0.000E+00	0.000E+00
H 3	2.877E+03	5.341E+02	1.838E+02	6.706E-01	1.190E-10	7.710E-23
BE 10	8.676E-05	8.675E-05	8.675E-05	8.675E-05	8.674E-05	8.672E-05
C 14	3.489E-03	3.476E-03	3.469E-03	3.427E-03	3.265E-03	3.073E-03
SE 79	1.259E+01	1.259E+01	1.259E+01	1.257E+01	1.252E+01	1.245E+01
KR 81	4.187E-07	4.186E-07	4.186E-07	4.185E-07	4.179E-07	4.172E-07
KR 85	6.425E+04	9.235E+03	2.703E+03	4.190E+00	2.454E-11	2.235E-25
RB 87	8.460E-04	8.460E-04	8.460E-04	8.460E-04	8.460E-04	8.460E-04
SR 90	1.558E+06	7.631E+05	4.855E+05	4.492E+04	3.293E+00	2.234E-05
Y 90	1.559E+06	7.632E+05	4.856E+05	4.493E+04	3.294E+00	2.234E-05
ZR 93	6.503E+01	6.503E+01	6.503E+01	6.502E+01	6.501E+01	6.500E+01
NB 93M	4.688E+01	5.855E+01	6.055E+01	6.177E+01	6.176E+01	6.175E+01
NB 94	6.770E-04	6.763E-04	6.759E-04	6.736E-04	6.644E-04	6.532E-04
TC 98	1.989E-05	1.989E-05	1.989E-05	1.989E-05	1.989E-05	1.988E-05
TC 99	4.289E+02	4.289E+02	4.289E+02	4.287E+02	4.282E+02	4.275E+02
RH102	3.956E-03	3.042E-06	3.243E-08	1.351E-18	0.000E+00	0.000E+00
RU106	5.493E-02	6.033E-11	1.278E-16	0.000E+00	0.000E+00	0.000E+00
RH106	5.491E-02	6.033E-11	1.278E-16	0.000E+00	0.000E+00	0.000E+00

**Attachment H: Input and Output for ORIGEN2 Run Decaying Al Calcine Inventory
as a Function of Time after 1986 (Continued)**

aldecay.out

ORIGEN2 V2.1 (8-1-91), Run on 10/07/97 at 11:36:25

ELEMENT	30.0YR	49.0YR	149.0YR	549.0YR	1049.0YR
PD107	4.674E-01	4.674E-01	4.674E-01	4.674E-01	4.674E-01
AG108	3.586E-07	3.044E-07	2.744E-07	1.590E-07	1.792E-08
AG108M	4.028E-06	3.420E-06	3.083E-06	1.786E-06	2.013E-07
AG109M	4.649E-11	3.618E-18	1.138E-22	0.000E+00	0.000E+00
CD109	4.649E-11	3.618E-18	1.138E-22	0.000E+00	0.000E+00
AG110	9.898E-11	6.242E-24	2.700E-32	0.000E+00	0.000E+00
AG110M	7.442E-09	4.693E-22	2.048E-30	0.000E+00	0.000E+00
CD113M	1.046E+02	2.516E+01	1.020E+01	8.814E-02	4.917E-10
IN115	4.079E-10	4.079E-10	4.079E-10	4.079E-10	4.079E-10
SN119M	5.484E-09	1.892E-22	5.635E-31	0.000E+00	0.000E+00
SN121M	1.854E+00	1.223E+00	9.397E-01	2.348E-01	9.134E-04
TE123	7.565E-13	7.565E-13	7.565E-13	7.565E-13	7.565E-13
SB125	2.262E+02	1.242E-01	1.070E-03	1.449E-14	0.000E+00
TE125M	5.517E+01	3.030E-02	2.610E-04	3.536E-15	0.000E+00
SN126	1.120E+01	1.120E+01	1.120E+01	1.119E+01	1.116E+01
SB126	1.567E+00	1.568E+00	1.567E+00	1.566E+00	1.562E+00
SB126M	1.120E+01	1.120E+01	1.120E+01	1.119E+01	1.116E+01
I129	7.013E-01	7.013E-01	7.013E-01	7.013E-01	7.013E-01
CS134	1.039E+02	4.334E-03	7.305E-06	1.838E-20	0.000E+00
CS135	1.095E+01	1.095E+01	1.095E+01	1.095E+01	1.095E+01
CS137	1.650E+06	8.249E+05	5.318E+05	5.276E+04	5.110E+00
BA137M	1.561E+06	7.804E+05	5.031E+05	4.991E+04	4.834E+00
LA138	6.316E-09	6.316E-09	6.316E-09	6.316E-09	6.316E-09
CE142	8.664E-04	8.664E-04	8.664E-04	8.664E-04	8.664E-04
CE144	4.296E-03	1.069E-14	4.785E-22	0.000E+00	0.000E+00
PR144	4.297E-03	1.069E-14	4.785E-22	0.000E+00	0.000E+00
PR144M	5.156E-05	1.283E-16	5.742E-24	0.000E+00	0.000E+00
ND144	4.161E-08	4.161E-08	4.161E-08	4.161E-08	4.161E-08
PM146	6.561E-01	1.496E-02	1.365E-03	4.589E-09	0.000E+00
SM146	7.293E-07	7.479E-07	7.483E-07	7.484E-07	7.484E-07
PM147	8.383E+03	3.027E+00	1.999E-02	6.703E-14	0.000E+00
SM147	2.928E-04	2.930E-04	2.930E-04	2.930E-04	2.930E-04
SM148	3.099E-10	3.099E-10	3.099E-10	3.099E-10	3.099E-10
SM149	1.284E-10	1.284E-10	1.284E-10	1.284E-10	1.284E-10
EU150	6.855E-05	3.847E-05	2.669E-05	3.891E-06	1.759E-09
SM151	2.110E+04	1.674E+04	1.446E+04	6.696E+03	3.075E+02
EU152	3.289E+01	7.129E+00	2.707E+00	1.656E-02	2.320E-11
GD152	8.824E-12	9.728E-12	9.883E-12	9.977E-12	9.978E-12
GD153	1.292E-10	3.033E-24	7.076E-33	0.000E+00	0.000E+00
EU154	4.326E+03	3.855E+02	8.336E+01	2.634E-02	2.627E-16
EU155	1.523E+03	2.300E+01	1.616E+00	1.375E-06	0.000E+00
HO166M	2.131E-04	2.095E-04	2.072E-04	1.955E-04	1.552E-04
TM171	8.683E-11	1.718E-15	1.814E-18	3.801E-34	0.000E+00

Attachment I

Attachment I: Source Listing, Input and Output for FORTRAN Program ROUND

```

PROGRAM ROUND
C
C----- WRITTEN BY D.R. WENZEL
C
C          To round output tables to 2 places of accuracy
C          and to normalize the total Ci in Bin Set 1 to
C          Ci/g
C
C          CHARACTER * 25 NUCLIDE
C          CHARACTER * 85 TITLE
C          REAL *4 OLD(6), NEW(6)
C          DIMENSION TOTAL(6)
C
C          OPEN(3,FILE ='ALDECAY.MOD', STATUS='OLD',FORM='FORMATTED',
+            ERR = 900)
C          OPEN(6,FILE ='ROUND.OUT', STATUS='UNKNOWN', ERR = 920)
+
C
C----- Convert from Ci/Bin Set 1 to Ci/g
C          (Bin Set 1/217 cu m) x (1.E-6 mL/cu m) x (mL/1.09 g)
C          = 4.228E-9
C
C          CORFAC = 4.228E-9
C
C----- Zero out column summaries
C
C          DO 50 I=1,6
C            TOTAL(I) = 0.
C          50 CONTINUE
C
C----- Modify the name on the first line of data
C
C          READ(3,300) TITLE
C          300 FORMAT(A85)
C          WRITE(6,600)
C          600 FORMAT(1X,'ROUND.OUT')
C
C----- Echo the next 3 lines of data
C
C          DO 100 I=1,3
C            READ(3,300) TITLE
C            WRITE(6,610) TITLE
C          610 FORMAT(A85)
C          100 CONTINUE
C
C----- Read data with 4 places of accuracy
C
C          60 READ(3,310,END=990) NUCLIDE,(OLD(I), I=1,6)
C          310 FORMAT(A25,6(E10.3))
C          DO 120 I=1,6
C
C----- Convert from Ci/Bin Set 1 to Ci/g calcine
C
C          NEW(I) = OLD(I) * CORFAC
C
C----- Keep a sum of the total Ci/mL for each decay time

```


**Attachment I: Source Listing, Input and Output for FORTRAN Program ROUND
(Continued)**

```
C
      TOTAL(I) = TOTAL(I) + NEW(I)
120  CONTINUE
C
C----- Write output with 2 places of accuracy
C
      WRITE(6,620) NUCLIDE, (NEW(I), I=1, 6)
      620  FORMAT(A25, 6(1PE10.1))
      GO TO 60
C
C----- ERROR STATEMENTS
C
      900  WRITE(6,9000)
      9000 FORMAT(2X, 'ERROR IN OPENING FILE 3')
      GO TO 999
C
      920  WRITE(6,9020)
      9020 FORMAT(2X, 'ERROR IN OPENING FILE 6')
      GO TO 999
C
C----- Write totals for each decay time
C
      990  WRITE(6,630) (TOTAL(I), I=1, 6)
      630  FORMAT(1X, /, 17X, 'Total', 3x, 6(1PE10.1))
C
C----- PROGRAM END
C
      999  CONTINUE
      END
```

Attachment I: Source Listing, Input and Output for FORTRAN Program ROUND (Continued)

Input File aldecay.mod

ORIGEN2 V2.1 (8-1-91), Run on 10/09/97 at 15:37:33

			1986	2016	2035	100yr	500yr	1000yr
Tl207	4.770E+00	m	2.570E-03	5.560E-03	6.417E-03	7.423E-03	7.621E-03	7.796E-03
Tl208	3.053E+00	m	1.927E-02	5.855E-05	4.852E-05	1.879E-05	8.106E-07	4.232E-07
Tl209	2.200E+00	m	1.076E-07	1.126E-07	1.207E-07	2.259E-07	1.686E-06	5.791E-06
Pb209	3.253E+00	h	4.977E-06	5.212E-06	5.587E-06	1.046E-05	7.807E-05	2.681E-04
Pb210	2.226E+01	yr	1.695E-04	1.017E-03	1.774E-03	6.478E-03	2.695E-02	4.922E-02
Pb211	3.610E+01	m	2.578E-03	5.575E-03	6.435E-03	7.443E-03	7.642E-03	7.818E-03
Pb212	1.064E+01	h	5.363E-02	1.629E-04	1.350E-04	5.229E-05	2.256E-06	1.178E-06
Pb214	2.680E+01	m	7.075E-04	2.199E-03	3.139E-03	8.043E-03	2.695E-02	4.923E-02
Bi210M	3.000E+06	yr	2.146E-20	2.146E-20	2.146E-20	2.146E-20	2.146E-20	2.146E-20
Bi210	5.013E+00	d	1.696E-04	1.017E-03	1.774E-03	6.478E-03	2.695E-02	4.922E-02
Bi211	2.130E+00	m	2.578E-03	5.575E-03	6.435E-03	7.443E-03	7.642E-03	7.818E-03
Bi212	6.055E+01	m	5.362E-02	1.629E-04	1.350E-04	5.229E-05	2.256E-06	1.178E-06
Bi213	4.565E+01	m	4.980E-06	5.212E-06	5.587E-06	1.046E-05	7.807E-05	2.681E-04
Bi214	1.990E+01	m	7.072E-04	2.199E-03	3.139E-03	8.043E-03	2.695E-02	4.923E-02
Po210	1.384E+02	d	1.591E-04	1.017E-03	1.774E-03	6.478E-03	2.695E-02	4.922E-02
Po211	5.160E-01	s	7.216E-06	1.561E-05	1.802E-05	2.084E-05	2.140E-05	2.189E-05
Po212	3.000E-07	s	3.436E-02	1.044E-04	8.652E-05	3.350E-05	1.445E-06	7.546E-07
Po213	4.200E-06	s	4.870E-06	5.100E-06	5.466E-06	1.023E-05	7.639E-05	2.623E-04
Po214	1.637E-04	s	7.072E-04	2.198E-03	3.139E-03	8.041E-03	2.695E-02	4.922E-02
Po215	1.778E-03	s	2.578E-03	5.575E-03	6.435E-03	7.443E-03	7.642E-03	7.818E-03
Po216	1.460E-01	s	5.361E-02	1.629E-04	1.350E-04	5.229E-05	2.256E-06	1.178E-06
Po218	3.050E+00	m	7.076E-04	2.199E-03	3.140E-03	8.044E-03	2.696E-02	4.924E-02
At217	3.230E-02	s	4.979E-06	5.212E-06	5.587E-06	1.046E-05	7.807E-05	2.681E-04
Rn219	3.960E+00	s	2.578E-03	5.575E-03	6.435E-03	7.443E-03	7.642E-03	7.818E-03
Rn220	5.561E+01	s	5.361E-02	1.629E-04	1.350E-04	5.229E-05	2.256E-06	1.178E-06
Rn222	3.824E+00	d	7.077E-04	2.199E-03	3.140E-03	8.044E-03	2.696E-02	4.924E-02
Fr221	4.800E+00	m	4.979E-06	5.212E-06	5.587E-06	1.046E-05	7.807E-05	2.681E-04
Fr223	2.180E+01	m	3.550E-05	7.691E-05	8.871E-05	1.027E-04	1.055E-04	1.079E-04
Ra223	1.143E+01	d	2.578E-03	5.575E-03	6.435E-03	7.443E-03	7.642E-03	7.818E-03
Ra224	3.620E+00	d	5.362E-02	1.629E-04	1.350E-04	5.229E-05	2.256E-06	1.178E-06
Ra225	1.480E+01	d	4.981E-06	5.212E-06	5.587E-06	1.046E-05	7.807E-05	2.681E-04
Ra226	1.600E+03	yr	7.075E-04	2.199E-03	3.140E-03	8.044E-03	2.696E-02	4.924E-02
Ra228	5.750E+00	yr	1.431E-08	2.096E-08	2.127E-08	2.162E-08	2.274E-08	2.415E-08
Ac225	1.000E+01	d	4.980E-06	5.212E-06	5.587E-06	1.046E-05	7.807E-05	2.681E-04
Ac227	2.177E+01	yr	2.572E-03	5.573E-03	6.428E-03	7.443E-03	7.643E-03	7.818E-03
Ac228	6.130E+00	h	1.431E-08	2.096E-08	2.128E-08	2.162E-08	2.274E-08	2.415E-08
Th227	1.872E+01	d	2.543E-03	5.498E-03	6.347E-03	7.341E-03	7.537E-03	7.710E-03
Th228	1.913E+00	yr	5.341E-02	1.629E-04	1.350E-04	5.229E-05	2.256E-06	1.178E-06
Th229	7.340E+03	yr	4.980E-06	5.212E-06	5.587E-06	1.046E-05	7.807E-05	2.681E-04
Th230	7.700E+04	yr	1.158E-01	1.167E-01	1.173E-01	1.204E-01	1.331E-01	1.490E-01
Th231	2.552E+01	h	1.222E+01	2.424E-02	2.424E-02	2.425E-02	2.427E-02	2.430E-02
Th232	1.405E+10	yr	2.121E-08	2.129E-08	2.134E-08	2.162E-08	2.274E-08	2.415E-08
Th234	2.410E+01	d	1.301E-01	1.376E-03	1.376E-03	1.376E-03	1.376E-03	1.376E-03
Pa231	3.726E+04	yr	7.442E-03	7.454E-03	7.461E-03	7.496E-03	7.638E-03	7.813E-03
Pa233	2.700E+01	d	3.320E+00	1.187E+00	1.187E+00	1.191E+00	1.202E+00	1.208E+00
Pa234M	1.170E+00	m	1.301E-01	1.376E-03	1.376E-03	1.376E-03	1.376E-03	1.376E-03
Pa234	6.700E+00	h	1.691E-04	1.789E-06	1.789E-06	1.789E-06	1.789E-06	1.789E-06
U232	7.200E+01	yr	2.082E-04	1.576E-04	1.315E-04	5.090E-05	2.204E-06	1.153E-06
U233	1.592E+05	yr	8.096E-06	1.647E-04	2.633E-04	7.832E-04	2.874E-03	5.501E-03
U234	2.445E+05	yr	3.482E+00	3.525E+00	3.547E+00	3.621E+00	3.677E+00	3.674E+00
U235	7.038E+08	yr	2.424E-02	2.424E-02	2.424E-02	2.425E-02	2.427E-02	2.430E-02
U236	2.342E+07	yr	5.645E-02	5.647E-02	5.648E-02	5.654E-02	5.680E-02	5.711E-02
U237	6.750E+00	d	4.981E-04	4.898E-03	1.962E-03	1.593E-05	2.864E-11	2.742E-11
U238	4.470E+09	yr	1.376E-03	1.376E-03	1.376E-03	1.376E-03	1.376E-03	1.376E-03
U240	1.410E+01	h	1.634E-12	5.110E-11	5.110E-11	5.110E-11	5.110E-11	5.110E-11
Np235	3.961E+02	d	1.006E-09	4.726E-18	2.511E-23	0.000E+00	0.000E+00	0.000E+00

Attachment I: Source Listing, Input and Output for FORTRAN Program ROUND (Continued)

Input File aldecay.mod (Continued)

ORIGEN2 V2.1 (8-1-91), Run on 10/09/97 at 15:37:33

			1986	2016	2035	100yr	500yr	1000yr
Np236	1.150E+05	yr	1.289E-05	1.289E-05	1.289E-05	1.288E-05	1.285E-05	1.281E-05
Np237	2.140E+06	yr	1.185E+00	1.187E+00	1.187E+00	1.191E+00	1.202E+00	1.208E+00
Np238	2.117E+00	d	1.964E-04	2.141E-05	1.963E-05	1.244E-05	2.008E-06	2.054E-07
Np239	2.355E+00	d	3.615E-02	4.506E-03	4.498E-03	4.456E-03	4.292E-03	4.095E-03
Np240M	7.400E+00	m	4.089E-10	5.110E-11	5.110E-11	5.110E-11	5.110E-11	5.110E-11
Pu236	2.851E+00	yr	4.465E-05	1.190E-06	1.160E-06	1.159E-06	1.156E-06	1.153E-06
Pu238	8.775E+01	yr	5.640E+02	4.450E+02	3.830E+02	1.738E+02	7.376E+00	1.421E-01
Pu239	2.413E+04	yr	5.712E+01	5.707E+01	5.704E+01	5.688E+01	5.623E+01	5.542E+01
Pu240	6.569E+03	yr	2.271E+01	2.263E+01	2.259E+01	2.235E+01	2.142E+01	2.032E+01
Pu241	1.440E+01	yr	8.462E+02	1.996E+02	7.999E+01	6.492E-01	1.169E-06	1.119E-06
Pu242	3.758E+05	yr	1.711E-03	1.711E-03	1.711E-03	1.711E-03	1.710E-03	1.708E-03
Pu243	4.956E+00	h	1.019E-14	1.019E-14	1.019E-14	1.019E-14	1.019E-14	1.019E-14
Pu244	8.260E+07	yr	5.117E-11	5.117E-11	5.117E-11	5.117E-11	5.117E-11	5.117E-11
Am241	4.322E+02	yr	1.130E+02	1.286E+02	1.286E+02	1.119E+02	5.892E+01	2.643E+01
Am242M	1.520E+02	yr	4.910E-03	4.282E-03	3.927E-03	2.489E-03	4.017E-04	4.108E-05
Am242	1.602E+01	h	4.885E-03	4.261E-03	3.907E-03	2.476E-03	3.996E-04	4.088E-05
Am243	7.380E+03	yr	4.519E-03	4.506E-03	4.498E-03	4.456E-03	4.292E-03	4.095E-03
Cm242	1.628E+02	d	4.045E-03	3.524E-03	3.231E-03	2.048E-03	3.305E-04	3.381E-05
Cm243	2.850E+01	yr	4.761E-04	2.295E-04	1.446E-04	1.270E-05	7.567E-10	3.961E-15
Cm244	1.811E+01	yr	2.228E-02	7.068E-03	3.416E-03	7.434E-05	1.668E-11	8.145E-20
Cm245	8.500E+03	yr	1.217E-06	1.214E-06	1.212E-06	1.203E-06	1.164E-06	1.117E-06
Cm246	4.750E+03	yr	2.781E-08	2.769E-08	2.761E-08	2.721E-08	2.566E-08	2.385E-08
Cm247	1.560E+07	yr	1.019E-14	1.019E-14	1.019E-14	1.019E-14	1.019E-14	1.019E-14
Cm248	3.390E+05	yr	3.172E-15	3.171E-15	3.171E-15	3.171E-15	3.168E-15	3.165E-15
Cf249	3.506E+02	yr	6.561E-15	6.183E-15	5.955E-15	4.887E-15	2.215E-15	8.241E-16
Cf250	1.308E+01	yr	2.576E-15	5.254E-16	1.920E-16	9.581E-19	5.973E-28	1.877E-39
Cf251	9.000E+02	yr	1.685E-17	1.646E-17	1.623E-17	1.502E-17	1.103E-17	7.499E-18
Cf252	2.639E+00	yr	3.445E-17	1.300E-20	0.000E+00	0.000E+00	0.000E+00	0.000E+00
H 3	1.228E+01	yr	2.877E+03	5.341E+02	1.838E+02	6.706E-01	1.190E-10	7.710E-23
Be 10	1.600E+06	yr	8.676E-05	8.675E-05	8.675E-05	8.675E-05	8.674E-05	8.672E-05
C 14	5.730E+03	yr	3.489E-03	3.476E-03	3.469E-03	3.427E-03	3.265E-03	3.073E-03
Se 79	6.500E+04	yr	1.259E+01	1.259E+01	1.259E+01	1.257E+01	1.252E+01	1.245E+01
Kr 81	2.100E+05	yr	4.187E-07	4.186E-07	4.186E-07	4.185E-07	4.179E-07	4.172E-07
Kr 85	1.072E+01	yr	6.425E+04	9.235E+03	2.703E+03	4.190E+00	2.454E-11	2.235E-25
Rb 87	4.730E+10	yr	8.460E-04	8.460E-04	8.460E-04	8.460E-04	8.460E-04	8.460E-04
Sr 90	2.912E+01	yr	1.558E+06	7.631E+05	4.855E+05	4.492E+04	3.293E+00	2.234E-05
Y 90	6.410E+01	h	1.559E+06	7.632E+05	4.856E+05	4.493E+04	3.294E+00	2.234E-05
Zr 93	1.530E+06	yr	6.503E+01	6.503E+01	6.503E+01	6.502E+01	6.501E+01	6.500E+01
Nb 93M	1.360E+01	yr	4.688E+01	5.855E+01	6.055E+01	6.177E+01	6.176E+01	6.175E+01
Nb 94	2.030E+04	yr	6.770E-04	6.763E-04	6.759E-04	6.736E-04	6.644E-04	6.532E-04
Tc 98	4.200E+06	yr	1.989E-05	1.989E-05	1.989E-05	1.989E-05	1.989E-05	1.988E-05
Tc 99	2.130E+05	yr	4.289E+02	4.289E+02	4.289E+02	4.287E+02	4.282E+02	4.275E+02
Rh102	2.900E+00	yr	3.956E-03	3.042E-06	3.243E-08	1.351E-18	0.000E+00	0.000E+00
Ru106	3.682E+02	d	5.493E-02	6.033E-11	1.278E-16	0.000E+00	0.000E+00	0.000E+00
Rh106	2.992E+01	s	5.491E-02	6.033E-11	1.278E-16	0.000E+00	0.000E+00	0.000E+00
Pd107	6.500E+06	yr	4.674E-01	4.674E-01	4.674E-01	4.674E-01	4.674E-01	4.674E-01
Ag108	2.370E+00	m	3.586E-07	3.044E-07	2.744E-07	1.590E-07	1.792E-08	1.170E-09
Ag108M	1.270E+02	yr	4.028E-06	3.420E-06	3.083E-06	1.786E-06	2.013E-07	1.315E-08
Ag109M	3.960E+01	s	4.649E-11	3.618E-18	1.138E-22	0.000E+00	0.000E+00	0.000E+00
Cd109	4.640E+02	d	4.649E-11	3.618E-18	1.138E-22	0.000E+00	0.000E+00	0.000E+00
Ag110	2.457E+01	s	9.898E-11	6.242E-24	2.700E-32	0.000E+00	0.000E+00	0.000E+00
Ag110M	2.499E+02	d	7.442E-09	4.693E-22	2.048E-30	0.000E+00	0.000E+00	0.000E+00
Cd113M	1.360E+01	yr	1.046E+02	2.516E+01	1.020E+01	8.814E-02	4.917E-10	2.370E-20
In115	5.100E+15	yr	4.079E-10	4.079E-10	4.079E-10	4.079E-10	4.079E-10	4.079E-10
Sn119M	2.930E+02	d	5.484E-09	1.892E-22	5.635E-31	0.000E+00	0.000E+00	0.000E+00

Attachment I: Source Listing, Input and Output for FORTRAN Program ROUND (Continued)

Input File aldeca.mod (Continued)

ORIGEN2 V2.1 (8-1-91), Run on 10/09/97 at 15:37:33

			1986	2016	2035	100yr	500yr	1000yr
Sn121M	5.000E+01	yr	1.854E+00	1.223E+00	9.397E-01	2.348E-01	9.134E-04	8.886E-07
Te123	1.000E+13	yr	7.565E-13	7.565E-13	7.565E-13	7.565E-13	7.565E-13	7.565E-13
Sb125	2.770E+00	yr	2.262E+02	1.242E-01	1.070E-03	1.449E-14	0.000E+00	0.000E+00
Te125M	5.800E+01	d	5.517E+01	3.030E-02	2.610E-04	3.536E-15	0.000E+00	0.000E+00
Sn126	1.000E+05	yr	1.120E+01	1.120E+01	1.120E+01	1.119E+01	1.116E+01	1.112E+01
Sb126	1.240E+01	d	1.567E+00	1.568E+00	1.567E+00	1.566E+00	1.562E+00	1.557E+00
Sb126M	1.900E+01	m	1.120E+01	1.120E+01	1.120E+01	1.119E+01	1.116E+01	1.112E+01
I129	1.570E+07	yr	7.013E-01	7.013E-01	7.013E-01	7.013E-01	7.013E-01	7.013E-01
Cs134	2.062E+00	yr	1.039E+02	4.334E-03	7.305E-06	1.838E-20	0.000E+00	0.000E+00
Cs135	2.300E+06	yr	1.095E+01	1.095E+01	1.095E+01	1.095E+01	1.095E+01	1.095E+01
Cs137	3.000E+01	yr	1.650E+06	8.249E+05	5.318E+05	5.276E+04	5.110E+00	4.911E-05
Ba137M	2.552E+00	m	1.561E+06	7.804E+05	5.031E+05	4.991E+04	4.834E+00	4.645E-05
La138	1.350E+11	yr	6.316E-09	6.316E-09	6.316E-09	6.316E-09	6.316E-09	6.316E-09
Ce142	1.050E+11	yr	8.664E-04	8.664E-04	8.664E-04	8.664E-04	8.664E-04	8.664E-04
Ce144	2.843E+02	d	4.296E-03	1.069E-14	4.785E-22	0.000E+00	0.000E+00	0.000E+00
Pr144	1.728E+01	m	4.297E-03	1.069E-14	4.785E-22	0.000E+00	0.000E+00	0.000E+00
Pr144M	7.200E+00	m	5.156E-05	1.283E-16	5.742E-24	0.000E+00	0.000E+00	0.000E+00
Nd144	2.100E+15	yr	4.161E-08	4.161E-08	4.161E-08	4.161E-08	4.161E-08	4.161E-08
Pm146	2.020E+03	d	6.561E-01	1.496E-02	1.365E-03	4.589E-09	0.000E+00	0.000E+00
Sm146	1.030E+08	yr	7.293E-07	7.479E-07	7.483E-07	7.484E-07	7.484E-07	7.484E-07
Pm147	2.623E+00	yr	8.383E+03	3.027E+00	1.999E-02	6.703E-14	0.000E+00	0.000E+00
Sm147	1.070E+11	yr	2.928E-04	2.930E-04	2.930E-04	2.930E-04	2.930E-04	2.930E-04
Sm148	8.000E+15	yr	3.099E-10	3.099E-10	3.099E-10	3.099E-10	3.099E-10	3.099E-10
Sm149	1.000E+15	yr	1.284E-10	1.284E-10	1.284E-10	1.284E-10	1.284E-10	1.284E-10
Eu150	3.600E+01	yr	6.855E-05	3.847E-05	2.669E-05	3.891E-06	1.759E-09	1.160E-13
Sm151	9.000E+01	yr	2.110E+04	1.674E+04	1.446E+04	6.696E+03	3.075E+02	6.536E+00
Eu152	1.360E+01	yr	3.289E+01	7.129E+00	2.707E+00	1.656E-02	2.320E-11	1.989E-22
Gd152	1.080E+14	yr	8.824E-12	9.728E-12	9.883E-12	9.977E-12	9.978E-12	9.978E-12
Gd153	2.416E+02	d	1.292E-10	3.033E-24	7.076E-33	0.000E+00	0.000E+00	0.000E+00
Eu154	8.600E+00	yr	4.326E+03	3.855E+02	8.336E+01	2.634E-02	2.627E-16	8.281E-34
Eu155	4.960E+00	yr	1.523E+03	2.300E+01	1.616E+00	1.375E-06	0.000E+00	0.000E+00
Ho166M	1.200E+03	yr	2.131E-04	2.095E-04	2.072E-04	1.955E-04	1.552E-04	1.163E-04
Tm171	1.920E+00	yr	8.683E-11	1.718E-15	1.814E-18	3.801E-34	0.000E+00	0.000E+00

Attachment I: Source Listing, Input and Output for FORTRAN Program ROUND (Continued)

Output File round.out

ORIGEN2 V2.1 (8-1-91), Run on 10/09/97 at 15:37:33

			1986	2016	2035	100yr	500yr	1000yr
Tl207	4.770E+00	m	1.1E-11	2.4E-11	2.7E-11	3.1E-11	3.2E-11	3.3E-11
Tl208	3.053E+00	m	8.1E-11	2.5E-13	2.1E-13	7.9E-14	3.4E-15	1.8E-15
Tl209	2.200E+00	m	4.5E-16	4.8E-16	5.1E-16	9.6E-16	7.1E-15	2.4E-14
Pb209	3.253E+00	h	2.1E-14	2.2E-14	2.4E-14	4.4E-14	3.3E-13	1.1E-12
Pb210	2.226E+01	yr	7.2E-13	4.3E-12	7.5E-12	2.7E-11	1.1E-10	2.1E-10
Pb211	3.610E+01	m	1.1E-11	2.4E-11	2.7E-11	3.1E-11	3.2E-11	3.3E-11
Pb212	1.064E+01	h	2.3E-10	6.9E-13	5.7E-13	2.2E-13	9.5E-15	5.0E-15
Pb214	2.680E+01	m	3.0E-12	9.3E-12	1.3E-11	3.4E-11	1.1E-10	2.1E-10
Bi210M	3.000E+06	yr	9.1E-29	9.1E-29	9.1E-29	9.1E-29	9.1E-29	9.1E-29
Bi210	5.013E+00	d	7.2E-13	4.3E-12	7.5E-12	2.7E-11	1.1E-10	2.1E-10
Bi211	2.130E+00	m	1.1E-11	2.4E-11	2.7E-11	3.1E-11	3.2E-11	3.3E-11
Bi212	6.055E+01	m	2.3E-10	6.9E-13	5.7E-13	2.2E-13	9.5E-15	5.0E-15
Bi213	4.565E+01	m	2.1E-14	2.2E-14	2.4E-14	4.4E-14	3.3E-13	1.1E-12
Bi214	1.990E+01	m	3.0E-12	9.3E-12	1.3E-11	3.4E-11	1.1E-10	2.1E-10
Po210	1.384E+02	d	6.7E-13	4.3E-12	7.5E-12	2.7E-11	1.1E-10	2.1E-10
Po211	5.160E-01	s	3.1E-14	6.6E-14	7.6E-14	8.8E-14	9.0E-14	9.3E-14
Po212	3.000E-07	s	1.5E-10	4.4E-13	3.7E-13	1.4E-13	6.1E-15	3.2E-15
Po213	4.200E-06	s	2.1E-14	2.2E-14	2.3E-14	4.3E-14	3.2E-13	1.1E-12
Po214	1.637E-04	s	3.0E-12	9.3E-12	1.3E-11	3.4E-11	1.1E-10	2.1E-10
Po215	1.778E-03	s	1.1E-11	2.4E-11	2.7E-11	3.1E-11	3.2E-11	3.3E-11
Po216	1.460E-01	s	2.3E-10	6.9E-13	5.7E-13	2.2E-13	9.5E-15	5.0E-15
Po218	3.050E+00	m	3.0E-12	9.3E-12	1.3E-11	3.4E-11	1.1E-10	2.1E-10
At217	3.230E-02	s	2.1E-14	2.2E-14	2.4E-14	4.4E-14	3.3E-13	1.1E-12
Rn219	3.960E+00	s	1.1E-11	2.4E-11	2.7E-11	3.1E-11	3.2E-11	3.3E-11
Rn220	5.561E+01	s	2.3E-10	6.9E-13	5.7E-13	2.2E-13	9.5E-15	5.0E-15
Rn222	3.824E+00	d	3.0E-12	9.3E-12	1.3E-11	3.4E-11	1.1E-10	2.1E-10
Fr221	4.800E+00	m	2.1E-14	2.2E-14	2.4E-14	4.4E-14	3.3E-13	1.1E-12
Fr223	2.180E+01	m	1.5E-13	3.3E-13	3.8E-13	4.3E-13	4.5E-13	4.6E-13
Ra223	1.143E+01	d	1.1E-11	2.4E-11	2.7E-11	3.1E-11	3.2E-11	3.3E-11
Ra224	3.620E+00	d	2.3E-10	6.9E-13	5.7E-13	2.2E-13	9.5E-15	5.0E-15
Ra225	1.480E+01	d	2.1E-14	2.2E-14	2.4E-14	4.4E-14	3.3E-13	1.1E-12
Ra226	1.600E+03	yr	3.0E-12	9.3E-12	1.3E-11	3.4E-11	1.1E-10	2.1E-10
Ra228	5.750E+00	yr	6.1E-17	8.9E-17	9.0E-17	9.1E-17	9.6E-17	1.0E-16
Ac225	1.000E+01	d	2.1E-14	2.2E-14	2.4E-14	4.4E-14	3.3E-13	1.1E-12
Ac227	2.177E+01	yr	1.1E-11	2.4E-11	2.7E-11	3.1E-11	3.2E-11	3.3E-11
Ac228	6.130E+00	h	6.1E-17	8.9E-17	9.0E-17	9.1E-17	9.6E-17	1.0E-16
Th227	1.872E+01	d	1.1E-11	2.3E-11	2.7E-11	3.1E-11	3.2E-11	3.3E-11
Th228	1.913E+00	yr	2.3E-10	6.9E-13	5.7E-13	2.2E-13	9.5E-15	5.0E-15
Th229	7.340E+03	yr	2.1E-14	2.2E-14	2.4E-14	4.4E-14	3.3E-13	1.1E-12
Th230	7.700E+04	yr	4.9E-10	4.9E-10	5.0E-10	5.1E-10	5.6E-10	6.3E-10
Th231	2.552E+01	h	5.2E-08	1.0E-10	1.0E-10	1.0E-10	1.0E-10	1.0E-10
Th232	1.405E+10	yr	9.0E-17	9.0E-17	9.0E-17	9.1E-17	9.6E-17	1.0E-16
Th234	2.410E+01	d	5.5E-10	5.8E-12	5.8E-12	5.8E-12	5.8E-12	5.8E-12
Pa231	3.726E+04	yr	3.1E-11	3.2E-11	3.2E-11	3.2E-11	3.2E-11	3.3E-11
Pa233	2.700E+01	d	1.4E-08	5.0E-09	5.0E-09	5.0E-09	5.1E-09	5.1E-09
Pa234M	1.170E+00	m	5.5E-10	5.8E-12	5.8E-12	5.8E-12	5.8E-12	5.8E-12
Pa234	6.700E+00	h	7.1E-13	7.6E-15	7.6E-15	7.6E-15	7.6E-15	7.6E-15
U232	7.200E+01	yr	8.8E-13	6.7E-13	5.6E-13	2.2E-13	9.3E-15	4.9E-15
U233	1.592E+05	yr	3.4E-14	7.0E-13	1.1E-12	3.3E-12	1.2E-11	2.3E-11
U234	2.445E+05	yr	1.5E-08	1.5E-08	1.5E-08	1.5E-08	1.6E-08	1.6E-08
U235	7.038E+08	yr	1.0E-10	1.0E-10	1.0E-10	1.0E-10	1.0E-10	1.0E-10
U236	2.342E+07	yr	2.4E-10	2.4E-10	2.4E-10	2.4E-10	2.4E-10	2.4E-10
U237	6.750E+00	d	2.1E-12	2.1E-11	8.3E-12	6.7E-14	1.2E-19	1.2E-19
U238	4.470E+09	yr	5.8E-12	5.8E-12	5.8E-12	5.8E-12	5.8E-12	5.8E-12
U240	1.410E+01	h	6.9E-21	2.2E-19	2.2E-19	2.2E-19	2.2E-19	2.2E-19
Np235	3.961E+02	d	4.3E-18	2.0E-26	1.1E-31	0.0E+00	0.0E+00	0.0E+00

Attachment I: Source Listing, Input and Output for FORTRAN Program ROUND (Continued)

Output File round.out (Continued)

ORIGEN2 V2.1 (8-1-91), Run on 10/09/97 at 15:37:33

			1986	2016	2035	100yr	500yr	1000yr
Np236	1.150E+05	yr	5.4E-14	5.4E-14	5.4E-14	5.4E-14	5.4E-14	5.4E-14
Np237	2.140E+06	yr	5.0E-09	5.0E-09	5.0E-09	5.0E-09	5.1E-09	5.1E-09
Np238	2.117E+00	d	8.3E-13	9.1E-14	8.3E-14	5.3E-14	8.5E-15	8.7E-16
Np239	2.355E+00	d	1.5E-10	1.9E-11	1.9E-11	1.9E-11	1.8E-11	1.7E-11
Np240M	7.400E+00	m	1.7E-18	2.2E-19	2.2E-19	2.2E-19	2.2E-19	2.2E-19
Pu236	2.851E+00	yr	1.9E-13	5.0E-15	4.9E-15	4.9E-15	4.9E-15	4.9E-15
Pu238	8.775E+01	yr	2.4E-06	1.9E-06	1.6E-06	7.3E-07	3.1E-08	6.0E-10
Pu239	2.413E+04	yr	2.4E-07	2.4E-07	2.4E-07	2.4E-07	2.4E-07	2.3E-07
Pu240	6.569E+03	yr	9.6E-08	9.6E-08	9.6E-08	9.4E-08	9.1E-08	8.6E-08
Pu241	1.440E+01	yr	3.6E-06	8.4E-07	3.4E-07	2.7E-09	4.9E-15	4.7E-15
Pu242	3.758E+05	yr	7.2E-12	7.2E-12	7.2E-12	7.2E-12	7.2E-12	7.2E-12
Pu243	4.956E+00	h	4.3E-23	4.3E-23	4.3E-23	4.3E-23	4.3E-23	4.3E-23
Pu244	8.260E+07	yr	2.2E-19	2.2E-19	2.2E-19	2.2E-19	2.2E-19	2.2E-19
Am241	4.322E+02	yr	4.8E-07	5.4E-07	5.4E-07	4.7E-07	2.5E-07	1.1E-07
Am242M	1.520E+02	yr	2.1E-11	1.8E-11	1.7E-11	1.1E-11	1.7E-12	1.7E-13
Am242	1.602E+01	h	2.1E-11	1.8E-11	1.7E-11	1.0E-11	1.7E-12	1.7E-13
Am243	7.380E+03	yr	1.9E-11	1.9E-11	1.9E-11	1.9E-11	1.8E-11	1.7E-11
Cm242	1.628E+02	d	1.7E-11	1.5E-11	1.4E-11	8.7E-12	1.4E-12	1.4E-13
Cm243	2.850E+01	yr	2.0E-12	9.7E-13	6.1E-13	5.4E-14	3.2E-18	1.7E-23
Cm244	1.811E+01	yr	9.4E-11	3.0E-11	1.4E-11	3.1E-13	7.1E-20	3.4E-28
Cm245	8.500E+03	yr	5.1E-15	5.1E-15	5.1E-15	5.1E-15	4.9E-15	4.7E-15
Cm246	4.750E+03	yr	1.2E-16	1.2E-16	1.2E-16	1.2E-16	1.1E-16	1.0E-16
Cm247	1.560E+07	yr	4.3E-23	4.3E-23	4.3E-23	4.3E-23	4.3E-23	4.3E-23
Cm248	3.390E+05	yr	1.3E-23	1.3E-23	1.3E-23	1.3E-23	1.3E-23	1.3E-23
Cf249	3.506E+02	yr	2.8E-23	2.6E-23	2.5E-23	2.1E-23	9.4E-24	3.5E-24
Cf250	1.308E+01	yr	1.1E-23	2.2E-24	8.1E-25	4.1E-27	2.5E-36	0.0E+00
Cf251	9.000E+02	yr	7.1E-26	7.0E-26	6.9E-26	6.4E-26	4.7E-26	3.2E-26
Cf252	2.639E+00	yr	1.5E-25	5.5E-29	0.0E+00	0.0E+00	0.0E+00	0.0E+00
H 3	1.228E+01	yr	1.2E-05	2.3E-06	7.8E-07	2.8E-09	5.0E-19	3.3E-31
Be 10	1.600E+06	yr	3.7E-13	3.7E-13	3.7E-13	3.7E-13	3.7E-13	3.7E-13
C 14	5.730E+03	yr	1.5E-11	1.5E-11	1.5E-11	1.4E-11	1.4E-11	1.3E-11
Se 79	6.500E+04	yr	5.3E-08	5.3E-08	5.3E-08	5.3E-08	5.3E-08	5.3E-08
Kr 81	2.100E+05	yr	1.8E-15	1.8E-15	1.8E-15	1.8E-15	1.8E-15	1.8E-15
Kr 85	1.072E+01	yr	2.7E-04	3.9E-05	1.1E-05	1.8E-08	1.0E-19	9.4E-34
Rb 87	4.730E+10	yr	3.6E-12	3.6E-12	3.6E-12	3.6E-12	3.6E-12	3.6E-12
Sr 90	2.912E+01	yr	6.6E-03	3.2E-03	2.1E-03	1.9E-04	1.4E-08	9.4E-14
Y 90	6.410E+01	h	6.6E-03	3.2E-03	2.1E-03	1.9E-04	1.4E-08	9.4E-14
Zr 93	1.530E+06	yr	2.7E-07	2.7E-07	2.7E-07	2.7E-07	2.7E-07	2.7E-07
Nb 93M	1.360E+01	yr	2.0E-07	2.5E-07	2.6E-07	2.6E-07	2.6E-07	2.6E-07
Nb 94	2.030E+04	yr	2.9E-12	2.9E-12	2.9E-12	2.8E-12	2.8E-12	2.8E-12
Tc 98	4.200E+06	yr	8.4E-14	8.4E-14	8.4E-14	8.4E-14	8.4E-14	8.4E-14
Tc 99	2.130E+05	yr	1.8E-06	1.8E-06	1.8E-06	1.8E-06	1.8E-06	1.8E-06
Rh102	2.900E+00	yr	1.7E-11	1.3E-14	1.4E-16	5.7E-27	0.0E+00	0.0E+00
Ru106	3.682E+02	d	2.3E-10	2.6E-19	5.4E-25	0.0E+00	0.0E+00	0.0E+00
Rh106	2.992E+01	s	2.3E-10	2.6E-19	5.4E-25	0.0E+00	0.0E+00	0.0E+00
Pd107	6.500E+06	yr	2.0E-09	2.0E-09	2.0E-09	2.0E-09	2.0E-09	2.0E-09
Ag108	2.370E+00	m	1.5E-15	1.3E-15	1.2E-15	6.7E-16	7.6E-17	4.9E-18
Ag108M	1.270E+02	yr	1.7E-14	1.4E-14	1.3E-14	7.6E-15	8.5E-16	5.6E-17
Ag109M	3.960E+01	s	2.0E-19	1.5E-26	4.8E-31	0.0E+00	0.0E+00	0.0E+00
Cd109	4.640E+02	d	2.0E-19	1.5E-26	4.8E-31	0.0E+00	0.0E+00	0.0E+00
Ag110	2.457E+01	s	4.2E-19	2.6E-32	1.1E-40	0.0E+00	0.0E+00	0.0E+00
Ag110M	2.499E+02	d	3.1E-17	2.0E-30	8.7E-39	0.0E+00	0.0E+00	0.0E+00
Cd113M	1.360E+01	yr	4.4E-07	1.1E-07	4.3E-08	3.7E-10	2.1E-18	1.0E-28
In115	5.100E+15	yr	1.7E-18	1.7E-18	1.7E-18	1.7E-18	1.7E-18	1.7E-18

Attachment I: Source Listing, Input and Output for FORTRAN Program ROUND (Continued)

Output File round.out (Continued)

ORIGEN2 V2.1 (8-1-91), Run on 10/09/97 at 15:37:33

			1986	2016	2035	100yr	500yr	1000yr
Sn119M	2.930E+02	d	2.3E-17	8.0E-31	2.4E-39	0.0E+00	0.0E+00	0.0E+00
Sn121M	5.000E+01	yr	7.8E-09	5.2E-09	4.0E-09	9.9E-10	3.9E-12	3.8E-15
Te123	1.000E+13	yr	3.2E-21	3.2E-21	3.2E-21	3.2E-21	3.2E-21	3.2E-21
Sb125	2.770E+00	yr	9.6E-07	5.3E-10	4.5E-12	6.1E-23	0.0E+00	0.0E+00
Te125M	5.800E+01	d	2.3E-07	1.3E-10	1.1E-12	1.5E-23	0.0E+00	0.0E+00
Sn126	1.000E+05	yr	4.7E-08	4.7E-08	4.7E-08	4.7E-08	4.7E-08	4.7E-08
Sb126	1.240E+01	d	6.6E-09	6.6E-09	6.6E-09	6.6E-09	6.6E-09	6.6E-09
Sb126M	1.900E+01	m	4.7E-08	4.7E-08	4.7E-08	4.7E-08	4.7E-08	4.7E-08
I129	1.570E+07	yr	3.0E-09	3.0E-09	3.0E-09	3.0E-09	3.0E-09	3.0E-09
Cs134	2.062E+00	yr	4.4E-07	1.8E-11	3.1E-14	7.8E-29	0.0E+00	0.0E+00
Cs135	2.300E+06	yr	4.6E-08	4.6E-08	4.6E-08	4.6E-08	4.6E-08	4.6E-08
Cs137	3.000E+01	yr	7.0E-03	3.5E-03	2.2E-03	2.2E-04	2.2E-08	2.1E-13
Ba137M	2.552E+00	m	6.6E-03	3.3E-03	2.1E-03	2.1E-04	2.0E-08	2.0E-13
La138	1.350E+11	yr	2.7E-17	2.7E-17	2.7E-17	2.7E-17	2.7E-17	2.7E-17
Ce142	1.050E+11	yr	3.7E-12	3.7E-12	3.7E-12	3.7E-12	3.7E-12	3.7E-12
Ce144	2.843E+02	d	1.8E-11	4.5E-23	2.0E-30	0.0E+00	0.0E+00	0.0E+00
Pr144	1.728E+01	m	1.8E-11	4.5E-23	2.0E-30	0.0E+00	0.0E+00	0.0E+00
Pr144M	7.200E+00	m	2.2E-13	5.4E-25	2.4E-32	0.0E+00	0.0E+00	0.0E+00
Nd144	2.100E+15	yr	1.8E-16	1.8E-16	1.8E-16	1.8E-16	1.8E-16	1.8E-16
Pm146	2.020E+03	d	2.8E-09	6.3E-11	5.8E-12	1.9E-17	0.0E+00	0.0E+00
Sm146	1.030E+08	yr	3.1E-15	3.2E-15	3.2E-15	3.2E-15	3.2E-15	3.2E-15
Pm147	2.623E+00	yr	3.5E-05	1.3E-08	8.5E-11	2.8E-22	0.0E+00	0.0E+00
Sm147	1.070E+11	yr	1.2E-12	1.2E-12	1.2E-12	1.2E-12	1.2E-12	1.2E-12
Sm148	8.000E+15	yr	1.3E-18	1.3E-18	1.3E-18	1.3E-18	1.3E-18	1.3E-18
Sm149	1.000E+15	yr	5.4E-19	5.4E-19	5.4E-19	5.4E-19	5.4E-19	5.4E-19
Eu150	3.600E+01	yr	2.9E-13	1.6E-13	1.1E-13	1.6E-14	7.4E-18	4.9E-22
Sm151	9.000E+01	yr	8.9E-05	7.1E-05	6.1E-05	2.8E-05	1.3E-06	2.8E-08
Eu152	1.360E+01	yr	1.4E-07	3.0E-08	1.1E-08	7.0E-11	9.8E-20	8.4E-31
Gd152	1.080E+14	yr	3.7E-20	4.1E-20	4.2E-20	4.2E-20	4.2E-20	4.2E-20
Gd153	2.416E+02	d	5.5E-19	1.3E-32	3.0E-41	0.0E+00	0.0E+00	0.0E+00
Eu154	8.600E+00	yr	1.8E-05	1.6E-06	3.5E-07	1.1E-10	1.1E-24	3.5E-42
Eu155	4.960E+00	yr	6.4E-06	9.7E-08	6.8E-09	5.8E-15	0.0E+00	0.0E+00
Ho166M	1.200E+03	yr	9.0E-13	8.9E-13	8.8E-13	8.3E-13	6.6E-13	4.9E-13
Tm171	1.920E+00	yr	3.7E-19	7.3E-24	7.7E-27	1.6E-42	0.0E+00	0.0E+00
Total			2.7E-02	1.3E-02	8.6E-03	8.5E-04	4.6E-06	3.0E-06

Attachment J

Attachment J: Photon Spectrums in photons/s/g calcine for Al Calcine

AL PHOTON.FP

ORIGEN2 V2.1 (8-1-91), Run on 10/07/97 at 11:36:25

Photon Spectrum fission products in Al calcine in Bin Set #1

EMEAN	1986	2016	2035	100YR	500YR	1000Y
1.000E-02	4.576E+16	2.233E+16	1.421E+16	1.330E+15	1.569E+12	1.381E+12
2.500E-02	9.459E+15	4.613E+15	2.936E+15	2.744E+14	3.726E+11	3.421E+11
3.750E-02	9.951E+15	4.880E+15	3.120E+15	2.981E+14	1.271E+11	1.002E+11
5.750E-02	8.762E+15	4.272E+15	2.718E+15	2.533E+14	1.699E+11	1.500E+11
8.500E-02	5.227E+15	2.543E+15	1.618E+15	1.508E+14	2.513E+11	2.392E+11
1.250E-01	3.426E+15	1.642E+15	1.043E+15	9.680E+13	2.797E+10	2.065E+10
2.250E-01	4.413E+15	2.151E+15	1.368E+15	1.269E+14	3.179E+10	2.228E+10
3.750E-01	1.892E+15	9.230E+14	5.872E+14	5.479E+13	4.565E+11	4.509E+11
5.750E-01	6.049E+16	3.022E+16	1.947E+16	1.931E+15	1.191E+12	1.001E+12
8.500E-01	3.843E+14	1.559E+14	9.632E+13	8.821E+12	5.098E+10	5.016E+10
1.250E+00	1.850E+14	5.650E+13	3.276E+13	2.888E+12	1.242E+10	1.216E+10
1.750E+00	1.032E+13	4.037E+12	2.474E+12	2.244E+11	1.697E+07	5.187E+05
2.250E+00	8.637E+08	4.207E+08	2.676E+08	2.476E+07	1.815E+03	3.277E-02
2.750E+00	4.378E+05	1.073E-02	1.025E-02	1.025E-02	1.025E-02	1.025E-02
3.500E+00	5.708E+04	7.611E-03	7.548E-03	7.548E-03	7.548E-03	7.548E-03
5.000E+00	2.247E-03	2.247E-03	2.247E-03	2.247E-03	2.247E-03	2.247E-03
7.000E+00	1.458E-04	1.458E-04	1.458E-04	1.458E-04	1.458E-04	1.458E-04
9.500E+00	9.219E-06	9.221E-06	9.221E-06	9.221E-06	9.221E-06	9.221E-06

AL PHOTON.ACT

ORIGEN2 V2.1 (8-1-91), Run on 10/07/97 at 11:36:25

Photon Spectrum actinides in Al calcine in Bin Set #1

EMEAN	1986	2016	2035	100YR	500YR	1000Y
1.000E-02	4.620E+12	3.958E+12	3.596E+12	2.243E+12	8.387E+11	5.245E+11
2.500E-02	1.833E+11	1.249E+11	1.250E+11	1.094E+11	5.999E+10	2.973E+10
3.750E-02	2.122E+10	1.760E+10	1.657E+10	1.181E+10	5.043E+09	2.517E+09
5.750E-02	1.561E+12	1.770E+12	1.771E+12	1.541E+12	8.123E+11	3.653E+11
8.500E-02	9.256E+10	2.185E+10	2.167E+10	2.099E+10	2.039E+10	2.044E+10
1.250E-01	1.461E+10	5.050E+09	5.022E+09	4.875E+09	4.481E+09	4.258E+09
2.250E-01	5.468E+09	1.787E+09	1.781E+09	1.806E+09	2.055E+09	2.407E+09
3.750E-01	4.952E+10	1.475E+10	1.479E+10	1.492E+10	1.532E+10	1.573E+10
5.750E-01	8.950E+08	8.829E+07	1.072E+08	2.009E+08	5.682E+08	1.009E+09
8.500E-01	4.335E+08	3.885E+07	4.334E+07	6.306E+07	1.483E+08	2.548E+08
1.250E+00	6.225E+07	2.903E+07	4.089E+07	1.027E+08	3.417E+08	6.235E+08
1.750E+00	7.907E+07	2.279E+07	3.236E+07	8.230E+07	2.753E+08	5.028E+08
2.250E+00	2.284E+06	6.972E+06	9.929E+06	2.535E+07	8.487E+07	1.550E+08
2.750E+00	6.764E+08	2.204E+06	1.902E+06	1.120E+06	1.518E+06	2.723E+06
3.500E+00	3.537E+04	4.749E+04	5.549E+04	1.003E+05	2.896E+05	5.177E+05
5.000E+00	1.142E+04	1.013E+04	9.464E+03	7.222E+03	5.207E+03	4.818E+03
7.000E+00	1.240E+03	1.101E+03	1.031E+03	7.952E+02	5.850E+02	5.442E+02
9.500E+00	1.377E+02	1.224E+02	1.147E+02	8.907E+01	6.633E+01	6.192E+01

Attachment J: Photon Spectrums in photons/s/g calcine for Al Calcine (Continued)

Al photon4.sum

ORIGEN2 V2.1 (8-1-91), Run on 10/07/97 at 11:36:25

Photon Spectrum Al Calcine in Bin Set #1

EMEAN	1986	2016	2035	100YR	500YR	1000Y
1.000E-02	4.576E+16	2.233E+16	1.421E+16	1.332E+15	2.408E+12	1.906E+12
2.500E-02	9.459E+15	4.613E+15	2.936E+15	2.745E+14	4.326E+11	3.718E+11
3.750E-02	9.951E+15	4.880E+15	3.120E+15	2.981E+14	1.321E+11	1.027E+11
5.750E-02	8.764E+15	4.274E+15	2.720E+15	2.548E+14	9.822E+11	5.153E+11
8.500E-02	5.227E+15	2.543E+15	1.618E+15	1.508E+14	2.717E+11	2.596E+11
1.250E-01	3.426E+15	1.642E+15	1.043E+15	9.680E+13	3.245E+10	2.491E+10
2.250E-01	4.413E+15	2.151E+15	1.368E+15	1.269E+14	3.385E+10	2.469E+10
3.750E-01	1.892E+15	9.230E+14	5.872E+14	5.480E+13	4.718E+11	4.666E+11
5.750E-01	6.049E+16	3.022E+16	1.947E+16	1.931E+15	1.192E+12	1.002E+12
8.500E-01	3.843E+14	1.559E+14	9.632E+13	8.821E+12	5.113E+10	5.041E+10
1.250E+00	1.850E+14	5.650E+13	3.276E+13	2.888E+12	1.276E+10	1.278E+10
1.750E+00	1.032E+13	4.037E+12	2.474E+12	2.245E+11	2.923E+08	5.033E+08
2.250E+00	8.660E+08	4.277E+08	2.775E+08	5.011E+07	8.487E+07	1.550E+08
2.750E+00	6.768E+08	2.204E+06	1.902E+06	1.120E+06	1.518E+06	2.723E+06
3.500E+00	9.245E+04	4.749E+04	5.549E+04	1.003E+05	2.896E+05	5.177E+05
5.000E+00	1.142E+04	1.013E+04	9.464E+03	7.222E+03	5.207E+03	4.818E+03
7.000E+00	1.240E+03	1.101E+03	1.031E+03	7.952E+02	5.850E+02	5.442E+02
9.500E+00	1.377E+02	1.224E+02	1.147E+02	8.907E+01	6.633E+01	6.192E+01

Al photons.sum

ORIGEN2 V2.1 (8-1-91), Run on 10/07/97 at 11:36:25

Photon Spectrum for Al Calcine in photons/s/g calcine

EMEAN	1986	2016	2035	100YR	500YR	1000Y
1.000E-02	1.935E+08	9.443E+07	6.010E+07	5.633E+06	1.018E+04	8.056E+03
2.500E-02	3.999E+07	1.950E+07	1.241E+07	1.161E+06	1.829E+03	1.572E+03
3.750E-02	4.207E+07	2.063E+07	1.319E+07	1.260E+06	5.587E+02	4.343E+02
5.750E-02	3.705E+07	1.807E+07	1.150E+07	1.077E+06	4.153E+03	2.179E+03
8.500E-02	2.210E+07	1.075E+07	6.841E+06	6.377E+05	1.149E+03	1.098E+03
1.250E-01	1.449E+07	6.942E+06	4.410E+06	4.093E+05	1.372E+02	1.053E+02
2.250E-01	1.866E+07	9.094E+06	5.784E+06	5.365E+05	1.431E+02	1.044E+02
3.750E-01	8.000E+06	3.903E+06	2.483E+06	2.317E+05	1.995E+03	1.973E+03
5.750E-01	2.558E+08	1.278E+08	8.232E+07	8.164E+06	5.038E+03	4.236E+03
8.500E-01	1.625E+06	6.591E+05	4.072E+05	3.730E+04	2.162E+02	2.132E+02
1.250E+00	7.822E+05	2.389E+05	1.385E+05	1.221E+04	5.396E+01	5.405E+01
1.750E+00	4.363E+04	1.707E+04	1.046E+04	9.491E+02	1.236E+00	2.128E+00
2.250E+00	3.661E+00	1.808E+00	1.173E+00	2.119E-01	3.588E-01	6.553E-01
2.750E+00	2.862E+00	9.319E-03	8.042E-03	4.735E-03	6.418E-03	1.151E-02
3.500E+00	3.909E-04	2.008E-04	2.346E-04	4.241E-04	1.224E-03	2.189E-03
5.000E+00	4.828E-05	4.283E-05	4.001E-05	3.053E-05	2.202E-05	2.037E-05
7.000E+00	5.243E-06	4.655E-06	4.359E-06	3.362E-06	2.473E-06	2.301E-06
9.500E+00	5.822E-07	5.175E-07	4.850E-07	3.766E-07	2.804E-07	2.618E-07

LOCKHEED MARTIN

Lockheed Martin Idaho Technologies Company

INTERDEPARTMENTAL COMMUNICATION

Date: Sep. 23, 1997

To: Daryl A. Lopez MS 3765

From: Leland M. Montierth *LMM* MS 3548

Subject: DETERMINATION OF k_{eff} FOR HIGH LEVEL WASTE CANISTERS
IN VARIOUS CONFIGURATIONS-MNT-03-97.

References: 1. Integrated Data Base Report-1995: U.S. Spent Nuclear Fuel
and Radioactive Waste Inventories, Projections, and Characteristics,
DOE/RW-0006, Rev. 12, Dec. 1996, from Table 2.17.

2. EDF-FDO-001, entitled "Estimates of Feed and Waste Volumes,
Compositions and Property", by C. M. Barnes, Aug. 21, 1997, from
Table 24.

High level waste (HLW) Savannah River Design Vitriified Glass Canisters (VGCs) containing glass made from alumina calcine with actinides were evaluated for criticality concerns. Treated here are the cases of a single VGC with water reflection, a single VGC in a flooded lead cask and an array of 4 VGCs with water, lead and concrete reflection. These cases are used as worst case scenarios to model a single VGC in a Peach Bottom cask and 4 VGCs placed in either a Dual Purpose Canister (DPC), a basket inside a lag storage port in the Dry Transfer Cell (DTC) hot cell, or 4 VGCs placed in a DPC in a NUHOMS module.

Briefly summarized, the specifications are: the VGCs were modeled as cylinders of 24" diameter by 10' tall and composed of glass made from alumina calcine containing actinides; the glass density was taken to be 2.5 g/cm³ (and its composition was Al₂O₃-12.7%, AMP-6.6%, B₂O₃-8.1%, Cs₂O-0.1%, Fe₂O₃-0.1%, Na₂O-18% and SiO₂-54.4%) from Ref. 1; the specific activities of the actinides were taken from Ref. 2; fission products and other non-actinide radioactive nuclides were neglected; since B-10 is a strong neutron poison, the B-10 content of the glass was replaced by B-11; the fissionable, i.e., non-fissile, nuclides were neglected since they can act as poisons in thermal systems; and all structural materials, specifically steel and stainless steel, that compose the VGCs and casks were neglected.

The case of a single VGC with essentially infinite water reflection was evaluated using the SCALE system (KENOVA Monte-Carlo transport code with 44 group cross-sections) and using the conservative assumptions listed above, k_{eff} was found to be 0.0515 ± 0.0002 . This result was compared to the MCNP-4a Monte-Carlo code (continuous cross-sections) which gave a result of 0.0506 ± 0.003 . All other calculations were determined using the SCALE system since it gives statistically equivalent results and requires significantly less run time.

The most reactive case for a single VGC in a lead cask was determined by varying the inside diameter of the cask while keeping the thickness of the lead constant (at essentially infinite thickness) and filling the space between the VGC and fuel with water. The value of k_{eff} was found to be 0.0617 ± 0.0002 which occurred for 1.0 cm of water in the cask. Also, to check the assumption of neglecting the fissionable actinides, a lead cask containing one VGC but no water was evaluated and k_{eff} was found to be 0.0539 ± 0.0002 for both neglecting and not neglecting the fissionable actinides.

Next 4 VGCs were placed in a 2x2 array with infinite water reflection. The most reactive spacing (or pitch) for the VGCs was found to be for the VGCs just touching. For this case k_{eff} was found to be 0.0686 ± 0.0002 . The same array but surrounded by 1 cm of water with lead and concrete reflectors gave values of k_{eff} of 0.0702 ± 0.0002 and 0.0692 ± 0.0002 , respectively. These cases should envelope virtually all cases of 4 intact VGCs contained in any combination of containers, casks and/or wells flooded or dry.

It should be noted that since these codes are validated for critical systems, i.e., $k_{eff} = 1$, and due to uncertainties in the cross-sections that values of k_{eff} this low are somewhat meaningless except to say that the HLW canisters treated here are very subcritical. Therefore, criticality is not a concern for the VGCs in the systems analyzed.

LMM

cc: J. Todd Taylor MS 3548
K. L. Williams MS 3765

Lockheed Idaho Technologies Company

INTERDEPARTMENTAL COMMUNICATION

DATE: January 5, 1998

TO: L.W. Fish, MS 3765 6-1794

FROM: J.W. Sterbentz, MS 3885 6-9810

SUBJECT: NEUTRON DOSE RATE ESTIMATES FOR CANISTERS OF
CALCINE AND SBW TRU-WASTES (JWS-1-98)

REFERENCES:

- (1) Fact sheet provided by L. Fish, December 5, 1997: Revised actinide specific activities (Ci/m³) for three different transuranic high level waste (HLW) compositions.
- (2) A.G. Croff, "A User's Manual for the ORIGEN2 Computer Code", ORNL/TM-7175, July 1980.
- (3) "MCNP4A: Monte Carlo N-Particle Transport Code System", Los Alamos National Laboratory, computer code identification number CCC-200 distributed by Oak Ridge National Laboratory via RSIC.
- (4) ANSI/ANS-6.1.1-1977, "Neutron and Gamma-Ray Flux-to-Dose Factors," American National Standard Institute/American Nuclear Society, 1977.

Introduction

The purpose of this analysis is to estimate maximum contact neutron dose rates (mrem/hr) for an overpack canister/container with different transuranic HLW waste mixtures. The three waste mixtures are: (1) alumina calcine, (2) zirconia calcine, and (3) sodium-bearing waste (SBW). Isotopic nuclide concentrations are per Reference 1.

The alumina and zirconia calcine are evaluated in one type of container and the SBW in another. Waste containers are then placed in the same overpack canister.

The neutrons emanating from the overpack canisters will be the result of both (α, n) and spontaneous fission (SF) nuclear reactions taking place in the transuranic HLW composition.

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Container Descriptions

The waste containers dimensions are per Reference 1.

The cylindrical alumina and zirconia calcine waste container is 45" in length with an inner radius of 11.25" and a total volume of approximately 0.3 m³.

The SBW waste container is 37" in length with a 7.25" inner diameter and total volume of 0.1 m³. The SBW container also fits into the same canister as the alumina and zirconia calcine waste container.

Canister Description

The overpack canister dimensions and construction material are per Reference 1.

The cylindrical overpack canister (into which a single container of either type will fit) is 48" in length with a 12.75" inner diameter and an approximate total volume of 0.4 m³. The canister wall thickness is 0.25" SS304.

(Alpha,n) Neutron Emission from the Waste Compositions

Based on the isotopic actinide alpha activity of the three different waste compositions and the respective container volumes, a conservative estimate of the total alpha activity for each composition is given in Table 1:

Table 1. Container Alpha Activity (disintegrations/sec).

Waste Type	Alpha Activity (dis/sec)
Alumina Calcine	8.99E+11
Zirconia Calcine	8.76E+12
SBW	2.29E+12

If the conservative assumption is made that the alpha particles have 100% interaction with only aluminum atoms in the waste matrix, the (α ,n) neutron emission rate can be conservatively estimated as follows in Table 2:

Table 2. Container Neutron Emission Rate From (α ,n) Reactions.

Waste Type	Neutron Emission Rate (n/sec)
Alumina Calcine	6.65E+05
Zirconia Calcine	6.48E+06
SBW	1.70E+06

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The (α ,n) neutron production rate assuming 100% alpha interaction with aluminum atoms is always higher than interaction with any other major waste constituent, e.g. oxygen, silicon, zirconium, phosphorus, iron, and calcium.

Spontaneous Fission (SF) Neutron Emission from the Waste.
Specific SF neutron emission rates are based on the ORIGEN2 computer code (Reference 2). Table 3 summarizes the SF neutron emission rates for the three different waste compositions in their respective containers.

Table 3. Container Neutron Emission Rate From Spontaneous Fission Reactions.

Waste Type	SF Neutron Emission Rate (n/sec)
Alumina Calcine	4.52E+03
Zirconia Calcine	3.34E+04
SBW	7.34E+03

Results

The total neutron emission rates {(α ,n) plus SF} for the three different waste compositions/container are given in Table 4:

Table 4. Container Total Neutron Emission Rate.

Waste Type	Total Neutron Emission Rate (n/sec)
Alumina Calcine	6.70E+05
Zirconia Calcine	6.52E+06
SBW	1.71E+06

It is clear from Table 4 that the greatest neutron source strength results from a container containing the zirconia calcine waste composition.

Neutron Transport Model

Two basic MCNP4A explicit canister/container geometry models were developed for the two different waste containers in an overpack canister. Neutron transport was performed using the MCNP4A computer code (Reference 3).

The container volume or source region was assumed to have a uniformly distributed neutron source and either an air or concrete matrix filler. The concrete matrix density was taken to be 1.8 g/cc per Reference 1.

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Results

Neutron dose rate estimates are given in Table 5 below for the following four cases:

- Case 1: Uniformly-distributed neutron source in the waste container volume filled with air only (MCNP4A model). Dose rate is calculated on the outer surface of the overpack canister (surface average).
- Case 2: Uniformly-distributed neutron source in the waste container volume filled with 1.8 g/cc concrete (MCNP4A model). Dose rate is calculated on the outer surface of the overpack canister (surface average).
- Case 3: Spherical container. Point neutron source in the center of an air filled sphere of radius equal to the waste container. Dose rate is conservatively calculated on the spherical container surface.
- Case 4: Cylindrical container. Neutron surface source uniformly-distributed on the inside container walls with all neutrons directed radially outward. Dose rate is conservatively calculated on the container surface.

Table 5. Contact Neutron Dose Rates (mrem/hr).

Waste Composition	Case 1	Case 2	Case 3	Case 4
Zirconia Calcine	39.9	26.0	83.8	41.9
SBW	10.7	8.6	52.8	20.7

Cases 3 and 4 are special simplified geometries that allow one to readily hand calculate dose rates and thereby provide an upper bound check on the code calculated results.

The flux-to-dose conversion factors are taken from Reference 4.

Conclusions

Of the three waste types evaluated, the zirconia calcine waste produced the strongest neutron emission rate. The plutonium in the zirconia calcine, particularly the Pu-238 concentration, had the greatest contribution to the source strength. The conservatively estimated neutron emission rates from the (α ,n) reactions are approximately two orders of magnitude greater than the SF rate.

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Canister contact neutron dose rate estimates using the zirconia calcine waste range from approximately 26-84 mrem/hr. Corresponding case dose rates for the alumina calcine are always less than the zirconia calcine results, because of its factor of ten lower neutron emission rate and the fact that these two compositions use the same container (same volume).

The neutron dose rates for the SBW in its own special, smaller container are also less than the zirconia calcine cases again due to the lower estimated source strength.

The case 2 geometry model (Table 5) for the zirconia calcine waste mixed with concrete will ultimately produce the most realistic neutron dose rates. For this case, the contact, surface-averaged neutron dose rate on the overpack canister surface is 26.0 mrem/hr, well below the 270 mrem/hr limit. This result assumes a uniform distribution of the actinides or neutron source in the concrete waste matrix inside the zirconia calcine container.

Cases 3 and 4 although probably not as realistic as Case 2 provide a conservative upper bound that still results in a contact neutron dose rate well below the 270 mrem/hr limit.

The MCNP4A and ORIGEN2 codes are internationally known and widely used computer codes for neutronic and depletion calculations. Both codes are used in the analysis here and are executed on an Hewlett-Packard HP720 workstation. The codes have traceability back to their originators/sponsors and have been fully verified to operate on this type of workstation.

cc: J.W. Sterbentz files MS 3885

ENGINEERING DESIGN FILE

Project/Task Waste Disposal Options

EDF Page 1 of 2

TITLE: Review of ceramic silicone foam for radioactive waste disposal
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Summary: The High-level Waste Program at the INEEL has investigated the use of ceramic silicone foam as a containment and stabilization medium for the disposal of mixed, high-level and low-level radioactive wastes (HLW and LLW). Such mixed wastes are currently stored at the Idaho Chemical Processing Plant as calcine solids and as sodium-bearing liquid waste.

Ceramic silicone foam, chemical name polydimethylsiloxane, is a silicon-containing compound that could be blended with the wastes to be packaged for disposal as LLW in landfills or as HLW in geologic repositories. It can be produced with different densities and by using appropriate additives as getters, can be used to bind chemically specific waste constituents.

No published information could be found describing radioactive-waste immobilization with this material. Most of the information is based on very brief news releases from Orbit Technologies, a company that is marketing the foam as their product, one "white paper" from Ecology and Environment (a company in partnership with Orbit), and conversations with representatives from Orbit, E & E, and Lockheed Martin Idaho Technologies.

Some potential advantages of ceramic silicone foam include the following:

1. It could be used for HLW or LLW, although the Nuclear Regulatory Commission and the Department of Energy would have to approve those applications. It could be used for transuranic wastes, fission products, and residual low-activity wastes, separately or blended together in calcine. A spokesman from Orbit Technologies stated that this foam was tested and used successfully at Chernobyl to help contain radioactive contaminants around the reactor facility and that it has withstood giga-rad doses of gamma radiation.
2. The emptied bin sets and the waste storage tanks at the Idaho Chemical Processing Plant could be filled with low-density, expansive foam.
3. Ceramic silicone foam can be cured at room temperature and atmospheric pressure. Ambient conditions would be more economical to produce an approved substitute for vitrified borosilicate glass, which is approved for HLW disposal. Vitrification requires high-temperature processing and off-gas treatment.
4. According to personnel at Orbit Technologies and Ecology and Environment, a higher density version of ceramic silicone foam could contain from 25 to 70 weight-percent of waste in the mixture; however, this has not been demonstrated. The density of this foam would be roughly the same as that of grout.
5. Orbit Technologies' personnel also claim that ceramic silicone foam is capable of accommodating up to 20 weight-percent liquids; although this would require a longer time to cure the waste form adequately.

Some disadvantages of using ceramic silicone foam for radioactive waste applications are

1. No encapsulation tests are known to have been performed using radioactive wastes. The waste form must be able to pass the toxic characteristic leach procedure.
2. Tests demonstrating long-term stability could be required for the NRC and the DOE to approve this material for use in radioactive waste applications.
3. The cost of ceramic silicone foam required to produce a gallon of waste is estimated to be \$30. A small amount of platinum is used as a catalyst.

Ceramic silicone foam may prove to be an effective solution for radioactive waste disposal, but successful development and long-term testing using real wastes is necessary.

References

1. "Evaluation of an Alternative Stabilization Method for INEL High-Level Waste," Ecology and Environment, November 25, 1996.
2. Telephone conversation with Steve Prewett, Orbit Technologies, April 8, 1997.
3. Telephone conversations with Don Veron, Ecology and Environment, March 10 and March 28, 1997.
4. Conversation with Guy Loomis, LMITCO, April 9, 1997.
5. Telephone conversation with Jim Lahey, president of Orbit Technologies, April 8, 1997.

Distribution (complete package): Distribution (summary page only):		
Author: T.G. McDonald <i>T.G. McDonald 1/27/98</i>	Reviewed: <i>L.W. Fish 2/15/98</i>	Approved: <i>M.E. Russell 2/16/98</i>

Lockheed Martin Idaho Technologies Company**NOTEGRAM**

Date: July 30, 1997
To: Neal Russell
From: Tom McDonald
Subject: Highlights from the July 23 meeting with WIPP representative Mike Brown.

Attendees: Tom McDonald, Brent Helm, Neal Russell, Jila Binaee, Larry Fish, Brent Palmer, Dennis Harrell, Jim Bosley, and Craig Tyler from LMITCO; Mike Brown from DOE-CAO; Jerry Wells from DOE-ID.

WIPP representative Mike Brown was present to answer any questions concerning the proposed disposal at WIPP of the separated transuranic waste (TRUW) derived from the ICPP calcine and sodium-bearing waste (SBW). After he had reviewed the waste-source information and the separations process that would produce the TRUW, he indicated that WIPP should be able to accept the TRUW for disposal. A significant criterion for the acceptance of the TRUW is that it be originated from defense-related activities. Although WIPP will not accept HLW, Brown believes that the separation process option would be sufficient to produce waste from the HLW that could be defined as TRUW.

Since WIPP would pay for disposal, transportation, and shipping cask costs, no TRUW disposal costs would be incurred by INEEL with disposal of TRUW at WIPP. The scheduled starting date of 2011 for the TRUW processing would mesh well with the earliest acceptance date at WIPP for this waste. Brown stated that sufficient disposal space would be available for the estimated volume of TRUW (approximately 100 m³ or 209 canisters) for remote-handled waste as well as contact-handled. When Brown was informed of another disposal option that would result in 1800 m³ of remote-handled waste from calcined SBW, he stated that sufficient space could be available for disposal.

He suggested that INEEL submit an issue paper to WIPP soon so that WIPP could offer guidance to proceed with disposal studies without publicizing INEEL's intentions. He wants to see a draft copy of the INEEL EIS when it is completed so that he could offer further review and guidance to avoid undesirable political and legal barriers.

TGM 7/9/97

HLW = High-level waste

LLW = Low-level waste

ORNL = Oak Ridge National Lab

* Proposed waste disposal plan

Memo from T.G. McDonald

Date: August 19, 1997

To: N.E. Russell

Subject: Reconstructed questions and answers from the July 23 meeting with WIPP representative Mike Brown

The following is a list of the most important questions asked of and answered by Mike Brown of the Waste Isolation Pilot Plant. I no longer have my original list of questions that I had written prior to the meeting. With the help of L.W. Fish and our meeting notes, I reconstructed a list of questions and answers and sent them to Mike Brown for his comments, which are incorporated herein.

Q1. We sent you (WIPP) a simple diagram depicting the origins of our high-level waste (HLW) and our proposed method for separating the transuranic (TRU) waste from the rest of the HLW. Do you think that our separated TRU waste would be acceptable for disposal at WIPP?

A1. Probably. Our primary acceptance criterion for TRU waste is that it originate from defense-related activities. Based on the statement that nearly all of the INEEL's waste comes from the reprocessing of spent nuclear fuel for the Navy and from reactor experiments and materials tests for the Navy, we believe that INEEL's separated TRU waste meets that acceptance criterion.

Q2. We understand that WIPP will not accept HLW. Our calcined waste is considered to be HLW, but we plan to process it in such a way that we will separate the TRU from the rest of the waste, leaving a remainder of fission products and some RCRA metals. Will WIPP accept for disposal our TRU waste that has been separated from our HLW?

A2. Your TRU wastes that have been separated from HLW could be acceptable at WIPP, as long as it meets our other acceptance criteria such as plutonium-equivalent curie limits, fissile-gram-equivalent limits for plutonium, contact dose limits for remote or contact-handled containers, and others detailed in the waste acceptance criteria document.

Q3. We also plan to separate TRU waste from our low-level waste known as sodium-bearing waste (SBW). This SBW results from decontaminating our calcining equipment; therefore, that TRU has the same origins as the HLW. Will WIPP accept TRU waste separated from our SBW?

A3. Probably, as long as it meets all waste acceptance criteria, including minimum concentration limits.

Q4. If we were to send our HLW to Yucca Mountain's disposal site, we would have to pay a share of that site's development costs in the form of disposal fees. What would our disposal costs be at WIPP for our separated TRU waste?

A4. None. WIPP is fully funded and would charge you nothing for disposal costs. WIPP will also provide you with shipping casks, free of charge, and will also cover the transportation costs.

Q5. We believe that all of our separated TRU waste will require remote handling (R.H.). Our projected TRU volume is approximately 100 cubic meters, requiring more than 200 remote-handled canisters. We may also process the SBW-TRU differently, creating an additional 1800 cubic meters of TRU waste for disposal. Is there a volume limit at WIPP for R.H.-TRU waste?

A5. We have in the Consultation and Cooperation Agreement with the state of New Mexico a volume limit of 7080 cubic meters for R.H.-TRU. Your 100 to 200 cubic meters of TRU waste could be readily accommodated, and we could probably accommodate the 1800 cubic meters of SBW-TRU, if necessary.

Q6. Our TRUEX separations facility will not be operational until 2011. Will WIPP have space available for our waste then?

A6. Probably. So long as we know well in advance, we can accommodate your disposal needs. The 2011 date actually fits our (WIPP's) schedule well, due to disposal commitments to Oak Ridge and others.

Q7. What is necessary to obtain disposal approvals from WIPP?

A7. Continue to work informally with us for now. Send us your draft environmental impact statement and draft waste disposal document so that we can offer further review and guidance.

Date: June 11, 1997

Project File Number: 73301
EDF Serial Number: EDF-FDO-007
Functional File Number: SPR-02

ENGINEERING DESIGN FILE

Project/Task: Waste Disposal Options

EDF Page 1 of 1

TITLE: Epoxies for low-level radioactive waste disposal

Summary: Epoxies are organic compounds consisting of thermosetting resins that can form cross-linked polymers. Many epoxies are resistant to most chemicals; however, most organics are susceptible to radiation damage. Polyimide is an organic used in elastomer seals that can withstand gamma-radiation doses of ten billion rads and remain usable. Unfortunately, no test results could be found that show that epoxies had been used to encapsulate low-level radioactive materials. Since such waste materials must be contained safely for thousands of years, meaningful test data are unlikely to be available for use in the design of the low-level, radioactive-waste treatment facilities at the INEEL.

Richard Boardman and T.D. Thomson (letter to D.V. Croson entitled Low-Level Waste Stabilization at the ICPP, dated September 29, 1994) discuss various materials and processes to contain low-level radioactive wastes. Included is a discussion of the advantages and disadvantages of the organic polyethylene (low and high-density) as an encapsulant. Polyethylene is a thermoplastic material and not a true epoxy, that has withstood cumulative radiation doses of 100 million rads, but has not been tested for alpha-emitting radiation. This material can contain 70 weight-percent wastes. However, long-term test results of low-level rad-wastes containing RCRA metals is sparse. Much more testing and development must be done before polyethylene could be recommended for this application.

Polydimethylsiloxane, referred to as ceramic silicone foam, could be considered a hybrid epoxy because it is not an organic hydrocarbon; its properties are typical of inorganic compounds. More information for this material is discussed by T.G. McDonald in EDF-FDO-005.

Distribution (complete package):
Distribution (summary page only):

Author:

T.G. McDonald 2/5/98

Reviewed:

L.W. Fish 2/5/98

Approved:

M.E. Russell 2/6/98

Project File Number 02BB0

Project/Task EIS Options Process Evaluations

Subtask Neutralization Options

Title: Evaluation of Several Neutralization Cases in Processing Calcine and Sodium-Bearing Wastes

Summary: This EDF briefly evaluates several neutralization cases for treatment of calcine and sodium bearing wastes (SBW).

Neutralization of low activity wastes produced either in the Full Separations Option or the TRU Separations Option is not justified. Although neutralization has the advantage of eliminating denitration equipment, the incremental disposal costs for the increased grout volumes are about \$350 million greater than denitrator savings for the Baseline Separations Option and \$210 million greater for the TRU Separations Option.

Neutralization of SBW is not applicable to the Cementitious Waste Option because the waste liquid is needed to leach calcine. Neutralization of SBW is not justified for the Vitrified Waste Option or the HIP Waste Option because costs for grout disposal and the facility needed to produce the grout are estimated to be much greater than savings in vitrification, HIPing, and NWCF operating costs. Neutralization of SBW has a significant cost advantage for the Direct Cementitious Waste Option if costs for NWCF modifications to comply with the proposed Maximum Achievable Control Technology rules are included in the evaluation.

Neutralization of SBW in the Separations Options is not viable unless a greater than Class C grout is an acceptable product. Cost savings for SBW neutralization applied to the TRU Separations Option are on the order of \$50 million. For the Full Separations Option, the cost differences are negligible.

Distribution (complete package): B. R. Helm, D. J. Harrell, W. H. Landman, T. G. McDonald, N. E. Russel, K. L. Williams

Distribution (summary package only): J. J. McCarthy

Author C. M Barnes <i>CMBarnes</i>	Dept. 4170	Reviewed T. G. McDonald <i>T.G. McDonald</i>	Date Nov 25, 1997	Approved W. H. Landman <i>WHL</i>	Date Nov 25, 1997
11/25/97		LMITCO Review 11/25/97	Date	LMITCO 11/25/97 Approval	Date

Neutralization followed by grouting has been suggested as a potential treatment for

- 1) Low activity wastes (LAW) generated in separation alternatives, and
- 2) Sodium bearing waste (SBW).

In the case of LAW, neutralization would replace denitration. If used to treat SBW, neutralization would reduce the amount of feed to any of the non-separations or separations options.

Neutralization of LAW in the Full Separations Alternative

The bases for estimating quantities and compositions of grout produced by neutralization of LAW are:

- 1) FY-97 LAW Grout Stabilization Development Program test results¹
- 2) The full separations option material balance.²

FY-97 tests of grouting neutralized, simulated LAW showed that an acceptable grout could be produced neutralizing the waste to a pH of 1.3, using a waste loading of 30 wt%, and a grout formulation of 1 part Portland cement, 3 parts blast furnace slag, and 1 part flyash.¹

Estimates of the quantity of grouted waste that would be produced for the neutralization case of the baseline separations alternative were made using material balances contained in CMB-01-97.² Initial calculations were made in which denitrator feed was neutralized to a pH of 1.3 with 50% caustic and then grouted with a waste loading of 30%. This resulted in grout volumes of 33,000 m³ for SBW and about 540,000 m³ for calcine.

To reduce these volumes, a second method for calculating grouted waste volumes was used, which assumed the LAW was evaporated after neutralization. The neutralized waste was evaporated to a concentration of 520 g/l solids, with an assumed density of 1250 g/l. Calculations of grout volume for this method are summarized in Table 1.

¹ A. K. Herbst, *FY-97 Status Report on the Low-Activity Waste Grout Stabilization Development Program*, AKH-02-97, October 20, 1997.

² C. B. Barnes, , D. D. Taylor, B. R. Helm, *Transmittal of Process Basis Information for the Feasibility Study of the Preferred Alternative for Treatment of ICPP Sodium-Bearing Wastes, Calcine, and Low-Level Wastes*, CMB-01-97, April 16, 1997.

Table 1. Estimated Grout Quantity from Neutralization of LAW in Baseline Separations Alternative.

	SBW (total 2-yr production quantities)	Calcine (total 20-yr production quantities)
Moles of H ⁺ in LAW	17,800,000	328,000,000
Moles NaOH to Neutralize 98% of acid	17,440,000	321,000,000
Kg of Na in NaOH	401,000	7,390,000
Kg nitrates in LAW	2,560,000	35,200,000
Kg other solids in LAW	596,000	6,870,000
Total kg solids	3,557,000	49,460,000
Liters of waste @ 520 g solids per liter	6,840,000	95,100,000
Kg liquid waste to grouting @ 1.25 kg/l	8,550,000	119,000,000
m ³ of grout at 30 wt % loading and 1800 kg/m ³	16,000	220,000

The quantities of grout produced if the LAW is denitrated are about 3200 m³ from SBW and 23,000 m³ from calcine. Thus the incremental grout production is 16,000 + 220,000 - 3200 - 23,000 = 210,000 m³.

The major cost differences between the full separations facilities and the same facilities modified to neutralize rather than denitrate LAW are:

1. The cost for disposal of the incremental grout volume for the neutralization case
2. The capital cost savings of the denitration system not required for the neutralization case
3. The operating cost savings of the denitration system not required for the neutralization case
4. The operating cost of the grout facility due to the higher production rate for the neutralization case.

Various landfill concepts are discussed in the *Waste Disposal Options Feasibility Study*, in draft form at this time. For grout produced by WTF separations alternatives, a design based on 50,000 m³ of class A and C grout was estimated to have a total estimated cost of \$102 million.³ Based on this estimate, the cost per m³ is about \$2000 and the disposal cost for the incremental 210,000 m³ of grouted waste is \$420 million.⁴

³ D. T. Peterson, J. R. Baker, *Class A/C Low Level Waste Landfills*, DTP-36-97 & JRB-59-97, July 21, 1997.

⁴ The value of \$2000 per cubic meter is conservative, as other concepts discussed in the *Waste Disposal Options Feasibility Study* have costs of \$2750 to \$5000 per cubic meter.

The capital cost estimate for the entire LAW Treatment Facility, which includes a the treatment building as well as denitration and grouting units, as given in the Fluor 90% Design WTF Feasibility Study Report, is \$152 million. The cost for denitration and off-gas treatment is about \$69 million, based on multiplying the total LAW Facility cost by the ratio of the estimated denitration and offgas treatment equipment costs to the estimated total equipment cost.

The grouting equipment is sized such that in the Fluor WTF design, denitrated waste solids are collected over a month's time and then grouted in approximately 16 hours. In the case of neutralization, the increased grout production would increase the operation to approximately 150 hours per month. This is well within the capability of the equipment with no modifications required. However, the additional operation time will result in additional operations costs. Savings in operation costs would be realized from the elimination of denitration and offgas treatment.

The 90% WFT design estimates the labor requirement for the LAWT to be 38 full-time equivalents (FTEs). The LAWT facility contains 8 cells, 5 with denitration and offgas treatment equipment and 3 with grouting equipment. If the manpower was proportional to the number of cells, then 24 ($38 \times 5/8$) would be associated with denitration and 14 with grouting. However, since the grouting equipment operates only 16 hours per month, not including time for washing between batches, and the denitration equipment operates full time, assume that 31 FTEs are associated with denitration and 7 with grouting.

If washing and decontamination takes 16 hours every grout batch, the neutralization case would increase operational time from 32 hours (16 hours producing grout plus 16 hours clean-up) to 166 hours (150 hours producing grout plus 16 hours clean-up), or a factor of 5.2. The increase in manpower will be approximately the same as this factor, thus will increase from 7 to 36. Savings in labor costs from a reduction in manpower from 38 to 36 FTE's is about \$200,000 per year, or \$4.4 million over 22 years. Thus the total cost differential for the neutralization option for the Full Separations Option is $\$420 - \$69 - \$4.4 = \347 million.

As a check on the sensitivity of these assumptions, suppose the neutralization case showed a 50% net savings in operative cost. According to the 90% design, the total annual operating cost for the LAWT facility is \$11.75 million. A 50% savings is thus about \$6 million per year. The net cost would then be $\$420 - 69 - 6 \times 22 = \219 million, or the payout time $(420-69)/6 = 58$ years. Thus neutralization of LAW is not justified for Full Separations, and this conclusion is not sensitive to the assumptions.

Neutralization of LAW in the TRU Separations Alternative

Estimates of the volume of grout that would be produced from the TRU Separations processes if LAW waste was neutralized rather than denitrated were made using the following assumptions:

1. Neutralization before evaporation
2. 98% neutralization with 20 wt% caustic (to a pH of ~1.3)
3. Evaporation to 520 g/l solids
4. 30 wt% loading of concentrated waste liquid in grout
5. Grout formulation of 1:3:1 Portland cement:blast furnace slag:flyash.

Based on LAW flowrates and compositions from the material balance for the TRU Separations Class C Grout Option, the following volumes of grout would be produced:

From SBW LAW	10,000 m ³
From Alumina Calcine LAW	42,000 m ³
From Zirconia Calcine LAW	<u>110,000 m³</u>
Total	162,000 m ³ .

The grout volume for the TRU Separations case with denitration is 22,400 m³, thus the incremental volume is about 140,000 m³. The incremental cost of a landfill for this volume is \$280 million.

The resultant grout is well under Class C limits, and, except for Cs-137 for alumina calcine, is below Class B limits, as shown below:

	Class C	Class B	Zr Calcine	Al Calcine	SBW
	Limit	Limit	Ci/m3	Ci/m3	Ci/m3
Ni-63	700	70			0.02
Sr-90	7,000	150	57	107	16
Cs-137	4,600	44	43	117	17
Tc-99	3	0.8	0.01	0.06	0.004
I-129	0.08	0.3			0.001
			nCi/g	nCi/g	nCi/g
Pu-241	3500	350	<1	<1	<1
Total alpha	100	10	<1	<1	<1

The estimated cost of the denitration and offgas system for the TRU Separations case is \$70 million. Thus the incremental capital cost for the neutralization case is about \$210 million.

Operating cost differences between the two cases are similar to the Full Separations Option discussed above. The denitrator is smaller than for the Full Separations Option, giving less savings from reduced denitrator operations costs, but the relative increase in grout production is also smaller. The net difference in operating costs between denitration and neutralization are expected to be small. Because of an incremental capital cost of \$210 million and no significant operating cost savings, neutralization of LAW for the TRU Separations Option is not justified.

Neutralization of Sodium Bearing Waste

Another case that has been proposed is neutralization of SBW. This case eliminates calcination of SBW for the non-separations options and eliminates the processing of SBW through separations units for the separations options. The costs and benefits of this concept vary from option to option.

The Cementitious Waste Option uses SBW to remove leachable metals from calcine prior to recalcination. Fresh acid could be used in place of SBW, but this would only increase costs with no identifiable advantage. Thus grouting of the SBW is not applicable to this option.

The volume of grout resulting from neutralization of SBW would be about 6000 m³, using the same assumptions as above for neutralization of LAW. Nitrates in SBW would account for about 72% of the total neutralized waste solids, while sodium from caustic would account for 8% and all solids other than nitrates in SBW would account for the remaining 20%.

The volume of grout produced from SBW in the Direct Cementitious Waste Option (DCWO), if the SBW is first calcined, is about 1400 m³. Thus the incremental grout production is 4600 m³, and the incremental cost of a landfill for this volume is about \$9.2 million. The SBW would be calcined in the existing calciner, the NWCF. However, to process SBW modifications are needed, estimated to have a total project cost of \$4.5 million.⁵ Additional equipment to handle and provide temporary storage for the liquid SBW would be needed in the DCWO that would not be needed if the SBW was calcined. Also, to produce the increased grout volume, either the plant size would need to increase or the plant would need to operate for a longer period. For the later, operations costs would increase for the neutralization case over the calcine case by about 35%, based on the ratio of grout volumes, although some savings may be realized from an early shutdown of the calciner. Since the landfill cost for the incremental grout volume exceeds the cost of calciner modifications, neutralization would not be justified for the DCWO.

⁵ H. Welland, *NWCF Process Modification for Sodium-Bearing Waste Project Conceptual Design*, Final, INEL/INT-97-00075, April, 1997.

In the Vitrified Waste Option (VWO) and the Hot Isostatic Press Waste Option (HWO) no grout is produced. Thus if the SBW was grouted and integrated with these options, a new grout facility would be needed rather than incremental capacity to an otherwise existing facility. The cost of a landfill for the grout would be about \$12 million. If SBW is grouted rather than vitrified or HIPed, the glass waste from the VWO would decrease by about 11%, or the HIPed waste volume would decrease by about 13%. It is difficult to predict with any certainty at this time the repository disposal cost for the glass or HIPed waste. However, it appears reasonable that the \$12 million landfill cost plus the cost of a grout plant would exceed the savings from NWCF modifications (\$4.5million) plus marginal savings in the vitrification or HIPing facilities due to the small decrease in capacity plus the marginal savings in disposal cost.

One final consideration in the evaluation of this suboption for the nonseparations options is the issue of Maximum Achievable Control Technology (MACT) compliance. Modification of the NWCF to meet MACT requirements have been estimated to have a total project cost of \$65 million.⁶ The VWO and HWO options would likely have equipment similar to the modifications proposed for the NWCF to meet MACT requirements, but the DCWO would not. If neutralization of SBW would avoid the cost of MACT modifications, neutralization may be justified over calcination of the SBW for the DCWO.

The separations options present some differences compared to the nonseparations options in the analysis of the SBW neutralization concept. Both Full and TRU Separations options assume that SBW will take two years of operation, and both have grouting facilities that are under-utilized. If the grout plant in the Full Separations 90% design is operated full-time, processing the SBW would take 55 days, allowing for time to decontaminate equipment between batches equal to 50% of the time in which grout is processed. The estimated operating cost for two years for the Separations Facility and the LAW Treatment facility of the Full Separations Option is \$110 million.⁷ The incremental grout volume is about 3200 m³, equivalent to an incremental landfill cost of \$6.4 million.

Since the Full Separations LAW Treatment Facility is designed for production of Class A grout, modifications would be needed to produce higher activity grout from SBW. A cost estimate for these modifications is given in the Fluor 90% design, Table I-18.11, and is \$101 million. The net cost difference is thus $101 + 6.4 - 110 = -\$2.6$ million, a value too small to provide a basis for justifying or rejecting the neutralization concept. Some additional saving would be realized from reduced equipment sized for the denitration system, which is controlled by the SBW case.

⁶ R. D. Adams, *Process Sodium Bearing Waste - Maximum Achievable Control Technology Compliance Project*, RDA-20-97, August 12, 1997.

⁷ Fluor Daniel, Inc., *Idaho Chemical Processing Plant Waste Treatment Facilities Feasibility Study Report*, 90% Design Review, October, 1997, Table 11.3.1.

The major issue in regard to SBW neutralization for the Full Separations Option is whether two types of grout are acceptable. Grout from calcine would be Class A, while grout from SBW would be greater than Class C because of its total alpha content. While all individual radionuclide concentrations are less than Class C limits, the total alpha content is about double the Class C limit. Unless the SBW grout could be blended with Class A waste (or SBW blended with LAW), the neutralization scheme does not appear viable for the Full Separations case, because of the production of greater than Class C grout.

If the neutralization scheme was applied to the TRU Separations Option which produces a Class C grout, there would not be the incremental cost for added shielding in the grout facility that would be incurred for the Baseline Separations Option. Savings in operations cost is estimated to be about \$55 million. Thus there is a cost incentive for the neutralization option. However, the grout produced from SBW would have the same radionuclide content as discussed above, and because of total alpha content, would be classified as greater than Class C.

Date: January 22, 1998

ENGINEERING DESIGN FILE

Project/Task Waste Disposal Options

EDF Page 1 of 2

TITLE: Background information for FGEs, dose rates, watts/canister, and PE-curies

Summary: This EDF documents the bases for some radiological data used in report INEEL/EXT-97-01145.

Radioisotope concentrations in the waste forms produced by the various, proposed options

The concentrations of radioisotopes in each of the waste forms were calculated by C.M. Barnes [EDF-FDO-001-Rev.1]. Barnes obtained data from D.R. Wenzel [EDF-FDO-003 & -004] for the zirconia and alumina calcine, and from R.J. Rivard [R.J. Rivard to J.A. Murphy, RJR-06-94, July 25, 1994] for the sodium-bearing waste. To correspond with the assumed starting date for waste processing, the data have been decayed to 2016. Much uncertainty exists in the data because actual samples were not routinely analyzed for isotopes or their concentrations. Core samples were taken in 1979 from Bins 3 and 7 in Bin Set 2, which contain alumina and zirconia calcine, and analyzed. Those analyses are the primary bases for Wenzel's zirconia and alumina calcine data, although the radiological properties of the zirconia and alumina calcines in other bin sets may not be the same those in Bin Set 2. Wenzel included the daughter products generated during the decay of specific radionuclides. Most of the isotope data from spent nuclear fuel from Navy reactors were estimated from the atom-percent burnups provided by the Navy.

FGE, PE-curie, and criticality calculations

The Waste Isolation Pilot Plant (WIPP) is the pending disposal site for defense-related transuranic (TRU) wastes. The published waste acceptance criteria of April, 1996, for the WIPP specifies that TRU waste concentrations may not exceed specified criticality limits of fissile-gram-equivalents of Pu-239 (600 FGE per canister, 325 FGE per 72-B shipping cask for remote-handled TRU), and specified activity limits of plutonium-equivalent curies (1000 PE-curies per canister for RH-TRU). All of the TRU from the HLW at the ICPP is considered to be remote-handled because it exceeds the contact-dose-rate-per-canister limit of 200 mrem/hr for contact-handled TRU. Each canister sent to the WIPP is limited to 325 FGE because of the 72-B cask transportation limit. Attached to this EDF are the calculations for FGE and PE-curies. Data from Barnes' EDF-FDO-001-Rev-1 (using the Wenzel modifications to the zirconia and alumina calcine data) and from the TRUPACT-II SAR-Rev.1 of May, 1989, were used in the FGE calculations. Data from Barnes' EDF and from Appendix A of the WIPP's acceptance criteria were used to calculate the PE-curies. TRU-waste-loading per canister and the number of canisters were based on FGE limits.

L.M. Montierth calculated the criticality coefficient, k_{eff} , to be 0.07 for a canister of vitrified HLW processed via the Full-Separations Option using alumina calcine. That value is well below the maximum allowable value of 0.95 [Interdepartmental Communication from Montierth to D.A. Lopez, MNT-03-97, September 23, 1997]. Although the vitrified, high-activity waste from the zirconia calcine would have a higher concentration of fissile material than that from the alumina calcine, Montierth does not believe that the k_{eff} would be significantly higher.

Dose rates, and watts per canister

The dose rates at contact (1 cm) and at 1 meter, and the decay-heat generation (watts/canister) of each waste form were calculated by H.K. Peterson [Interdepartmental Communication, H.K. Peterson to T.G. McDonald, HKP-26-97 December 4, 1997] using Microshield software, version 5.01. Barnes' isotope concentrations and waste-form densities for a specific amount of waste loaded in a particular type of

canister were used. For all waste forms except the low-activity grout from the separations processes, he used the stainless-steel, Savannah-River canister (24-inch outside diameter, 10 feet long, 3/8-inch wall thickness), each loaded with 0.72 m³ of final product. The low-activity, grouted wastes were modeled as being in 4-inch thick concrete containers, each containing 1 m³ of grouted waste. The same software was used to calculate the decay-heat generation. The only waste form that exceeds the HLW repository's limits for dose rate (160,000 rem/hr calculated versus 100,000 rem/hr) and watts per canister (12,350 calculated versus 1,500) is the vitrified-high-activity waste, Cs and Sr from the alumina calcine, from the TRU-Separations-Class-A-Grout Option. This represents the maximum activity because one would not likely retrieve a batch of pure alumina calcine without a mixture of some other calcines to dilute the concentrations of radionuclides. In contrast, the vitrified-high-activity wastes from the zirconia calcine and the sodium-bearing waste have calculated activities well below those limits.

Neutron dose rates for TRU waste

The WIPP criteria require that the neutron contribution to the total dose rate per canister shall not exceed 270 mrem/hr. J.W. Sterbentz [Interdepartmental Communication, J.W. Sterbentz to L.W. Fish, JWS-1-98, January 5, 1998] configured specific amounts of dry, TRU-waste centered within the WIPP's stainless-steel, half-canister (26-inch O.D., 52 inches long, 1/4-inch wall thickness, and 0.4 m³ capacity) to confirm that the neutron dose rate would be below that limit. He modeled 0.3 m³ of dried, TRU-waste extracted from the zirconia and alumina calcine, and 0.1 m³ of dried, TRU-waste extracted from the sodium-bearing waste. The dried, TRU waste is assumed to have a density of 1.5 grams/cm³.

Waste-form loading and numbers of canisters

Except for the hot-isostatic-press (HIP) waste forms, the dried-TRU waste forms, and the grouted low-activity waste forms, a waste loading of 0.72 m³ per canister (96% of that canister's total capacity) was used. TRU-waste loadings in the WIPP's half-canister are limited by calculations of FGE as follows: 0.1 m³ for TRU from sodium-bearing waste, and 0.25 m³ for TRU from zirconia or alumina calcine. In the HIP-Waste Option, each canister would contain three processed HIP-cans, each HIP-can containing 0.2 m³ of HIP-waste, for a total of 0.6 m³ per canister. To determine the number of canisters required for each of the final disposal options, the total estimated volume of waste produced by each option was divided by the waste-loading per canister.

Attachments: FGE and PE-curies calculations

Table 10.1 FGE and specific activities from TRUPACT-II SAR Rev.1

Appendix A from the WIPP WAC, April, 1996

Interdepartmental Communication from L.M. Montierth to D.A. Lopez, *Determination of k_{eff} for High Level Waste Canisters in Various Configurations*, MNT-03-97, Sept. 23, 1997

Interdepartmental Communication from J.W. Sterbentz to L.W. Fish, *Neutron Dose Rate Estimates for Canisters of Calcine and SBW TRU-Wastes*, JWS-1-98, January 5, 1998

Distribution (complete package): Distribution (summary page only):		
Author: T.G. McDonald	Reviewed: L.W. Fish	Approved: N.E. Russell
<i>T.G. McDonald 2/5/98</i>	<i>L.W. Fish 2/5/98</i>	<i>N.E. Russell 2/6/98</i>

EGF calculations	Tom McDermid 1/6/98 TRU-5eps options
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$$\overline{I_{SE}} = \overline{C/m^3} \times \overline{FGF} \div \overline{C/gm} \times \overline{m^3} = \overline{FGF}$$

Am ²⁴¹	5.5	0.0187	3.47	152	45	193.785
Np ²³⁷	0.012	0.015	0.000713	152	38	193.785
Pu ²³⁸	490	0.11	17.3	152	474	152m ³
Pu ²³⁹	7.8	1	0.0629	152	18,849	$\frac{596 \text{ eaks}}{152 \text{ m}^3} = 0.25 \text{ m}^3/\text{can}$
Pu ²⁴⁰	7.2	0.0225	0.23	152	107	
Pu ²⁴¹	230	2.25	104	152	756	
U ²³⁵	0.0025	1	2.19×10^6	152	173,516	193.785

$\therefore$ FGF is limiting factor
 $600 \text{ cars} > 79 \text{ cars}$
 $\frac{1000}{79021} = 79 \text{ cars}$
 $\text{Max PF currency/car} = 1000 \text{ c.}$

$\begin{array}{r} 52 \\ 152 \\ \hline 79,021 \end{array}$

B. From Alumina calcine (Decayed to 2016)

$$\overline{\text{ISO}} = \frac{\text{Ca}^{2+}}{\text{m}^3} \times \text{FAE} \div \frac{\text{Ca}^{2+}}{\text{g/m}^3} \times \text{m}^3 = \text{FAE}$$

Time	Lat	Long	Alt	Dist	Time	Lat	Long	Alt	Dist
14	0.0187	3.47	48	4	14	0.0187	3.47	48	4
0.13	0.015	0.00713	48	131	0.13	0.015	0.00713	48	131
0.238	0.11	17.3	48	15	0.238	0.11	17.3	48	15
0.239	1	0.0629	48	4808	0.239	1	0.0629	48	4808
0.240	0.0225	0.23	48	10	0.240	0.0225	0.23	48	10
0.241	2.25	104	48	23	0.241	2.25	104	48	23
0.0026	1	2.19x10 ⁻⁶	48	55986	0.0026	1	2.19x10 ⁻⁶	48	55986

Σ FGF = 61.977

$\frac{48m^3}{191ccu} = 0.25m^3/ccu$

$$\frac{191 \text{ cars}}{48 \text{ m}^3} = 0.25 \text{ m}^3/\text{car}$$

P-E Curves from ALUMINUM-TRAC

ISO	$C/m^3 \div \text{Factor}$	$\times m^3$	P-E Curves
241	14	1	48
238	50	1.1	48
239	6.3	1	48
240	2.1	1	48
241	22.	52	48
			<u>320</u>
			3277

$\therefore P-E \text{ Curves} = 3277$

$3277 \div 1000 = 3 \text{ cans}$

$191 > 3, \therefore PGE \text{ is limiting factor}$

$$\frac{3277}{1000} = 3.277$$

FGE calculations (cont.)

C. From SBW (decayed to 1988-1993) FGE:

$$\text{Iso } \frac{\text{Ci}}{\text{m}^3} \times \text{FGE} \div \frac{\text{Ci}}{\text{gm}} \times \text{m}^3 = \text{FGE}$$

Am241	23	0.0187	3.47	10	1
Np237	1	0.015	0.000713	10	210
Pu238	390	0.11	17.3	10	25
Pu239	35	1	0.0629	10	5564
Pu240	8.8	0.0225	0.23	10	9
Pu241	370	2.25	104	10	80
U235	0.0075	1	2.19×10^{-6}	10	34,247
$\Sigma \text{ FGE} =$					40,135

$$\frac{40,135}{325} = 124 \text{ cans}$$

$$\frac{10 \text{ m}^3}{124 \text{ cans}} = 0.08 \text{ m}^3/\text{can} \sim 0.1 \text{ m}^3/\text{can}$$

PE Curies from SBW-TRU

Iso	$\frac{\text{Ci}}{\text{m}^3}$	Factor	$\times \text{m}^3$	PE curies
Am241	23	1	10	230
Pu238	390	1.1	10	3545
Pu239	35	1	10	350
Pu240	8.8	1	10	88
Pu241	370	52	10	71
$\Sigma \text{ PE curies} =$				4284

$$\frac{4284}{1000} = 4 \text{ cans}$$

$124 > 4$, $\therefore$ FGE is limiting factor

Summary:

1. Waste volumes, dried TRU

- a. From zirconia calcine = 152 m^3
- b. From alumina calcine = 48 m^3
- c. From SBW = 10 m^3
- Total = 210 m^3

2. Number of canisters (based on FGE limit of 325/cask)

- a. From zirconia-TRU = 596 canisters.
- b. From alumina-TRU = 191 canisters
- c. From SBW-TRU = $\frac{124}{1} = 124$ canisters
- Total = 911

Canister dimensions for remote-handled TRU $\frac{1}{2}$ -canister for the WIPP:

26" O.Diam. x 52" long x $\frac{1}{4}$ " wall thickness
capacity: 0.4 m^3

3. Volume of dried TRU / canister (FGE limit of 325/cask)

- a. Zirconia-TRU = $0.25 \text{ m}^3/\text{can}$
- b. alumina-TRU = $0.25 \text{ m}^3/\text{can}$
- c. SBW-TRU = $0.1 \text{ m}^3/\text{can}$

Table 10.1
Pu-239 FISSILE GRAM EQUIVALENT, DECAY HEAT,
AND SPECIFIC ACTIVITY OF MANY RADIONUCLIDES
(CONTINUED)

NUCLIDE	ATOMIC NUMBER	Pu-239 FGE	DECAY HEAT (W/g)	SPECIFIC ACTIVITY (Ci/g)
Ac 227	89	0.00E+00	3.68E-02	7.32E+01
Th 228	90	0.00E+00	2.71E+01	8.29E+02
Th 230	90	0.00E+00	5.75E-04	2.04E-02
Th 232	90	0.00E+00	2.68E-09	1.11E-07
Pa 231	91	0.00E+00	1.46E-03	4.78E-02
U 232	92	0.00E+00	6.93E-01	2.16E+01
U 233	92	1.00E+00	2.84E-04	9.76E-03
U 234	92	0.00E+00	1.82E-04	6.32E-03
U 235	92	1.00E+00	6.04E-08	2.19E-06
U 236	92	0.00E+00	1.78E-06	6.54E-05
U 237	92	0.00E+00	1.64E+02	8.25E+04
U 238	92	0.00E+00	8.62E-09	3.40E-07
Np 237	93	1.50E-02	2.09E-05	7.13E-04
Pu 236	94	0.00E+00	1.87E+01	5.37E+02
Pu 238	94	1.13E-01	5.73E-01	1.73E+01
Pu 239	94	1.00E+00	1.95E-03	6.29E-02
Pu 240	94	2.25E-02	7.16E-03	2.30E-01
Pu 241	94	2.25E+00	3.31E-03	1.04E+02
Pu 242	94	7.50E-03	1.17E-04	3.97E-03
Pu 244	94	0.00E+00	5.22E-07	1.79E-05
Am 241	95	1.87E-02	1.16E-01	3.47E+00
Am 242m	95	3.46E+01	4.32E-03	9.83E+00
Am 243	95	1.29E-02	6.49E-03	2.02E-01
Cm 242	96	0.00E+00	1.23E+02	3.35E+03
Cm 243	96	5.00E+00	1.90E+00	5.22E+01
Cm 244	96	9.00E-02	2.86E+00	8.18E+01
Cm 245	96	1.50E+01	5.77E-03	1.74E-01
Cm 246	96	0.00E+00	1.02E-02	3.11E-01
Cm 247	96	5.00E-01	2.98E-06	9.38E-05
Cm 248	96	0.00E+00	5.53E-04	4.30E-03
Cm 250	96	0.00E+00	1.59E-01	2.10E-01
Bk 247	97	0.00E+00	3.69E-02	1.06E+00
Bk 249	97	0.00E+00	3.24E-01	1.66E+03
Cf 249	98	4.50E+01	1.54E-01	4.14E+00
Cf 250	98	0.00E+00	4.12E+00	1.11E+02
Cf 251	98	9.00E+01	5.89E-02	1.60E+00
Cf 252	98	0.00E+00	4.06E+01	5.44E+02
Es 252	99	0.00E+00	4.37E+01	1.11E+03
Es 254	99	0.00E+00	7.35E+01	1.88E+03

Reference 10.2.1 and 10.2.2

Table 10.1
Pu-239 FISSILE GRAM EQUIVALENT, DECAY HEAT,
AND SPECIFIC ACTIVITY OF MANY RADIONUCLIDES

NUCLIDE		ATOMIC NUMBER	Pu-239 FGE	DECAY HEAT (W/g)	SPECIFIC ACTIVITY (Ci/g)
H	3	1	0.00E+00	3.28E-01	9.76E+03
C	14	6	0.00E+00	1.32E-03	4.51E+03
Na	22	11	0.00E+00	8.94E+01	6.32E+03
P	32	15	0.00E+00	1.19E+03	2.89E+05
Mn	54	25	0.00E+00	3.88E+01	7.82E+03
Fe	55	26	0.00E+00	8.49E-02	2.44E+03
Co	57	27	0.00E+00	7.29E+00	8.55E+03
Co	60	27	0.00E+00	1.76E+01	1.14E+03
Ni	63	28	0.00E+00	6.05E-03	5.98E+01
Cu	64	29	0.00E+00	7.21E+03	3.89E+06
As	73	33	0.00E+00	1.02E+01	2.25E+04
Kr	85	36	0.00E+00	5.94E-01	3.97E+02
Rb	86	37	0.00E+00	3.71E+02	8.22E+04
Sr	89	38	0.00E+00	1.01E+02	2.94E+04
Sr	90	38	0.00E+00	1.60E-01	1.38E+02
Y	88	39	0.00E+00	2.24E+02	1.41E+04
Zr	88	40	0.00E+00	4.46E+01	1.80E+04
Zr	95	40	0.00E+00	1.10E+02	2.17E+04
Ru	103	44	0.00E+00	1.05E+02	3.26E+04
Ru	106	44	0.00E+00	2.00E-01	3.38E+03
Ag	110m	47	0.00E+00	7.99E+01	4.80E+03
Cd	109	48	0.00E+00	1.68E+00	2.61E+03
Sb	125	51	0.00E+00	3.27E+00	1.04E+03
I	125	53	0.00E+00	6.38E+00	1.76E+04
I	129	53	0.00E+00	9.34E-08	1.79E-04
I	131	53	0.00E+00	4.23E+02	1.25E+05
Cs	134	55	0.00E+00	1.33E+01	1.31E+03
Cs	137	55	0.00E+00	9.74E-02	8.80E+01
Ba	133	56	0.00E+00	6.82E-01	2.53E+02
Ce	141	58	0.00E+00	4.19E+01	2.88E+04
Ce	144	58	0.00E+00	2.14E+00	3.22E+03
Pm	147	61	0.00E+00	3.44E-01	9.38E+02
Sm	151	62	0.00E+00	3.10E-03	2.66E+01
Eu	152	63	0.00E+00	1.35E+00	1.78E+02
Eu	154	63	0.00E+00	2.39E+00	2.67E+02
Eu	155	63	0.00E+00	3.42E-01	4.70E+02
Tm	168	69	0.00E+00	8.39E+01	8.44E+03
Ta	182	73	0.00E+00	5.60E+01	6.31E+03
Pb	210	82	0.00E+00	1.96E-02	7.72E+01
Po	210	84	0.00E+00	1.45E+02	4.54E+03
Ra	223	88	0.00E+00	1.83E+03	5.18E+04
Ra	226	88	0.00E+00	2.88E-02	1.00E+00
Ra	228	88	0.00E+00	2.76E-02	2.76E+02

A.0 CALCULATION OF PU-239 EQUIVALENT ACTIVITY

Pu-239 equivalent activity is determined using radionuclide-specific weighting factors. To obtain this correlation, the 50-year committed effective dose equivalent (CEDE) or dose conversion factor (DCF) for a unit intake of each radionuclide will be used. These DCFs have been determined by the methodology described in International Commission on Radiological Protection (ICRP) Publications 26 and 30 (References A1 and A2) and are consistent with current DOE guidance (Reference A3). The Pu-239 equivalent activity (AM) can be characterized by:

$$AM = \sum_{i=1}^K \frac{A_i}{WF_i}$$

where K is the number of transuranic (TRU) radionuclides, A_i is the total radioactivity of radionuclide i, and WF_i is the PE-Ci weighting factor for radionuclide i.

WF_i is further defined as the ratio:

$$WF_i = \frac{E_0}{E_i}$$

Where E_0 (rem/ μ Ci) is the 50-year CEDE due to the inhalation of Pu-239 particulates with a 1.0 μ m Activity Median Aerodynamic Diameter (AMAD) and a weekly (W) pulmonary clearance class, and E_i (rem/ μ Ci) is the 50-year CEDE due to the inhalation of radionuclide i particulates with a 1.0 μ m AMAD and the pulmonary clearance class resulting in the highest 50-year CEDE.

The value of E_0 and E_i may be obtained from DOE/EH-0071 (Reference A4). Weighting factors calculated in this manner are presented below for selected radionuclides of interest.

Adm

<u>Radionuclide</u>	<u>Pulmonary Clearance Class *</u>	<u>Weighting Factor</u>	<u>80 Ci Pu-239 Equivalent (CiE)</u>
U-233	Y	3.9	312
Np-237	W	1.0	80
Pu-236	W	3.2	256
Pu-238	W	1.1	88
Pu-239	W	1.0	80
Pu-240	W	1.0	80
Pu-241	W	52.0	4160
Pu-242	W	1.1	88
Am-241	W	1.0	80
Am-243	W	1.0	80
Cm-242	W	30.0	2400
Cm-244	W	1.9	152
Cf-252	Y	3.9	312

* (W) Weekly (Y) Yearly

To determine if a waste package with several radionuclides does not exceed 80 Ci Pu-239 equivalent, AM from the previous page must be less than or equal to 80.

No estimate of non-TRU radionuclides, except those within the scope of the above description, should be included.

WASTE DISPOSAL OPTIONS ASSUMPTIONS

Number	Assumption	References	Application to Volumes	Application to Alternatives	Contact and Date
1	All waste forms produced shall meet the LDR treatment standards for the RCRA-hazardous wastes, and shall be granted DETs when necessary. This shall be accomplished prior to the construction of the waste-processing plant.				
Basis	This assumption is necessary to support the contention that the waste forms are "road ready" at the completion of processing. It also drives an important process requirement for characterization and identification.	40 CFR 268.40 40 CFR 268.42 40 CFR 268.48			
2	All RCRA-listed-hazardous wastes shall be de-listed by Idaho and approved by the receiving State (or regional EPA) prior to the construction of the waste-processing plant.				
Basis	The key component of the INEEL waste management plan is the de-listing of various hazardous wastes in the various waste streams such that RCRA requirements do not apply .	40 CFR 260.20 40 CFR 260.22 DOE/ID-10544, Regulatory Analysis and Proposed Path Forward for the Idaho National Engineering Laboratory High-Level Waste Program, U. S. Department of Energy, Idaho Operations Office, Idaho National Engineering Laboratory, Nuclear Operations Division High-Level Waste Directorate, October 1996. Idaho Chemical Processing Plant High Activity Waste Treatment Project Regulatory Assessment Report, prepared by R. G. Morgan and S. E. Leroy, Duke Engineering Services, Inc. S. E. Leroy letter to V. L. Jacobson, dated April 25, 1997).			
3	The waste forms shall meet the disposal sites' acceptance criteria.				
Basis	This assumption is necessary to support the contention that the waste forms will be accepted for disposal at the proposed sites.	10 CFR 71 49 CFR 173			
4	HLW-treatment processes other than vitrification shall be granted equivalence to vitrification. (Applicable to the hot-isostatic-press waste form and the cementitious-waste forms in the nonseparations options)				
Basis	This assumption is necessary to support the contention that the HLW forms other than vitrified glass will be accepted for disposal at the proposed sites.	40 CFR 268.42			

WASTE DISPOSAL OPTIONS ASSUMPTIONS

5	The NRC shall determine that the low-activity wastes from separations processes are no longer HLW. (Applicable to all of the separations options)				
Basis	This assumption is necessary to support the contention that the Class-A and Class-C waste forms from the separations processes will be accepted for disposal at a LLW site.	38 FR 12342 D.M. Kiser, et al, <i>Low-level, class A/C waste, near surface land disposal facility design description</i> , INEEL/EXT-98-00051.			
6	The NRC shall determine that TRU wastes separated from the high-activity wastes are no longer HLW. (Applicable only to the two TRU-separations options)				
Basis	This assumption is necessary to support the contention that the TRU waste forms from the separations processes will be accepted for disposal at the WIPP.	DOE/WIPP, <i>Waste Acceptance Criteria for the Waste Isolation Pilot Plant</i> , DOE/WIPP-069, Rev. 5, April 1996.			
7	All HLW shall be processed into a disposable form by the end of 2035, and all HLW-forms shall be stored on-site until an HLW repository is available for their disposal.				
Basis	This assumption is necessary to support the contention that all HLW products will be "road ready" to satisfy the Settlement Agreement.	Settlement Agreement (between the DOE and the State of Idaho), October 16, 1995.			
8	The waste forms from the Cementitious and Direct-Cementitious-Waste Options shall be disposed of at the Greater Confinement Disposal site at the Nevada Test Site.				
Basis	This assumption is necessary to support the contention that the waste forms from the Cementitious Options will be accepted for disposal at the NTS.	A.E. Lee, <i>Preliminary design of the Nevada Test Site Greater Confinement Disposal Facility</i> , INEEL/EXT-97-01316, January, 1998.			
9	With the exception of the TRU-Separations-Class-C-Grout Option, all the other disposal options would require the construction of an interim storage facility for those high-level waste forms awaiting disposal at an HLW repository.				
Basis	An interim storage facility is being designed as part of the entire system. It is anticipated that the schedule for the interim storage facility will be coordinated to ensure that it will be on-line to support the processes.	J.K. Rawlins, "Interim Storage Scoping Study Report," INEEL/EXT-97-01393, January, 1998.			

Lockheed Martin Idaho Technologies Company

INTERDEPARTMENTAL COMMUNICATION

Date: December 4, 1997

To: Thomas G. McDonald MS 3765 6-0926

From: Henry K. Peterson *H. K. Peterson* MS 2107 6-8657

Subject: UPDATE OF RADIATION FIELD DEFINITION AND THERMAL GENERATION RATES FOR CALCINE PROCESS PACKAGES OF VARIOUS GEOMETRIES – HKP-26-97

References: a) Estimates of Feed and Waste Volumes, Compositions, and Properties, by C. M. Barnes, EDF-FDO-001, Rev.1,
b) MicroShield, Version 5.01, Grove Engineering, Rockville, MD

Transmitted herewith are radiation field and heat generation calculations for the revised source terms of reference a. All of these calculations, the radiation field and the heat generation rates, have been performed with MicroShield, Version 5.01. Following the presentation of the data will be a discussion of the "sensitivity of the various parameters that can factor into the calculations.

A – Vitrified Waste Option (Table 9):

For these calculations, the source term was modeled as a glass log with density of 2.6 g/cc and a length of 103.5 inches to give a volume of 0.72 m³ of waste within the canister. The canister that contains this log is stainless steel (SST) with an OD of 24 inches, an ID of 23.25 inches, and a length of 105 inches. All of the source term radionuclides have been decayed to the year 2016. Data for these options are as follows:

	<u>Alum. Cal.</u>	<u>Zirc. Cal.</u>	<u>SBW</u>
Doserate @ 1 cm (R/hr) -	172	73	6.1
Doserate @ 1 m (R/hr) -	35	15	1.2
Watts/Canister -	14.7	7.9	0.6

B – HIP Waste Option (Table 12):

For these calculations, the source term was modeled as a ceramic log with density of 3.2 g/cc and a length of 103.5 inches to give a volume of 0.72 m³ of waste within the canister. The canister that contains this log is stainless steel (SST) with an OD of 24 inches, an ID of 23.25 inches, and a length of 105 inches. All of the source term radionuclides have been decayed to the year 2016. Data for these options are as follows:

	<u>Alum. Cal.</u>	<u>Zirc. Cal.</u>	<u>SBW</u>
Doserate @ 1 cm (R/hr) -	580	165	14
Doserate @ 1 m (R/hr) -	116	33	2.8
Watts/Canister -	61	23	1.7

C – Cementitious Waste Option (Table 13):

For these calculations, the source term was modeled as a concrete log with density of 1.7 g/cc and a length of 103.5 inches to give a volume of 0.72 m³ of waste within the canister. The canister that contains this log is stainless steel (SST) with an OD of 24 inches, an ID of 23.25 inches, and a length of 105 inches. All of the source term radionuclides have been decayed to the year 2016. Data for this option are as follows:

Doserate @ 1 cm = 140 R/hr Doserate @ 1 m = 27 R/hr Watts/can. = 8.9

D – Direct Cementitious Waste Option (Table 17):

For these calculations, the source term was modeled as a glass log with density of 1.7 g/cc and a length of 103.5 inches to give a volume of 0.72 m³ of waste within the canister. The canister that contains this log is stainless steel (SST) with an OD of 24 inches, an ID of 23.25 inches, and a length of 105 inches. All of the source term radionuclides have been decayed to the year 2016. Data for these options are as follows:

	<u>Alum. Cal.</u>	<u>Zirc. Cal.</u>	<u>SBW</u>
Doserate @ 1 cm (R/hr) -	287	81	6.9
Doserate @ 1 m (R/hr) -	57	16	1.4
Watts/Canister -	16.4	6.0	0.45

E – Glass Waste from the Full Separations Option (Tables 24 and 18):

For these calculations, the source term was modeled as a glass log with density of 2.6 g/cc and a length of 103.5 inches to give a volume of 0.72 m³ of waste within the canister. The canister that contains this log is stainless steel (SST) with an OD of 24 inches, an ID of 23.25 inches, and a length of 105 inches. For the SBW option, radionuclides and corresponding quantities were taken from Table 18. All of the source term radionuclides have been decayed to the year 2016. (Data for the Alumina and Zirconia calcine are from a new Table 24 that was given to yourself on Dec. 4, 1997). Data for these options are as follows:

	<u>Alum. Cal.</u>	<u>Zirc. Cal.</u>	<u>SBW</u>
Doserate @ 1 cm (R/hr) -	2500	1480	2.4
Doserate @ 1 m (R/hr) -	500	300	0.4
Watts/Canister -	220	165	25

F – Grout from Full Separations Options (Tables 25 and 20):

For these calculations, the source term was modeled as a grouted low activity waste with density of 1.8 g/cc and a volume of 1.0 m³. The waste is contained within a concrete container with a 36-inch inside diameter, 64-inch inside length, and a wall thickness of 4 inches. For the SBW option, radionuclides and corresponding quantities were taken from Table 20. All of the source term radionuclides have been decayed to the year 2016. Data for these options are as follows:

	<u>Alum. Cal.</u>	<u>Zirc. Cal.</u>	<u>SBW</u>
Doserate @ 1 cm (R/hr) -	0.02	0.014	0.009
Doserate @ 1 m (R/hr) -	.007	0.004	0.003
Watts/Container -	0.004	0.002	0.001

G – TRU Waste contained in a modified canister (Table 31):

For these calculations, the source term was modeled as either a 0.3 m³ (for the alumina or zirconia calcine) or a 0.1 m³ volume (for SBW) of waste material distributed within a 0.4 m³ canister. For the SBW option, because the waste volume was small compared with the volume of the container, the waste volume was distributed throughout the volume of the container. The TRU waste has a projected density of 1.5 g/cc. The canister has a 26-inch outside diameter, a 25.5-inch inside diameter, and is 50 inches long. All of the source term radionuclide quantities have been decayed to the year 2016. Data for these options are as follows:

	<u>Alum. Cal.</u>	<u>Zirc. Cal.</u>	<u>SBW</u>
Waste vol. (m ³)/canister -	0.3	0.3	0.1
Doserate @ 1 cm (R/hr) -	18	61	2.4
Doserate @ 1 m (R/hr) -	1.6	5.4	0.3
Watts/Container -	0.75	5.8	1.0

H – Class C Grout in a 1 m³ concrete culvert (Table. 30):

For these calculations, the source term was modeled as a grouted waste with a projected density of 1.8 g/cc. The grout is poured into a culvert with the same dimensions as the culvert described in "F" above. All of the source term radionuclide quantities have been decayed to the year 2016. Data for these options are as follows:

	<u>Alum. Cal.</u>	<u>Zirc. Cal.</u>	<u>SBW</u>
Doserate @ 1 cm (R/hr) -	18.6	12.5	0.004
Doserate @ 1 m (R/hr) -	4.6	4.0	0.001
Watts/Container -	6.7	5.6	0.2

I – TRU Separations Class A Glass (Table 32b):

For these calculations, the source term was modeled as a glass log with density of alumina and zirconia glass at 2.56 g/cc and the density of SBW glass at 2.34 g/cc and a length of 103.5 inches

to give a volume of 0.72 m^3 of waste within the canister. The canister that contains this log is stainless steel (SST) with an OD of 24 inches, an ID of 23.25 inches, and a length of 105 inches. Data for this option are as follows:

	<u>Alumina Glass</u>	<u>Zirconia Glass</u>	<u>SBW Glass</u>
Doserate @ 1 cm (R/hr) =	1.6E+5	4900	1450
Doserate @ 1 m (R/hr) =	3.2E+4	960	285
Watts/can. =	12350	480	100

If there are any questions or comments concerning this analysis, please call me at the above-listed number.

hkp

Attachment

Cc: G. J. Stormberg, LMITCO, MS 2107
T. S. Bohn, LMITCO, MS 4138
D. R. Wenzel, LMITCO, MS 5209
HKP Letter File

MicroShield v5.01 (5.01-00121)
 Lockheed Martin Idaho Technologies Company
 Case File Heat Generation
 Case File: T12ALUM.MS5
 Case Title: T12alum

<u>Isotope</u>	<u>Activity Curies</u>	<u>Activity Bequerels</u>	<u>Heat Generation Watts/Curie</u>	<u>Heat Generation Watts</u>
Am-241	8.6394e-001	3.1966e+010	3.2813e-002	2.8348e-002
Am-242	0.0000e+000	0.0000e+000	1.1352e-003	0.0000e+000
Am-243	3.0958e-005	1.1454e+006	3.1704e-002	9.8149e-007
Ba-137m	5.3125e+003	1.9656e+014	3.9212e-003	2.0832e+001
Ce-144	7.1995e-017	2.6638e-006	6.6284e-004	4.7721e-020
Cm-242	2.4478e-005	9.0570e+005	3.6240e-002	8.8710e-007
Cm-244	4.8237e-005	1.7848e+006	3.4409e-002	1.6598e-006
Co-60	0.0000e+000	0.0000e+000	1.5423e-002	0.0000e+000
Cs-134	2.8798e-005	1.0655e+006	1.0179e-002	2.9314e-007
Cs-137	5.6156e+003	2.0778e+014	1.0122e-003	5.6844e+000
Eu-154	2.5918e+000	9.5897e+010	9.0517e-003	2.3460e-002
Eu-155	1.5839e-001	5.8604e+009	7.2543e-004	1.1490e-004
Ni-63	0.0000e+000	0.0000e+000	1.0155e-004	0.0000e+000
Np-237	7.9194e-003	2.9302e+008	2.8779e-002	2.2792e-004
Pa-233	7.9194e-003	2.9302e+008	2.4276e-003	1.9225e-005
Pm-147	2.1598e-002	7.9914e+008	3.6731e-004	7.9334e-006
Pr-144	7.1995e-017	2.6638e-006	7.3455e-003	5.2884e-019
Pu-238	3.0958e+000	1.1454e+011	3.2587e-002	1.0088e-001
Pu-239	3.8877e-001	1.4385e+010	3.0551e-002	1.1877e-002
Pu-240	1.5839e-001	5.8604e+009	3.0614e-002	4.8490e-003
Pu-241	1.3679e+000	5.0612e+010	3.1003e-005	4.2410e-005
Pu-242	1.1519e-005	4.2621e+005	2.9184e-002	3.3618e-007
Rh-106	3.9597e-013	1.4651e-002	9.5998e-003	3.8012e-015
Ru-106	3.9597e-013	1.4651e-002	5.9459e-005	2.3544e-017
Sb-125	8.6394e-004	3.1966e+007	3.1431e-003	2.7154e-006
Sm-151	1.1519e+002	4.2621e+012	1.1729e-004	1.3511e-002
Sr-90	5.1836e+003	1.9179e+014	1.1607e-003	6.0168e+000
Tc-99	2.8798e+000	1.0655e+011	5.0152e-004	1.4443e-003
Th-230	7.9194e-004	2.9302e+007	2.7809e-002	2.2023e-005
Th-231	1.3679e-004	5.0612e+006	1.0580e-003	1.4472e-007
U-232	1.0799e-006	3.9957e+004	3.1553e-002	3.4075e-008
U-233	1.1519e-006	4.2621e+004	2.8557e-002	3.2895e-008
U-234	2.4478e-002	9.0570e+008	2.8311e-002	6.9302e-004
U-235	1.5839e-004	5.8604e+006	2.7115e-002	4.2948e-006
U-236	3.8877e-004	1.4385e+007	2.6697e-002	1.0379e-005
U-237	3.3838e-005	1.2520e+006	1.9366e-003	6.5530e-008
U-238	9.3593e-006	3.4630e+005	2.4920e-002	2.3324e-007
Y-90	5.1836e+003	1.9179e+014	5.5411e-003	2.8723e+001

Total

Heat Generation:

6.1441e+001 ✓

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

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Run Date: November 20, 1997
Run Time: 12:59:54 AM
Duration: 00:01:37

File Ref: HKP-26-97
Date: 12/4/97
By: BJH/ldm
Checked: gbs

Case Title: T12alum

Description: R/hr @ 1 cm from canister surf., Alumina calcine (T-12)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions

Height 262.8 cm ✓ 8 ft 7.5 in
Radius 29.53 cm ✓ 11.6 in

Dose Points

1 X Y Z
31.48 cm ✓ 131.4 cm 0 cm
1 ft 0.4 in 4 ft 3.7 in 0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	7.20e+05 cm ³	Concrete	3.2 ✓
Shield 1	.95 cm	Iron	7.86
Transition	1.0 cm	Air	0.0011
Air Gap		Air	0.0011

Source Input

Grouping Method : Standard Indices

Number of Groups : 25

Lower Energy Cutoff : 0.015

Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Am-241	8.6394e-001	3.1966e+010	1.2000e+000 ✓	4.4400e+004
Am-242				
Am-243	3.0958e-005	1.1454e+006	4.3000e-005 ✓	1.5910e+000
Ba-137m	5.3125e+003	1.9656e+014	7.3790e+003 ✓	2.7302e+008
Ce-144	7.1995e-017	2.6638e-006	1.0000e-016 ✓	3.7000e-012
Cm-242	2.4478e-005	9.0570e+005	3.4000e-005 ✓	1.2580e+000
Cm-244	4.8237e-005	1.7848e+006	6.7000e-005 ✓	2.4790e+000
Co-60				
Cs-134	2.8798e-005	1.0655e+006	4.0000e-005 ✓	1.4800e+000
Cs-137	5.6156e+003	2.0778e+014	7.8000e+003 ✓	2.8860e+008
Eu-154	2.5918e+000	9.5897e+010	3.6000e+000 ✓	1.3320e+005
Eu-155	1.5839e-001	5.8604e+009	2.2000e-001 ✓	8.1400e+003
Ni-63				
Np-237	7.9194e-003	2.9302e+008	1.1000e-002 ✓	4.0700e+002
Pa-233	7.9194e-003	2.9302e+008	1.1000e-002 ✓	4.0700e+002
Pm-147	2.1598e-002	7.9914e+008	3.0000e-002 ✓	1.1100e+003
Pr-144	7.1995e-017	2.6638e-006	1.0000e-016 ✓	3.7000e-012
Pu-238	3.0958e+000	1.1454e+011	4.3000e+000 ✓	1.5910e+005
Pu-239	3.8877e-001	1.4385e+010	5.4000e-001 ✓	1.9980e+004
Pu-240	1.5839e-001	5.8604e+009	2.2000e-001 ✓	8.1400e+003
Pu-241	1.3679e+000	5.0612e+010	1.9000e+000 ✓	7.0300e+004
Pu-242	1.1519e-005	4.2621e+005	1.6000e-005 ✓	5.9200e-001
Rh-106	3.9597e-013	1.4651e-002	5.5000e-013 ✓	2.0350e-008
Ru-106	3.9597e-013	1.4651e-002	5.5000e-013 ✓	2.0350e-008
Sb-125	8.6394e-004	3.1966e+007	1.2000e-003 ✓	4.4400e+001

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 DOS File: T12ALUM.MS5
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<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Sm-151	1.1519e+002	4.2621e+012	1.6000e+002 ✓	5.9200e+006
Sr-90	5.1836e+003	1.9179e+014	7.2000e+003 ✓	2.6640e+008
Tc-99	2.8798e+000	1.0655e+011	4.0000e+000 ✓	1.4800e+005
Th-230	7.9194e-004	2.9302e+007	1.1000e-003 ✓	4.0700e+001
Th-231	1.3679e-004	5.0612e+006	1.9000e-004 ✓	7.0300e+000
U-232	1.0799e-006	3.9957e+004	1.5000e-006 ✓	5.5500e-002
U-233	1.1519e-006	4.2621e+004	1.6000e-006 ✓	5.9200e-002
U-234	2.4478e-002	9.0570e+008	3.4000e-002 ✓	1.2580e+003
U-235	1.5839e-004	5.8604e+006	2.2000e-004 ✓	8.1400e+000
U-236	3.8877e-004	1.4385e+007	5.4000e-004 ✓	1.9980e+001
U-237	3.3838e-005	1.2520e+006	4.7000e-005 ✓	1.7390e+000
U-238	9.3593e-006	3.4630e+005	1.3000e-005 ✓	4.8100e-001
Y-90	5.1836e+003	1.9179e+014	7.2000e+003 ✓	2.6640e+008

Buildup
 The material reference is : Source

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Results</u>			
		<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
		<u>MeV/cm²/sec</u>	<u>MeV/cm²/sec</u>	<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.015	9.520e+03	3.397e-218	4.365e-29	2.914e-219	3.744e-30
0.02	1.260e+09	2.583e-95	9.093e-24	8.948e-97	3.150e-25
0.03	1.158e+13	5.883e-26	1.847e-19	5.830e-28	1.831e-21
0.04	2.753e+12	1.497e-09	5.646e-09	6.623e-12	2.497e-11
0.05	5.307e+09	6.047e-06	3.604e-05	1.611e-08	9.600e-08
0.06	1.167e+10	1.036e-02	8.244e-02	2.058e-05	1.637e-04
0.08	1.868e+09	4.716e-01	4.424e+00	7.463e-04	7.000e-03
0.1	4.015e+10	9.767e+01	8.962e+02	1.494e-01	1.371e+00
0.15	6.054e+06	1.230e-01	9.371e-01	2.025e-04	1.543e-03
0.2	6.556e+09	3.127e+02	2.076e+03	5.519e-01	3.664e+00
0.3	1.468e+08	1.719e+01	9.357e+01	3.260e-02	1.775e-01
0.4	7.045e+08	1.443e+02	6.799e+02	2.812e-01	1.325e+00
0.5	2.110e+08	6.572e+01	2.762e+02	1.290e-01	5.422e-01
0.6	1.769e+14	7.725e+07	2.954e+08	1.508e+05	5.765e+05
0.8	3.740e+10	2.779e+04	9.215e+04	5.285e+01	1.753e+02
1.0	2.950e+10	3.310e+04	9.888e+04	6.101e+01	1.823e+02
1.5	3.742e+10	8.840e+04	2.217e+05	1.487e+02	3.730e+02
2.0	2.062e-08	8.126e-14	1.840e-13	1.257e-16	2.845e-16
TOTALS:	1.914e+14	7.740e+07	2.958e+08	1.510e+05	5.773e+05

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
DOS File: T12ALUM.MS5
Run Date: November 20, 1997
Run Time: 1:03:59 AM
Duration: 00:01:30

File Ref: HKP-26-97
Date: 12/4/97
By: AKK/bradw
Checked: gabel

Case Title: T12alum

Description: R/hr @ 1 m from canister surf., Alumina calcine (T-12)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions

Height 262.8 cm / 8 ft 7.5 in
Radius 29.53 cm / 11.6 in

Dose Points

	X	Y	Z
# 1	130.48 cm / 4 ft 3.4 in	131.4 cm / 4 ft 3.7 in	0 cm / 0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	7.20e+05 cm ³	Concrete	3.2 /
Shield 1	.95 cm	Iron	7.86
Transition	100.0 cm	Air	0.0011
Air Gap		Air	0.00122

Source Input

Grouping Method : Standard Indices

Number of Groups : 25

Lower Energy Cutoff : 0.015

Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Am-241	8.6394e-001	3.1966e+010	1.2000e+000 /	4.4400e+004
Am-242				
Am-243	3.0958e-005	1.1454e+006	4.3000e-005 /	1.5910e+000
Ba-137m	5.3125e+003	1.9656e+014	7.3790e+003 /	2.7302e+008
Ce-144	7.1995e-017	2.6638e-006	1.0000e-016 /	3.7000e-012
Cm-242	2.4478e-005	9.0570e+005	3.4000e-005 /	1.2580e+000
Cm-244	4.8237e-005	1.7848e+006	6.7000e-005 /	2.4790e+000
Co-60				
Cs-134	2.8798e-005	1.0655e+006	4.0000e-005 /	1.4800e+000
Cs-137	5.6156e+003	2.0778e+014	7.8000e+003 /	2.8860e+008
Eu-154	2.5918e+000	9.5897e+010	3.6000e+000 /	1.3320e+005
Eu-155	1.5839e-001	5.8604e+009	2.2000e-001 /	8.1400e+003
Ni-63				
Np-237	7.9194e-003	2.9302e+008	1.1000e-002 /	4.0700e+002
Pa-233	7.9194e-003	2.9302e+008	1.1000e-002 /	4.0700e+002
Pm-147	2.1598e-002	7.9914e+008	3.0000e-002 /	1.1100e+003
Pr-144	7.1995e-017	2.6638e-006	1.0000e-016 /	3.7000e-012
Pu-238	3.0958e+000	1.1454e+011	4.3000e+000 /	1.5910e+005
Pu-239	3.8877e-001	1.4385e+010	5.4000e-001 /	1.9980e+004
Pu-240	1.5839e-001	5.8604e+009	2.2000e-001 /	8.1400e+003
Pu-241	1.3679e+000	5.0612e+010	1.9000e+000 /	7.0300e+004
Pu-242	1.1519e-005	4.2621e+005	1.6000e-005 /	5.9200e-001
Rh-106	3.9597e-013	1.4651e-002	5.5000e-013 /	2.0350e-008
Ru-106	3.9597e-013	1.4651e-002	5.5000e-013 /	2.0350e-008
Sb-125	8.6394e-004	3.1966e+007	1.2000e-003 /	4.4400e+001

Page : 2
 DOS File: T12ALUM.MS5
 Run Date: November 20, 1997
 Run Time: 1:03:59 AM
 Duration: 00:01:30

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Sm-151	1.1519e+002	4.2621e+012	1.6000e+002	5.9200e+006
Sr-90	5.1836e+003	1.9179e+014	7.2000e+003	2.6640e+008
Tc-99	2.8798e+000	1.0655e+011	4.0000e+000	1.4800e+005
Th-230	7.9194e-004	2.9302e+007	1.1000e-003	4.0700e+001
Th-231	1.3679e-004	5.0612e+006	1.9000e-004	7.0300e+000
U-232	1.0799e-006	3.9957e+004	1.5000e-006	5.5500e-002
U-233	1.1519e-006	4.2621e+004	1.6000e-006	5.9200e-002
U-234	2.4478e-002	9.0570e+008	3.4000e-002	1.2580e+003
U-235	1.5839e-004	5.8604e+006	2.2000e-004	8.1400e+000
U-236	3.8877e-004	1.4385e+007	5.4000e-004	1.9980e+001
U-237	3.3838e-005	1.2520e+006	4.7000e-005	1.7390e+000
U-238	9.3593e-006	3.4630e+005	1.3000e-005	4.8100e-001
Y-90	5.1836e+003	1.9179e+014	7.2000e+003	2.6640e+008

Buildup

The material reference is : Transition

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Results</u>			
		<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
		<u>MeV/cm²/sec</u> <u>No Buildup</u>	<u>MeV/cm²/sec</u> <u>With Buildup</u>	<u>mR/hr</u> <u>No Buildup</u>	<u>mR/hr</u> <u>With Buildup</u>
0.015	9.520e+03	1.381e-192	8.653e-30	1.184e-193	7.422e-31
0.02	1.260e+09	2.816e-85	3.250e-24	9.753e-87	1.126e-25
0.03	1.158e+13	4.562e-24	5.661e-19	4.522e-26	5.610e-21
0.04	2.753e+12	1.748e-09	1.987e-07	7.731e-12	8.789e-10
0.05	5.307e+09	2.131e-06	3.524e-04	5.677e-09	9.387e-07
0.06	1.167e+10	2.494e-03	3.737e-01	4.954e-06	7.422e-04
0.08	1.868e+09	9.432e-02	7.604e+00	1.493e-04	1.203e-02
0.1	4.015e+10	1.887e+01	8.443e+02	2.886e-02	1.292e+00
0.15	6.054e+06	2.304e-02	4.271e-01	3.795e-05	7.033e-04
0.2	6.556e+09	5.758e+01	6.921e+02	1.016e-01	1.221e+00
0.3	1.468e+08	3.106e+00	2.381e+01	5.893e-03	4.517e-02
0.4	7.045e+08	2.580e+01	1.528e+02	5.026e-02	2.977e-01
0.5	2.110e+08	1.165e+01	5.788e+01	2.286e-02	1.136e-01
0.6	1.769e+14	1.359e+07	5.914e+07	2.653e+04	1.154e+05
0.8	3.740e+10	4.831e+03	1.738e+04	9.190e+00	3.305e+01
1.0	2.950e+10	5.698e+03	1.800e+04	1.050e+01	3.318e+01
1.5	3.742e+10	1.493e+04	3.839e+04	2.513e+01	6.459e+01
2.0	2.062e-08	1.356e-14	3.095e-14	2.097e-17	4.786e-17
TOTALS:	1.914e+14	1.362e+07	5.922e+07	2.658e+04	1.156e+05

MicroShield v5.01 (5.01-00121)
 Lockheed Martin Idaho Technologies Company
 Case File Heat Generation
 Case File: T12ZIR.MS5
 Case Title: T12zir

<u>Isotope</u>	<u>Activity Curies</u>	<u>Activity Bequerels</u>	<u>Heat Generation Watts/Curie</u>	<u>Heat Generation Watts</u>
Am-241	2.7358e+000	1.0122e+011	3.2813e-002	8.9770e-002
Am-243	4.6797e-008	1.7315e+003	3.1704e-002	1.4837e-009
Ba-137m	1.4982e+003	5.5434e+013	3.9212e-003	5.8748e+000
Ce-144	1.0079e-009	3.7293e+001	6.6284e-004	6.6810e-013
Cm-242	5.9756e-007	2.2110e+004	3.6240e-002	2.1656e-008
Cm-244	1.0799e-007	3.9957e+003	3.4409e-002	3.7159e-009
Co-60	9.3593e-002	3.4630e+009	1.5423e-002	1.4435e-003
Cs-134	2.7358e+000	1.0122e+011	1.0179e-002	2.7848e-002
Cs-137	1.5839e+003	5.8604e+013	1.0122e-003	1.6033e+000
Eu-154	6.2636e+000	2.3175e+011	9.0517e-003	5.6696e-002
Eu-155	9.3593e-003	3.4630e+008	7.2543e-004	6.7895e-006
Ni-63	0.0000e+000	0.0000e+000	1.0155e-004	0.0000e+000
Np-237	6.1196e-004	2.2642e+007	2.8779e-002	1.7612e-005
Pa-233	6.1196e-004	2.2642e+007	2.4276e-003	1.4856e-006
Pm-147	9.3593e-001	3.4630e+010	3.6731e-004	3.4378e-004
Pr-144	1.0079e-009	3.7293e+001	7.3455e-003	7.4037e-012
Pu-238	2.4478e+001	9.0570e+011	3.2587e-002	7.9767e-001
Pu-239	3.8877e-001	1.4385e+010	3.0551e-002	1.1877e-002
Pu-240	3.5278e-001	1.3053e+010	3.0614e-002	1.0800e-002
Pu-241	1.1519e+001	4.2621e+011	3.1003e-005	3.5713e-004
Pu-242	7.9194e-004	2.9302e+007	2.9184e-002	2.3112e-005
Rh-106	9.3593e-008	3.4630e+003	9.5998e-003	8.9848e-010
Ru-106	9.3593e-008	3.4630e+003	5.9459e-005	5.5650e-012
Sb-125	2.8798e-002	1.0655e+009	3.1431e-003	9.0515e-005
Sm-151	3.5278e+001	1.3053e+012	1.1729e-004	4.1376e-003
Sr-90	2.0879e+003	7.7251e+013	1.1607e-003	2.4234e+000
Tc-99	4.9677e-001	1.8380e+010	5.0152e-004	2.4914e-004
Th-230	4.6797e-006	1.7315e+005	2.7809e-002	1.3014e-007
Th-231	1.2239e-004	4.5285e+006	1.0580e-003	1.2949e-007
U-232	1.2239e-006	4.5285e+004	3.1553e-002	3.8618e-008
U-233	7.9194e-008	2.9302e+003	2.8557e-002	2.2615e-009
U-234	1.9439e-002	7.1923e+008	2.8311e-002	5.5034e-004
U-235	1.2239e-004	4.5285e+006	2.7115e-002	3.3187e-006
U-236	3.2398e-004	1.1987e+007	2.6697e-002	8.6492e-006
U-237	2.7358e-004	1.0122e+007	1.9366e-003	5.2982e-007
U-238	5.9756e-006	2.2110e+005	2.4920e-002	1.4891e-007
Y-90	2.0879e+003	7.7251e+013	5.5411e-003	1.1569e+001

Total

Heat Generation:

2.2472e+001

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
DOS File: T12ZIR.MS5
Run Date: November 20, 1997
Run Time: 1:31:32 AM
Duration: 00:01:35

File Ref: _____
Date: _____
By: _____
Checked: DB/Beh

Case Title: T12zir

Description: R/hr @ 1 cm from canister surf., Zirconia calcine (T-12)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions

Height 262.8 cm / 8 ft 7.5 in
Radius 29.53 cm / 11.6 in

Dose Points

	X	Y	Z
# 1	31.48 cm / 1 ft 0.4 in	131.4 cm / 4 ft 3.7 in	0 cm / 0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	7.20e+05 cm ³	Concrete	3.2 /
Shield 1	.95 cm	Iron	7.86
Transition	1.0 cm	Air	0.0011
Air Gap		Air	0.0012:

Source Input

Grouping Method : Standard Indices

Number of Groups : 25

Lower Energy Cutoff : 0.015

Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Am-241	2.7358e+000	1.0122e+011	3.8000e+000 /	1.4060e+005
Am-243	4.6797e-008	1.7315e+003	6.5000e-008 /	2.4050e-003
Ba-137m	1.4982e+003	5.5434e+013	2.0810e+003 /	7.6997e+007
Ce-144	1.0079e-009	3.7293e+001	1.4000e-009 /	5.1800e-005
Cm-242	5.9756e-007	2.2110e+004	8.3000e-007 /	3.0710e-002
Cm-244	1.0799e-007	3.9957e+003	1.5000e-007 /	5.5500e-003
Co-60	9.3593e-002	3.4630e+009	1.3000e-001 /	4.8100e+003
Cs-134	2.7358e+000	1.0122e+011	3.8000e+000 /	1.4060e+005
Cs-137	1.5839e+003	5.8604e+013	2.2000e+003 /	8.1400e+007
Eu-154	6.2636e+000	2.3175e+011	8.7000e+000 /	3.2190e+005
Eu-155	9.3593e-003	3.4630e+008	1.3000e-002 /	4.8100e+002
Ni-63				
Np-237	6.1196e-004	2.2642e+007	8.5000e-004 /	3.1450e+001
Pa-233	6.1196e-004	2.2642e+007	8.5000e-004 /	3.1450e+001
Pm-147	9.3593e-001	3.4630e+010	1.3000e+000 /	4.8100e+004
Pr-144	1.0079e-009	3.7293e+001	1.4000e-009 /	5.1800e-005
Pu-238	2.4478e+001	9.0570e+011	3.4000e+001 /	1.2580e+006
Pu-239	3.8877e-001	1.4385e+010	5.4000e-001 /	1.9980e+004
Pu-240	3.5278e-001	1.3053e+010	4.9000e-001 /	1.8130e+004
Pu-241	1.1519e+001	4.2621e+011	1.6000e+001 /	5.9200e+005
Pu-242	7.9194e-004	2.9302e+007	1.1000e-003 /	4.0700e+001
Rh-106	9.3593e-008	3.4630e+003	1.3000e-007 /	4.8100e-003
Ru-106	9.3593e-008	3.4630e+003	1.3000e-007 /	4.8100e-003
Sb-125	2.8798e-002	1.0655e+009	4.0000e-002 /	1.4800e+003
Sm-151	3.5278e+001	1.3053e+012	4.9000e+001 /	1.8130e+006

Page : 2
 DOS File: T12ZIR.MS5
 Run Date: November 20, 1997
 Run Time: 1:31:32 AM
 Duration: 00:01:35

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Sr-90	2.0879e+003	7.7251e+013	2.9000e+003	1.0730e+008
Tc-99	4.9677e-001	1.8380e+010	6.9000e-001	2.5530e+004
Th-230	4.6797e-006	1.7315e+005	6.5000e-006	2.4050e-001
Th-231	1.2239e-004	4.5285e+006	1.7000e-004	6.2900e+000
U-232	1.2239e-006	4.5285e+004	1.7000e-006	6.2900e-002
U-233	7.9194e-008	2.9302e+003	1.1000e-007	4.0700e-003
U-234	1.9439e-002	7.1923e+008	2.7000e-002	9.9900e+002
U-235	1.2239e-004	4.5285e+006	1.7000e-004	6.2900e+000
U-236	3.2398e-004	1.1987e+007	4.5000e-004	1.6650e+001
U-237	2.7358e-004	1.0122e+007	3.8000e-004	1.4060e+001
U-238	5.9756e-006	2.2110e+005	8.3000e-006	3.0710e-001
Y-90	2.0879e+003	7.7251e+013	2.9000e+003	1.0730e+008

Buildup

The material reference is : Source

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

Results

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Fluence Rate</u> <u>MeV/cm²/sec</u> <u>No Buildup</u>	<u>Fluence Rate</u> <u>MeV/cm²/sec</u> <u>With Buildup</u>	<u>Exposure Rate</u> <u>mR/hr</u> <u>No Buildup</u>	<u>Exposure Rate</u> <u>mR/hr</u> <u>With Buildup</u>
0.015	8.518e+03	3.040e-218	3.906e-29	2.607e-219	3.350e-30
0.02	3.859e+08	7.911e-96	2.785e-24	2.740e-97	9.646e-26
0.03	3.269e+12	1.661e-26	5.215e-20	1.646e-28	5.169e-22
0.04	8.180e+11	4.449e-10	1.678e-09	1.968e-12	7.420e-12
0.05	1.201e+10	1.368e-05	8.153e-05	3.645e-08	2.172e-07
0.06	3.696e+10	3.283e-02	2.612e-01	6.521e-05	5.188e-04
0.08	1.118e+08	2.821e-02	2.646e-01	4.465e-05	4.188e-04
0.1	9.387e+10	2.283e+02	2.095e+03	3.493e-01	3.206e+00
0.15	3.956e+06	8.035e-02	6.123e-01	1.323e-04	1.008e-03
0.2	1.591e+10	7.589e+02	5.038e+03	1.339e+00	8.892e+00
0.3	5.183e+07	6.067e+00	3.303e+01	1.151e-02	6.265e-02
0.4	1.988e+09	4.072e+02	1.918e+03	7.935e-01	3.738e+00
0.5	2.090e+09	6.511e+02	2.737e+03	1.278e+00	5.372e+00
0.6	5.002e+13	2.185e+07	8.353e+07	4.264e+04	1.630e+05
0.8	1.857e+11	1.379e+05	4.575e+05	2.624e+02	8.701e+02
1.0	7.759e+10	8.706e+04	2.601e+05	1.605e+02	4.794e+02
1.5	9.697e+10	2.291e+05	5.745e+05	3.854e+02	9.667e+02
2.0	2.887e-01	1.138e-06	2.575e-06	1.759e-09	3.982e-09
TOTALS:	5.463e+13	2.230e+07	8.484e+07	4.345e+04	1.654e+05

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
 DOS File: HKP.MS5
 Run Date: November 20, 1997
 Run Time: 1:25:08 AM
 Duration: 00:01:30

File Ref: HKP-26
 Date: 12/4/97
 By: [Signature]
 Checked: [Signature]

Case Title: T12zir
Description: R/hr @ 1 m from canister surf., Zirconia calcine (T-12)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions

Height	262.8 cm	8 ft 7.5 in
Radius	29.53 cm	11.6 in

Dose Points

	<u>X</u>	<u>Y</u>	<u>Z</u>
# 1	130.48 cm	131.4 cm	0 cm
	4 ft 3.4 in	4 ft 3.7 in	0.0 in

Shields

<u>Shield Name</u>	<u>Dimension</u>	<u>Material</u>	<u>Density</u>
Source	7.20e+05 cm ³	Concrete	3.2
Shield 1	.95 cm	Iron	7.86
Transition	100.0 cm	Air	0.0011
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded

Library : Grove

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Am-241	2.7358e+000	1.0122e+011	3.8000e+000 ✓	1.4060e+005
Am-243	4.6797e-008	1.7315e+003	6.5000e-008 ✓	2.4050e-003
Ba-137m	1.4982e+003	5.5434e+013	2.0810e+003 ✓	7.6997e+007
Ce-144	1.0079e-009	3.7293e+001	1.4000e-009 ✓	5.1800e-005
Cm-242	5.9756e-007	2.2110e+004	8.3000e-007 ✓	3.0710e-002
Cm-244	1.0799e-007	3.9957e+003	1.5000e-007 ✓	5.5500e-003
Co-60	9.3593e-002	3.4630e+009	1.3000e-001 ✓	4.8100e+003
Cs-134	2.7358e+000	1.0122e+011	3.8000e+000 ✓	1.4060e+005
Cs-137	1.5839e+003	5.8604e+013	2.2000e+003 ✓	8.1400e+007
Eu-154	6.2636e+000	2.3175e+011	8.7000e+000 ✓	3.2190e+005
Eu-155	9.3593e-003	3.4630e+008	1.3000e-002 ✓	4.8100e+002
Ni-63				
Np-237	6.1196e-004	2.2642e+007	8.5000e-004 ✓	3.1450e+001
Pa-233	6.1196e-004	2.2642e+007	8.5000e-004 ✓	3.1450e+001
Pm-147	9.3593e-001	3.4630e+010	1.3000e+000 ✓	4.8100e+004
Pr-144	1.0079e-009	3.7293e+001	1.4000e-009 ✓	5.1800e-005
Pu-238	2.4478e+001	9.0570e+011	3.4000e+001 ✓	1.2580e+006
Pu-239	3.8877e-001	1.4385e+010	5.4000e-001 ✓	1.9980e+004
Pu-240	3.5278e-001	1.3053e+010	4.9000e-001 ✓	1.8130e+004
Pu-241	1.1519e+001	4.2621e+011	1.6000e+001 ✓	5.9200e+005
Pu-242	7.9194e-004	2.9302e+007	1.1000e-003 ✓	4.0700e+001
Rh-106	9.3593e-008	3.4630e+003	1.3000e-007 ✓	4.8100e-003
Ru-106	9.3593e-008	3.4630e+003	1.3000e-007 ✓	4.8100e-003
Sb-125	2.8798e-002	1.0655e+009	4.0000e-002 ✓	1.4800e+003
Sm-151	3.5278e+001	1.3053e+012	4.9000e+001 ✓	1.8130e+006

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 DOS File: HKP.MS5
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<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Sr-90	2.0879e+003	7.7251e+013	2.9000e+003 ✓	1.0730e+008
Tc-99	4.9677e-001	1.8380e+010	6.9000e-001 ✓	2.5530e+004
Th-230	4.6797e-006	1.7315e+005	6.5000e-006 ✓	2.4050e-001
Th-231	1.2239e-004	4.5285e+006	1.7000e-004 ✓	6.2900e+000
U-232	1.2239e-006	4.5285e+004	1.7000e-006 ✓	6.2900e-002
U-233	7.9194e-008	2.9302e+003	1.1000e-007 ✓	4.0700e-003
U-234	1.9439e-002	7.1923e+008	2.7000e-002 ✓	9.9900e+002
U-235	1.2239e-004	4.5285e+006	1.7000e-004 ✓	6.2900e+000
U-236	3.2398e-004	1.1987e+007	4.5000e-004 ✓	1.6650e+001
U-237	2.7358e-004	1.0122e+007	3.8000e-004 ✓	1.4060e+001
U-238	5.9756e-006	2.2110e+005	8.3000e-006 ✓	3.0710e-001
Y-90	2.0879e+003	7.7251e+013	2.9000e+003 ✓	1.0730e+008

Buildup
 The material reference is : Transition

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Results</u>			
		<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
		<u>MeV/cm²/sec</u>	<u>MeV/cm²/sec</u>	<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.015	8.518e+03	1.236e-192	7.742e-30	1.060e-193	6.641e-31
0.02	3.859e+08	8.623e-86	9.954e-25	2.987e-87	3.448e-26
0.03	3.269e+12	1.288e-24	1.598e-19	1.276e-26	1.584e-21
0.04	8.180e+11	5.194e-10	5.905e-08	2.297e-12	2.611e-10
0.05	1.201e+10	4.821e-06	7.973e-04	1.284e-08	2.124e-06
0.06	3.696e+10	7.902e-03	1.184e+00	1.569e-05	2.352e-03
0.08	1.118e+08	5.643e-03	4.549e-01	8.930e-06	7.199e-04
0.1	9.387e+10	4.411e+01	1.974e+03	6.748e-02	3.020e+00
0.15	3.956e+06	1.506e-02	2.791e-01	2.480e-05	4.596e-04
0.2	1.591e+10	1.398e+02	1.680e+03	2.467e-01	2.965e+00
0.3	5.183e+07	1.097e+00	8.405e+00	2.080e-03	1.594e-02
0.4	1.988e+09	7.279e+01	4.311e+02	1.418e-01	8.400e-01
0.5	2.090e+09	1.154e+02	5.734e+02	2.265e-01	1.126e+00
0.6	5.002e+13	3.844e+06	1.673e+07	7.504e+03	3.265e+04
0.8	1.857e+11	2.399e+04	8.626e+04	4.562e+01	1.641e+02
1.0	7.759e+10	1.499e+04	4.734e+04	2.763e+01	8.726e+01
1.5	9.697e+10	3.870e+04	9.948e+04	6.512e+01	1.674e+02
2.0	2.887e-01	1.898e-07	4.333e-07	2.935e-10	6.700e-10
TOTALS:	5.463e+13	3.923e+06	1.696e+07	7.643e+03	3.307e+04

MicroShield v5.01 (5.01-00121)
 Lockheed Martin Idaho Technologies Company
 Case File Heat Generation
 Case File: T12SBW16.MS5
 Case Title: T12SBW

<u>Isotope</u>	<u>Activity</u> <u>Curies</u>	<u>Activity</u> <u>Bequerels</u>	<u>Heat Generation</u> <u>Watts/Curie</u>	<u>Heat Generation</u> <u>Watts</u>
Ac-225	1.4053e-009	5.1996e+001	3.4574e-002	4.8587e-011
Ac-227	9.3167e-008	3.4472e+003	4.7208e-004	4.3982e-011
Ac-228	1.3704e-013	5.0707e-003	8.0395e-003	1.1018e-015
Am-241	3.9869e-001	1.4752e+010	3.2813e-002	1.3082e-002
At-217	1.4053e-009	5.1996e+001	4.1888e-002	5.8865e-011
Ba-137m	1.2736e+002	4.7124e+012	3.9212e-003	4.9942e-001
Bi-210	2.2259e-008	8.2358e+002	2.3060e-003	5.1330e-011
Bi-211	9.2272e-008	3.4141e+003	3.9163e-002	3.6137e-009
Bi-212	1.1322e-013	4.1893e-003	1.6753e-002	1.8969e-015
Bi-213	1.4053e-009	5.1996e+001	4.1771e-003	5.8700e-012
Bi-214	1.1503e-007	4.2561e+003	1.2767e-002	1.4686e-009
Ce-144	1.0496e-007	3.8837e+003	6.6284e-004	6.9575e-011
Co-60	8.7759e-002	3.2471e+009	1.5423e-002	1.3535e-003
Cs-134	3.9791e-003	1.4722e+008	1.0179e-002	4.0503e-005
Cs-137	1.3463e+002	4.9814e+012	1.0122e-003	1.3628e-001
Eu-154	2.4181e-001	8.9471e+009	9.0517e-003	2.1888e-003
Eu-155	1.0315e-001	3.8164e+009	7.2543e-004	7.4825e-005
Fr-221	1.4053e-009	5.1996e+001	3.7907e-002	5.3271e-011
Fr-223	1.2857e-009	4.7571e+001	2.5771e-003	3.3134e-012
Ni-63	2.3492e-001	8.6921e+009	1.0155e-004	2.3856e-005
Np-237	1.4402e-002	5.3286e+008	2.8779e-002	4.1447e-004
Pa-231	3.3164e-007	1.2271e+004	3.2329e-002	1.0721e-008
Pa-233	1.4402e-002	5.3286e+008	2.4276e-003	3.4961e-005
Pa-234	6.6811e-008	2.4720e+003	1.4604e-002	9.7570e-010
Pa-234m	4.1757e-005	1.5450e+006	4.9490e-003	2.0665e-007
Pb-209	1.4052e-009	5.1993e+001	1.1714e-003	1.6461e-012
Pb-210	2.2316e-008	8.2569e+002	2.3060e-004	5.1459e-012
Pb-211	9.2272e-008	3.4141e+003	2.9963e-003	2.7647e-010
Pb-212	1.1322e-013	4.1893e-003	1.9044e-003	2.1562e-016
Pb-214	1.1503e-007	4.2561e+003	3.1921e-003	3.6719e-010
Po-210	2.0753e-008	7.6786e+002	3.1446e-002	6.5259e-010
Po-211	2.5190e-010	9.3204e+000	4.4166e-002	1.1126e-011
Po-212	7.2542e-014	2.6841e-003	5.2078e-002	3.7778e-015
Po-213	1.3749e-009	5.0873e+001	4.9660e-002	6.8279e-011
Po-214	1.1501e-007	4.2552e+003	4.5570e-002	5.2407e-009
Po-215	9.2273e-008	3.4141e+003	4.3787e-002	4.0403e-009
Po-216	1.1324e-013	4.1899e-003	4.0184e-002	4.5504e-015
Po-218	1.1505e-007	4.2570e+003	3.5576e-002	4.0932e-009
Pr-144	1.0497e-007	3.8838e+003	7.3455e-003	7.7104e-010
Pr-144m	1.5010e-009	5.5537e+001	3.3653e-004	5.0513e-013
Pu-238	3.6306e+000	1.3433e+011	3.2587e-002	1.1831e-001
Pu-239	4.5328e-001	1.6771e+010	3.0551e-002	1.3848e-002
Pu-240	1.0774e-001	3.9865e+009	3.0614e-002	3.2985e-003
Pu-241	1.3982e+000	5.1735e+010	3.1003e-005	4.3350e-005
Pu-242	5.8314e-005	2.1576e+006	2.9184e-002	1.7018e-006
Ra-223	9.2273e-008	3.4141e+003	3.4973e-002	3.2270e-009
Ra-224	1.1324e-013	4.1899e-003	3.3714e-002	3.8177e-015
Ra-225	1.4104e-009	5.2185e+001	7.0678e-004	9.9684e-013
Ra-226	1.1521e-007	4.2628e+003	2.8394e-002	3.2713e-009
Ra-228	1.3705e-013	5.0710e-003	6.8576e-005	9.3986e-018

<u>Isotope</u>	<u>Activity Curies</u>	<u>Activity Bequerels</u>	<u>Heat Generation Watts/Curie</u>	<u>Heat Generation Watts</u>
Rh-106	3.6852e-006	1.3635e+005	9.5998e-003	3.5377e-008
Rn-219	9.2273e-008	3.4141e+003	4.0502e-002	3.7373e-009
Rn-220	1.1324e-013	4.1899e-003	3.7278e-002	4.2213e-015
Rn-222	1.1505e-007	4.2570e+003	3.2543e-002	3.7442e-009
Ru-106	3.6852e-006	1.3635e+005	5.9459e-005	2.1912e-010
Sb-125	1.1123e-002	4.1156e+008	3.1431e-003	3.4962e-005
Sr-90	1.3095e+002	4.8451e+012	1.1607e-003	1.5200e-001
Tc-99	6.2631e-002	2.3174e+009	5.0152e-004	3.1411e-005
Te-125m	2.7257e-003	1.0085e+008	9.4493e-004	2.5756e-006
Th-227	9.1329e-008	3.3792e+003	3.5868e-002	3.2758e-009
Th-228	1.1336e-013	4.1944e-003	3.2139e-002	3.6433e-015
Th-229	1.4179e-009	5.2464e+001	2.9977e-002	4.2505e-011
Th-230	2.4261e-005	8.9765e+005	2.7809e-002	6.7467e-007
Th-231	7.1276e-004	2.6372e+007	1.0580e-003	7.5408e-007
Th-232	2.1102e-013	7.8076e-003	2.3811e-002	5.0245e-015
Th-234	4.1757e-005	1.5450e+006	3.9682e-004	1.6570e-008
Tl-207	9.2020e-008	3.4047e+003	2.9369e-003	2.7026e-010
Tl-208	4.0681e-014	1.5052e-003	2.3467e-002	9.5466e-016
Tl-209	3.0354e-011	1.1231e+000	1.6632e-002	5.0486e-013
U-233	1.3726e-006	5.0786e+004	2.8557e-002	3.9197e-008
U-234	1.2263e-001	4.5374e+009	2.8311e-002	3.4719e-003
U-235	7.1276e-004	2.6372e+007	2.7115e-002	1.9327e-005
U-236	1.9446e-004	7.1949e+006	2.6697e-002	5.1914e-006
U-237	3.4301e-005	1.2691e+006	1.9366e-003	6.6427e-008
U-238	4.1757e-005	1.5450e+006	2.4920e-002	1.0406e-006
Y-90	1.3098e+002	4.8464e+012	5.5411e-003	7.2579e-001

Total

Heat Generation:

1.6698e+000

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
SOS File: T12SBW16.MS5
Run Date: November 25, 1997
Run Time: 9:18:37 PM
Duration: 00:01:39

File Ref: HKP-26
Date: 12/14/99
By: [Signature]
Checked: [Signature]

for 2016
[Signature]

Case Title: T12SBW
Description: R/hr @ 1 cm from canister surf., SBW calcine (T-12)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions

Height 262.8 cm — 8 ft 7.5 in
Radius 29.53 cm — 11.6 in

Dose Points

1 X Y Z
 31.48 cm — 131.4 cm 0 cm
 1 ft 0.4 in — 4 ft 3.7 in 0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	7.20e+05 cm ³	Concrete	3.2
Shield 1	.95 cm	Iron	7.86
Transition	1.0 cm	Air	0.0011
Air Gap		Air	0.0012

Source Input

Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Ac-225	1.4053e-009	5.1996e+001	1.9519e-009	7.2222e-005
Ac-227	9.3167e-008	3.4472e+003	1.2941e-007	4.7881e-003
Ac-228	1.3704e-013	5.0707e-003	1.9035e-013	7.0431e-009
Am-241	3.9869e-001	1.4752e+010	5.5378e-001	2.0490e+004
At-217	1.4053e-009	5.1996e+001	1.9519e-009	7.2222e-005
Ba-137m	1.2736e+002	4.7124e+012	1.7691e+002	6.5455e+006
Bi-210	2.2259e-008	8.2358e+002	3.0917e-008	1.1439e-003
Bi-211	9.2272e-008	3.4141e+003	1.2816e-007	4.7421e-003
Bi-212	1.1322e-013	4.1893e-003	1.5727e-013	5.8188e-009
Bi-213	1.4053e-009	5.1996e+001	1.9519e-009	7.2221e-005
Bi-214	1.1503e-007	4.2561e+003	1.5977e-007	5.9116e-003
Ce-144	1.0496e-007	3.8837e+003	1.4579e-007	5.3944e-003
Co-60	8.7759e-002	3.2471e+009	1.2190e-001	4.5102e+003
Cs-134	3.9791e-003	1.4722e+008	5.5268e-003	2.0449e+002
Cs-137	1.3463e+002	4.9814e+012	1.8700e+002	6.9191e+006
Eu-154	2.4181e-001	8.9471e+009	3.3588e-001	1.2427e+004
Eu-155	1.0315e-001	3.8164e+009	1.4327e-001	5.3009e+003
Fr-221	1.4053e-009	5.1996e+001	1.9519e-009	7.2222e-005
Fr-223	1.2857e-009	4.7571e+001	1.7858e-009	6.6075e-005
Ni-63	2.3492e-001	8.6921e+009	3.2630e-001	1.2073e+004
Np-237	1.4402e-002	5.3286e+008	2.0004e-002	7.4013e+002
Pa-231	3.3164e-007	1.2271e+004	4.6064e-007	1.7044e-002
Pa-233	1.4402e-002	5.3286e+008	2.0003e-002	7.4013e+002
Pa-234	6.6811e-008	2.4720e+003	9.2800e-008	3.4336e-003
Pa-234m	4.1757e-005	1.5450e+006	5.8000e-005	2.1460e+000

Page : 2
 DOS File: T12SBW16.MS5
 Run Date: November 25, 1997
 Run Time: 9:18:37 PM
 Duration: 00:01:39

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Pb-209	1.4052e-009	5.1993e+001	1.9518e-009	7.2218e-005
Pb-210	2.2316e-008	8.2569e+002	3.0997e-008	1.1469e-003
Pb-211	9.2272e-008	3.4141e+003	1.2816e-007	4.7421e-003
Pb-212	1.1322e-013	4.1893e-003	1.5727e-013	5.8189e-009
Pb-214	1.1503e-007	4.2561e+003	1.5977e-007	5.9117e-003
Po-210	2.0753e-008	7.6786e+002	2.8826e-008	1.0665e-003
Po-211	2.5190e-010	9.3204e+000	3.4989e-010	1.2946e-005
Po-212	7.2542e-014	2.6841e-003	1.0076e-013	3.7281e-009
Po-213	1.3749e-009	5.0873e+001	1.9098e-009	7.0661e-005
Po-214	1.1501e-007	4.2552e+003	1.5974e-007	5.9104e-003
Po-215	9.2273e-008	3.4141e+003	1.2817e-007	4.7421e-003
Po-216	1.1324e-013	4.1899e-003	1.5729e-013	5.8197e-009
Po-218	1.1505e-007	4.2570e+003	1.5981e-007	5.9129e-003
Pr-144	1.0497e-007	3.8838e+003	1.4580e-007	5.3945e-003
Pr-144m	1.5010e-009	5.5537e+001	2.0849e-009	7.7141e-005
Pu-238	3.6306e+000	1.3433e+011	5.0429e+000	1.8659e+005
Pu-239	4.5328e-001	1.6771e+010	6.2960e-001	2.3295e+004
Pu-240	1.0774e-001	3.9865e+009	1.4965e-001	5.5371e+003
Pu-241	1.3982e+000	5.1735e+010	1.9421e+000	7.1859e+004
Pu-242	5.8314e-005	2.1576e+006	8.0997e-005	2.9969e+000
Ra-223	9.2273e-008	3.4141e+003	1.2817e-007	4.7421e-003
Ra-224	1.1324e-013	4.1899e-003	1.5729e-013	5.8197e-009
Ra-225	1.4104e-009	5.2185e+001	1.9590e-009	7.2484e-005
Ra-226	1.1521e-007	4.2628e+003	1.6003e-007	5.9210e-003
Ra-228	1.3705e-013	5.0710e-003	1.9037e-013	7.0435e-009
Rh-106	3.6852e-006	1.3635e+005	5.1186e-006	1.8939e-001
Rn-219	9.2273e-008	3.4141e+003	1.2817e-007	4.7421e-003
Rn-220	1.1324e-013	4.1899e-003	1.5729e-013	5.8197e-009
Rn-222	1.1505e-007	4.2570e+003	1.5981e-007	5.9129e-003
Ru-106	3.6852e-006	1.3635e+005	5.1186e-006	1.8939e-001
Sb-125	1.1123e-002	4.1156e+008	1.5450e-002	5.7165e+002
Sr-90	1.3095e+002	4.8451e+012	1.8189e+002	6.7298e+006
Tc-99	6.2631e-002	2.3174e+009	8.6994e-002	3.2188e+003
Te-125m	2.7257e-003	1.0085e+008	3.7860e-003	1.4008e+002
Th-227	9.1329e-008	3.3792e+003	1.2685e-007	4.6936e-003
Th-228	1.1336e-013	4.1944e-003	1.5746e-013	5.8260e-009
Th-229	1.4179e-009	5.2464e+001	1.9695e-009	7.2872e-005
Th-230	2.4261e-005	8.9765e+005	3.3698e-005	1.2468e+000
Th-231	7.1276e-004	2.6372e+007	9.9001e-004	3.6631e+001
Th-232	2.1102e-013	7.8076e-003	2.9310e-013	1.0845e-008
Th-234	4.1757e-005	1.5450e+006	5.8000e-005	2.1460e+000
Tl-207	9.2020e-008	3.4047e+003	1.2781e-007	4.7291e-003
Tl-208	4.0681e-014	1.5052e-003	5.6505e-014	2.0907e-009
Tl-209	3.0354e-011	1.1231e+000	4.2162e-011	1.5600e-006
U-233	1.3726e-006	5.0786e+004	1.9065e-006	7.0541e-002
U-234	1.2263e-001	4.5374e+009	1.7033e-001	6.3023e+003
U-235	7.1276e-004	2.6372e+007	9.9001e-004	3.6631e+001
U-236	1.9446e-004	7.1949e+006	2.7010e-004	9.9936e+000
U-237	3.4301e-005	1.2691e+006	4.7644e-005	1.7628e+000
U-238	4.1757e-005	1.5450e+006	5.8000e-005	2.1460e+000
Y-90	1.3098e+002	4.8464e+012	1.8193e+002	6.7315e+006

Buildup
 The material reference is : Source

Page : 3
 DOS File: T12SBW16.MS5
 Run Date: November 25, 1997
 Run Time: 9:18:37 PM
 Duration: 00:01:39

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

Energy MeV	Activity photons/sec	Results			
		Fluence Rate	Fluence Rate	Exposure Rate	Exposure Rate
		<u>MeV/cm²/sec</u>	<u>MeV/cm²/sec</u>	<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.015	4.961e+04	1.770e-217	2.275e-28	1.518e-218	1.951e-29
0.02	5.007e+01	1.026e-102	3.612e-31	3.555e-104	1.251e-32
0.03	2.783e+11	1.414e-27	4.441e-21	1.401e-29	4.401e-23
0.04	6.804e+10	3.701e-11	1.396e-10	1.637e-13	6.172e-13
0.05	6.957e+08	7.927e-07	4.724e-06	2.112e-09	1.258e-08
0.06	5.438e+09	4.831e-03	3.843e-02	9.596e-06	7.634e-05
0.08	1.273e+09	3.213e-01	3.014e+00	5.085e-04	4.769e-03
0.1	4.658e+09	1.133e+01	1.040e+02	1.733e-02	1.591e-01
0.15	1.429e+07	2.902e-01	2.212e+00	4.780e-04	3.642e-03
0.2	6.608e+08	3.151e+01	2.092e+02	5.562e-02	3.692e-01
0.3	2.685e+08	3.143e+01	1.711e+02	5.962e-02	3.246e-01
0.4	2.114e+08	4.331e+01	2.040e+02	8.439e-02	3.975e-01
0.5	6.416e+07	1.999e+01	8.401e+01	3.923e-02	1.649e-01
0.6	4.241e+12	1.852e+06	7.083e+06	3.616e+03	1.382e+04
0.8	3.628e+09	2.695e+03	8.939e+03	5.127e+00	1.700e+01
1.0	6.004e+09	6.736e+03	2.012e+04	1.242e+01	3.709e+01
1.5	6.743e+09	1.593e+04	3.995e+04	2.680e+01	6.722e+01
2.0	1.214e+03	4.783e-03	1.083e-02	7.397e-06	1.674e-05
3.0	1.502e-03	1.177e-08	2.343e-08	1.597e-11	3.179e-11
TOTALS:	4.617e+12	1.878e+06	7.153e+06	3.660e+03	1.395e+04

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
DOS File: T12SBW16.MS5
Run Date: November 25, 1997
Run Time: 9:26:13 PM
Duration: 00:01:37

File Ref: HKP-26-91
Date: 12/4/97
By: JHedgeman
Checked: JHedgeman

Case Title: T12SBW
Description: R/hr @ 1 m from canister surf., SBW calcine (T-12)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions
Height 262.8 cm / 8 ft 7.5 in
Radius 29.53 cm / 11.6 in

Dose Points
1 X 130.48 cm / 4 ft 3.4 in Y 131.4 cm / 4 ft 3.7 in Z 0 cm / 0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	7.20e+05 cm ³	Concrete	3.2
Shield 1	.95 cm	Iron	7.86
Transition	100.0 cm	Air	0.0011
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Ac-225	1.4053e-009	5.1996e+001	1.9519e-009	7.2222e-005
Ac-227	9.3167e-008	3.4472e+003	1.2941e-007	4.7881e-003
Ac-228	1.3704e-013	5.0707e-003	1.9035e-013	7.0431e-009
Am-241	3.9869e-001	1.4752e+010	5.5378e-001	2.0490e+004
At-217	1.4053e-009	5.1996e+001	1.9519e-009	7.2222e-005
Ba-137m	1.2736e+002	4.7124e+012	1.7691e+002	6.5455e+006
Bi-210	2.2259e-008	8.2358e+002	3.0917e-008	1.1439e-003
Bi-211	9.2272e-008	3.4141e+003	1.2816e-007	4.7421e-003
Bi-212	1.1322e-013	4.1893e-003	1.5727e-013	5.8188e-009
Bi-213	1.4053e-009	5.1996e+001	1.9519e-009	7.2221e-005
Bi-214	1.1503e-007	4.2561e+003	1.5977e-007	5.9116e-003
Ce-144	1.0496e-007	3.8837e+003	1.4579e-007	5.3944e-003
Co-60	8.7759e-002	3.2471e+009	1.2190e-001	4.5102e+003
Cs-134	3.9791e-003	1.4722e+008	5.5268e-003	2.0449e+002
Cs-137	1.3463e+002	4.9814e+012	1.8700e+002	6.9191e+006
Eu-154	2.4181e-001	8.9471e+009	3.3588e-001	1.2427e+004
Eu-155	1.0315e-001	3.8164e+009	1.4327e-001	5.3009e+003
Fr-221	1.4053e-009	5.1996e+001	1.9519e-009	7.2222e-005
Fr-223	1.2857e-009	4.7571e+001	1.7858e-009	6.6075e-005
Ni-63	2.3492e-001	8.6921e+009	3.2630e-001	1.2073e+004
Np-237	1.4402e-002	5.3286e+008	2.0004e-002	7.4013e+002
Pa-231	3.3164e-007	1.2271e+004	4.6064e-007	1.7044e-002
Pa-233	1.4402e-002	5.3286e+008	2.0003e-002	7.4013e+002
Pa-234	6.6811e-008	2.4720e+003	9.2800e-008	3.4336e-003
Pa-234m	4.1757e-005	1.5450e+006	5.8000e-005	2.1460e+000

Page : 2
 DOS File: T12SBW16.MS5
 Run Date: November 25, 1997
 Run Time: 9:26:13 PM
 Duration: 00:01:37

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Pb-209	1.4052e-009	5.1993e+001	1.9518e-009	7.2218e-005
Pb-210	2.2316e-008	8.2569e+002	3.0997e-008	1.1469e-003
Pb-211	9.2272e-008	3.4141e+003	1.2816e-007	4.7421e-003
Pb-212	1.1322e-013	4.1893e-003	1.5727e-013	5.8189e-009
Pb-214	1.1503e-007	4.2561e+003	1.5977e-007	5.9117e-003
Po-210	2.0753e-008	7.6786e+002	2.8826e-008	1.0665e-003
Po-211	2.5190e-010	9.3204e+000	3.4989e-010	1.2946e-005
Po-212	7.2542e-014	2.6841e-003	1.0076e-013	3.7281e-009
Po-213	1.3749e-009	5.0873e+001	1.9098e-009	7.0661e-005
Po-214	1.1501e-007	4.2552e+003	1.5974e-007	5.9104e-003
Po-215	9.2273e-008	3.4141e+003	1.2817e-007	4.7421e-003
Po-216	1.1324e-013	4.1899e-003	1.5729e-013	5.8197e-009
Po-218	1.1505e-007	4.2570e+003	1.5981e-007	5.9129e-003
Pr-144	1.0497e-007	3.8838e+003	1.4580e-007	5.3945e-003
Pr-144m	1.5010e-009	5.5537e+001	2.0849e-009	7.7141e-005
Pu-238	3.6306e+000	1.3433e+011	5.0429e+000	1.8659e+005
Pu-239	4.5328e-001	1.6771e+010	6.2960e-001	2.3295e+004
Pu-240	1.0774e-001	3.9865e+009	1.4965e-001	5.5371e+003
Pu-241	1.3982e+000	5.1735e+010	1.9421e+000	7.1859e+004
Pu-242	5.8314e-005	2.1576e+006	8.0997e-005	2.9969e+000
Ra-223	9.2273e-008	3.4141e+003	1.2817e-007	4.7421e-003
Ra-224	1.1324e-013	4.1899e-003	1.5729e-013	5.8197e-009
Ra-225	1.4104e-009	5.2185e+001	1.9590e-009	7.2484e-005
Ra-226	1.1521e-007	4.2628e+003	1.6003e-007	5.9210e-003
Ra-228	1.3705e-013	5.0710e-003	1.9037e-013	7.0435e-009
Rh-106	3.6852e-006	1.3635e+005	5.1186e-006	1.8939e-001
Rn-219	9.2273e-008	3.4141e+003	1.2817e-007	4.7421e-003
Rn-220	1.1324e-013	4.1899e-003	1.5729e-013	5.8197e-009
Rn-222	1.1505e-007	4.2570e+003	1.5981e-007	5.9129e-003
Ru-106	3.6852e-006	1.3635e+005	5.1186e-006	1.8939e-001
Sb-125	1.1123e-002	4.1156e+008	1.5450e-002	5.7165e+002
Sr-90	1.3095e+002	4.8451e+012	1.8189e+002	6.7298e+006
Tc-99	6.2631e-002	2.3174e+009	8.6994e-002	3.2188e+003
Te-125m	2.7257e-003	1.0085e+008	3.7860e-003	1.4008e+002
Th-227	9.1329e-008	3.3792e+003	1.2685e-007	4.6936e-003
Th-228	1.1336e-013	4.1944e-003	1.5746e-013	5.8260e-009
Th-229	1.4179e-009	5.2464e+001	1.9695e-009	7.2872e-005
Th-230	2.4261e-005	8.9765e+005	3.3698e-005	1.2468e+000
Th-231	7.1276e-004	2.6372e+007	9.9001e-004	3.6631e+001
Th-232	2.1102e-013	7.8076e-003	2.9310e-013	1.0845e-008
Th-234	4.1757e-005	1.5450e+006	5.8000e-005	2.1460e+000
Tl-207	9.2020e-008	3.4047e+003	1.2781e-007	4.7291e-003
Tl-208	4.0681e-014	1.5052e-003	5.6505e-014	2.0907e-009
Tl-209	3.0354e-011	1.1231e+000	4.2162e-011	1.5600e-006
U-233	1.3726e-006	5.0786e+004	1.9065e-006	7.0541e-002
U-234	1.2263e-001	4.5374e+009	1.7033e-001	6.3023e+003
U-235	7.1276e-004	2.6372e+007	9.9001e-004	3.6631e+001
U-236	1.9446e-004	7.1949e+006	2.7010e-004	9.9936e+000
U-237	3.4301e-005	1.2691e+006	4.7644e-005	1.7628e+000
U-238	4.1757e-005	1.5450e+006	5.8000e-005	2.1460e+000
Y-90	1.3098e+002	4.8464e+012	1.8193e+002	6.7315e+006

Buildup
 The material reference is : Transition

Page : 3
 DOS File: T12SBW16.MS5
 Run Date: November 25, 1997
 Run Time: 9:26:13 PM
 Duration: 00:01:37

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Results</u>			
		<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
		<u>MeV/cm²/sec</u>	<u>MeV/cm²/sec</u>	<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.015	4.961e+04	7.196e-192	4.509e-29	6.172e-193	3.867e-30
0.02	5.007e+01	1.119e-92	1.291e-31	3.875e-94	4.473e-33
0.03	2.783e+11	1.097e-25	1.361e-20	1.087e-27	1.349e-22
0.04	6.804e+10	4.320e-11	4.912e-09	1.911e-13	2.172e-11
0.05	6.957e+08	2.793e-07	4.619e-05	7.441e-10	1.230e-07
0.06	5.438e+09	1.163e-03	1.742e-01	2.309e-06	3.460e-04
0.08	1.273e+09	6.426e-02	5.181e+00	1.017e-04	8.199e-03
0.1	4.658e+09	2.189e+00	9.794e+01	3.348e-03	1.498e-01
0.15	1.429e+07	5.440e-02	1.008e+00	8.957e-05	1.660e-03
0.2	6.608e+08	5.803e+00	6.975e+01	1.024e-02	1.231e-01
0.3	2.685e+08	5.681e+00	4.354e+01	1.078e-02	8.260e-02
0.4	2.114e+08	7.742e+00	4.585e+01	1.508e-02	8.933e-02
0.5	6.416e+07	3.542e+00	1.760e+01	6.953e-03	3.455e-02
0.6	4.241e+12	3.260e+05	1.418e+06	6.363e+02	2.768e+03
0.8	3.628e+09	4.687e+02	1.685e+03	8.914e-01	3.206e+00
1.0	6.004e+09	1.160e+03	3.663e+03	2.138e+00	6.752e+00
1.5	6.743e+09	2.691e+03	6.917e+03	4.528e+00	1.164e+01
2.0	1.214e+03	7.981e-04	1.822e-03	1.234e-06	2.817e-06
3.0	1.502e-03	1.935e-09	3.825e-09	2.625e-12	5.190e-12
TOTALS:	4.617e+12	3.303e+05	1.431e+06	6.439e+02	2.790e+03

MicroShield v5.01 (5.01-00121)
 Lockheed Martin Idaho Technologies Company
 Case File Heat Generation
 Case File: T9ALUM.MS5
 Case Title: T9alum

<u>Isotope</u>	<u>Activity</u> <u>Curies</u>	<u>Activity</u> <u>Bequerels</u>	<u>Heat Generation</u> <u>Watts/Curie</u>	<u>Heat Generation</u> <u>Watts</u>
Am-241	2.0879e-001	7.7251e+009	3.2813e-002	6.8508e-003
Am-243	7.1995e-006	2.6638e+005	3.1704e-002	2.2825e-007
Ba-137m	1.2937e+003	4.7869e+013	3.9212e-003	5.0731e+000
Ce-144	1.7999e-017	6.6595e-007	6.6284e-004	1.1930e-020
Cm-242	5.9036e-006	2.1843e+005	3.6240e-002	2.1395e-007
Cm-244	1.1519e-005	4.2621e+005	3.4409e-002	3.9637e-007
Cs-134	7.0555e-006	2.6105e+005	1.0179e-002	7.1819e-008
Cs-137	1.3679e+003	5.0612e+013	1.0122e-003	1.3847e+000
Eu-154	6.2636e-001	2.3175e+010	9.0517e-003	5.6696e-003
Eu-155	3.8157e-002	1.4118e+009	7.2543e-004	2.7680e-005
Np-237	1.9439e-003	7.1923e+007	2.8779e-002	5.5943e-005
Pa-233	1.9439e-003	7.1923e+007	2.4276e-003	4.7189e-006
Pm-147	5.1116e-003	1.8913e+008	3.6731e-004	1.8776e-006
Pr-144	1.7999e-017	6.6595e-007	7.3455e-003	1.3221e-019
Pu-238	7.1995e-001	2.6638e+010	3.2587e-002	2.3461e-002
Pu-239	9.3593e-002	3.4630e+009	3.0551e-002	2.8593e-003
Pu-240	3.7437e-002	1.3852e+009	3.0614e-002	1.1461e-003
Pu-241	3.3118e-001	1.2254e+010	3.1003e-005	1.0268e-005
Pu-242	2.8078e-006	1.0389e+005	2.9184e-002	8.1944e-008
Rh-106	1.0079e-013	3.7293e-003	9.5998e-003	9.6759e-016
Ru-106	1.0079e-013	3.7293e-003	5.9459e-005	5.9930e-018
Sb-125	2.0879e-004	7.7251e+006	3.1431e-003	6.5623e-007
Sm-151	2.8078e+001	1.0389e+012	1.1729e-004	3.2932e-003
Sr-90	1.2239e+003	4.5285e+013	1.1607e-003	1.4206e+000
Tc-99	7.0555e-001	2.6105e+010	5.0152e-004	3.5385e-004
Th-230	1.9439e-004	7.1923e+006	2.7809e-002	5.4057e-006
Th-231	3.3118e-005	1.2254e+006	1.0580e-003	3.5037e-008
U-232	2.6638e-007	9.8561e+003	3.1553e-002	8.4052e-009
U-233	2.7358e-007	1.0122e+004	2.8557e-002	7.8125e-009
U-234	5.9036e-003	2.1843e+008	2.8311e-002	1.6714e-004
U-235	3.9597e-005	1.4651e+006	2.7115e-002	1.0737e-006
U-236	9.3593e-005	3.4630e+006	2.6697e-002	2.4987e-006
U-237	7.9194e-006	2.9302e+005	1.9366e-003	1.5337e-008
U-238	2.3038e-006	8.5242e+004	2.4920e-002	5.7412e-008
Y-90	1.2239e+003	4.5285e+013	5.5411e-003	6.7818e+000

Total

Heat Generation:

1.4704e+001

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
DOS File: T9ALUM.MS5
Run Date: November 20, 1997
Run Time: 1:55:10 AM
Duration: 00:01:33

File Ref: HKP-26
Date: 12/4/99
By: PHH/BAW
Checked: 12/5/99

Case Title: T9alum
Description: R/hr @ 1 cm from canister surf., Alumina calcine (T-9)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions
Height 262.8 cm / 8 ft 7.5 in
Radius 29.53 cm / 11.6 in

Dose Points
1 X 31.48 cm / 1 ft 0.4 in Y 131.4 cm / 4 ft 3.7 in Z 0 cm / 0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	7.20e+05 cm ³	Concrete	2.6
Shield 1	.95 cm	Iron	7.86
Transition	1.0 cm	Air	0.0011
Air Gap		Air	0.0011

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Am-241	2.0879e-001	7.7251e+009	2.9000e-001 /	1.0730e+004
Am-243	7.1995e-006	2.6638e+005	1.0000e-005 /	3.7000e-001
Ba-137m	1.2937e+003	4.7869e+013	1.7970e+003 /	6.6489e+007
Ce-144	1.7999e-017	6.6595e-007	2.5000e-017 /	9.2500e-013
Cm-242	5.9036e-006	2.1843e+005	8.2000e-006 /	3.0340e-001
Cm-244	1.1519e-005	4.2621e+005	1.6000e-005 /	5.9200e-001
Cs-134	7.0555e-006	2.6105e+005	9.8000e-006 /	3.6260e-001
Cs-137	1.3679e+003	5.0612e+013	1.9000e+003 /	7.0300e+007
Eu-154	6.2636e-001	2.3175e+010	8.7000e-001 /	3.2190e+004
Eu-155	3.8157e-002	1.4118e+009	5.3000e-002 /	1.9610e+003
Np-237	1.9439e-003	7.1923e+007	2.7000e-003 /	9.9900e+001
Pa-233	1.9439e-003	7.1923e+007	2.7000e-003 /	9.9900e+001
Pm-147	5.1116e-003	1.8913e+008	7.1000e-003 /	2.6270e+002
Pr-144	1.7999e-017	6.6595e-007	2.5000e-017	9.2500e-013
Pu-238	7.1995e-001	2.6638e+010	1.0000e+000 /	3.7000e+004
Pu-239	9.3593e-002	3.4630e+009	1.3000e-001 /	4.8100e+003
Pu-240	3.7437e-002	1.3852e+009	5.2000e-002 /	1.9240e+003
Pu-241	3.3118e-001	1.2254e+010	4.6000e-001 /	1.7020e+004
Pu-242	2.8078e-006	1.0389e+005	3.9000e-006 /	1.4430e-001
Rh-106	1.0079e-013	3.7293e-003	1.4000e-013 /	5.1800e-009
Ru-106	1.0079e-013	3.7293e-003	1.4000e-013 /	5.1800e-009
Sb-125	2.0879e-004	7.7251e+006	2.9000e-004 /	1.0730e+001
Sm-151	2.8078e+001	1.0389e+012	3.9000e+001 /	1.4430e+006
Sr-90	1.2239e+003	4.5285e+013	1.7000e+003 /	6.2900e+007
Tc-99	7.0555e-001	2.6105e+010	9.8000e-001 /	3.6260e+004

Page : 2
 DOS File: T9ALUM.MS5
 Run Date: November 20, 1997
 Run Time: 1:55:10 AM
 Duration: 00:01:33

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Th-230	1.9439e-004	7.1923e+006	2.7000e-004 ✓	9.9900e+000
Th-231	3.3118e-005	1.2254e+006	4.6000e-005 ✓	1.7020e+000
U-232	2.6638e-007	9.8561e+003	3.7000e-007 ✓	1.3690e-002
U-233	2.7358e-007	1.0122e+004	3.8000e-007 ✓	1.4060e-002
U-234	5.9036e-003	2.1843e+008	8.2000e-003 ✓	3.0340e+002
U-235	3.9597e-005	1.4651e+006	5.5000e-005 ✓	2.0350e+000
U-236	9.3593e-005	3.4630e+006	1.3000e-004 ✓	4.8100e+000
U-237	7.9194e-006	2.9302e+005	1.1000e-005 ✓	4.0700e-001
U-238	2.3038e-006	8.5242e+004	3.2000e-006 ✓	1.1840e-001
Y-90	1.2239e+003	4.5285e+013	1.7000e+003 ✓	6.2900e+007

Buildup
 The material reference is : Source

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	.23

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Results</u>			
		<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
		<u>MeV/cm²/sec</u>	<u>MeV/cm²/sec</u>	<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.015	2.305e+03	1.692e-216	1.057e-29	1.451e-217	9.065e-31
0.02	3.072e+08	7.591e-95	2.216e-24	2.629e-96	7.677e-26
0.03	2.820e+12	3.343e-26	4.499e-20	3.313e-28	4.459e-22
0.04	6.703e+11	5.560e-10	2.089e-09	2.459e-12	9.240e-12
0.05	1.282e+09	1.948e-06	1.155e-05	5.189e-09	3.078e-08
0.06	2.819e+09	3.177e-03	2.513e-02	6.310e-06	4.991e-05
0.08	4.503e+08	1.394e-01	1.301e+00	2.207e-04	2.058e-03
0.1	9.703e+09	2.874e+01	2.633e+02	4.397e-02	4.028e-01
0.15	1.489e+06	3.687e-02	2.822e-01	6.071e-05	4.646e-04
0.2	1.585e+09	9.226e+01	6.154e+02	1.628e-01	1.086e+00
0.3	3.604e+07	5.160e+00	2.819e+01	9.788e-03	5.347e-02
0.4	1.703e+08	4.271e+01	2.016e+02	8.322e-02	3.929e-01
0.5	5.098e+07	1.945e+01	8.186e+01	3.819e-02	1.607e-01
0.6	4.307e+13	2.305e+07	8.817e+07	4.499e+04	1.721e+05
0.8	9.038e+09	8.229e+03	2.726e+04	1.565e+01	5.186e+01
1.0	7.129e+09	9.802e+03	2.922e+04	1.807e+01	5.386e+01
1.5	9.043e+09	2.615e+04	6.529e+04	4.399e+01	1.099e+02
2.0	5.155e-09	2.482e-14	5.584e-14	3.839e-17	8.636e-17
TOTALS:	4.661e+13	2.309e+07	8.829e+07	4.507e+04	1.723e+05

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
 DOS File: T9ALUM.MS5
 Run Date: November 20, 1997
 Run Time: 2:02:41 AM
 Duration: 00:01:30

File Ref: HKP-26
 Date: 12/4/97
 By: [Signature]
 Checked: [Signature]

Case Title: T9alum
Description: R/hr @ 1 m from canister surf., Alumina calcine (T-9)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions
 Height 262.8 cm — 8 ft 7.5 in
 Radius 29.53 cm — 11.6 in

Dose Points

	<u>X</u>	<u>Y</u>	<u>Z</u>
# 1	130.48 cm —	131.4 cm	0 cm
	4 ft 3.4 in	4 ft 3.7 in	0.0 in

Shields

<u>Shield Name</u>	<u>Dimension</u>	<u>Material</u>	<u>Densit</u>
Source	7.20e+05 cm ³	Concrete	2.6
Shield 1	.95 cm	Iron	7.86
Transition	100.0 cm	Air	0.0011
Air Gap		Air	0.0011

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded

Library : Grove

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Am-241	2.0879e-001	7.7251e+009	2.9000e-001	1.0730e+004
Am-243	7.1995e-006	2.6638e+005	1.0000e-005	3.7000e-001
Ba-137m	1.2937e+003	4.7869e+013	1.7970e+003	6.6489e+007
Ce-144	1.7999e-017	6.6595e-007	2.5000e-017	9.2500e-013
Cm-242	5.9036e-006	2.1843e+005	8.2000e-006	3.0340e-001
Cm-244	1.1519e-005	4.2621e+005	1.6000e-005	5.9200e-001
Cs-134	7.0555e-006	2.6105e+005	9.8000e-006	3.6260e-001
Cs-137	1.3679e+003	5.0612e+013	1.9000e+003	7.0300e+007
Eu-154	6.2636e-001	2.3175e+010	8.7000e-001	3.2190e+004
Eu-155	3.8157e-002	1.4118e+009	5.3000e-002	1.9610e+003
Np-237	1.9439e-003	7.1923e+007	2.7000e-003	9.9900e+001
Pa-233	1.9439e-003	7.1923e+007	2.7000e-003	9.9900e+001
Pm-147	5.1116e-003	1.8913e+008	7.1000e-003	2.6270e+002
Pr-144	1.7999e-017	6.6595e-007	2.5000e-017	9.2500e-013
Pu-238	7.1995e-001	2.6638e+010	1.0000e+000	3.7000e+004
Pu-239	9.3593e-002	3.4630e+009	1.3000e-001	4.8100e+003
Pu-240	3.7437e-002	1.3852e+009	5.2000e-002	1.9240e+003
Pu-241	3.3118e-001	1.2254e+010	4.6000e-001	1.7020e+004
Pu-242	2.8078e-006	1.0389e+005	3.9000e-006	1.4430e-001
Rh-106	1.0079e-013	3.7293e-003	1.4000e-013	5.1800e-009
Ru-106	1.0079e-013	3.7293e-003	1.4000e-013	5.1800e-009
Sb-125	2.0879e-004	7.7251e+006	2.9000e-004	1.0730e+001
Sm-151	2.8078e+001	1.0389e+012	3.9000e+001	1.4430e+006
Sr-90	1.2239e+003	4.5285e+013	1.7000e+003	6.2900e+007
Tc-99	7.0555e-001	2.6105e+010	9.8000e-001	3.6260e+004

Page : 2
 DOS File: T9ALUM.MS5
 Run Date: November 20, 1997
 Run Time: 2:02:41 AM
 Duration: 00:01:30

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Th-230	1.9439e-004	7.1923e+006	2.7000e-004	9.9900e+000
Th-231	3.3118e-005	1.2254e+006	4.6000e-005	1.7020e+000
U-232	2.6638e-007	9.8561e+003	3.7000e-007	1.3690e-002
U-233	2.7358e-007	1.0122e+004	3.8000e-007	1.4060e-002
U-234	5.9036e-003	2.1843e+008	8.2000e-003	3.0340e+002
U-235	3.9597e-005	1.4651e+006	5.5000e-005	2.0350e+000
U-236	9.3593e-005	3.4630e+006	1.3000e-004	4.8100e+000
U-237	7.9194e-006	2.9302e+005	1.1000e-005	4.0700e-001
U-238	2.3038e-006	8.5242e+004	3.2000e-006	1.1840e-001
Y-90	1.2239e+003	4.5285e+013	1.7000e+003	6.2900e+007

Buildup
 The material reference is : Transition

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Results</u>			
		<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
		<u>MeV/cm²/sec</u> <u>No Buildup</u>	<u>MeV/cm²/sec</u> <u>With Buildup</u>	<u>mR/hr</u> <u>No Buildup</u>	<u>mR/hr</u> <u>With Buildup</u>
0.015	2.305e+03	4.874e-193	2.095e-30	4.181e-194	1.797e-31
0.02	3.072e+08	8.524e-86	7.922e-25	2.953e-87	2.744e-26
0.03	2.820e+12	1.367e-24	1.379e-19	1.355e-26	1.366e-21
0.04	6.703e+11	5.239e-10	5.956e-08	2.317e-12	2.634e-10
0.05	1.282e+09	6.337e-07	1.048e-04	1.688e-09	2.791e-07
0.06	2.819e+09	7.417e-04	1.111e-01	1.473e-06	2.207e-04
0.08	4.503e+08	2.798e-02	2.255e+00	4.427e-05	3.569e-03
0.1	9.703e+09	5.610e+00	2.509e+02	8.583e-03	3.839e-01
0.15	1.489e+06	6.974e-03	1.291e-01	1.148e-05	2.126e-04
0.2	1.585e+09	1.711e+01	2.054e+02	3.020e-02	3.625e-01
0.3	3.604e+07	9.374e-01	7.169e+00	1.778e-03	1.360e-02
0.4	1.703e+08	7.664e+00	4.526e+01	1.493e-02	8.820e-02
0.5	5.098e+07	3.459e+00	1.713e+01	6.789e-03	3.363e-02
0.6	4.307e+13	4.066e+06	1.763e+07	7.937e+03	3.441e+04
0.8	9.038e+09	1.433e+03	5.132e+03	2.726e+00	9.762e+00
1.0	7.129e+09	1.689e+03	5.308e+03	3.114e+00	9.785e+00
1.5	9.043e+09	4.418e+03	1.128e+04	7.433e+00	1.897e+01
2.0	5.155e-09	4.140e-15	9.370e-15	6.402e-18	1.449e-17
TOTALS:	4.661e+13	4.074e+06	1.765e+07	7.950e+03	3.445e+04

MicroShield v5.01 (5.01-00121)
 Lockheed Martin Idaho Technologies Company
 Case File Heat Generation
 Case File: T9ZIR.MS5
 Case Title: T9zir

<u>Isotope</u>	<u>Activity</u> <u>Curies</u>	<u>Activity</u> <u>Bequerels</u>	<u>Heat Generation</u> <u>Watts/Curie</u>	<u>Heat Generation</u> <u>Watts</u>
Am-241	1.0079e+000	3.7293e+010	3.2813e-002	3.3073e-002
Am-243	1.6559e-008	6.1268e+002	3.1704e-002	5.2499e-010
Ba-137m	5.4500e+002	2.0165e+013	3.9212e-003	2.1371e+000
Ce-144	3.7437e-010	1.3852e+001	6.6284e-004	2.4815e-013
Cm-242	2.1598e-007	7.9914e+003	3.6240e-002	7.8273e-009
Cm-244	3.7437e-008	1.3852e+003	3.4409e-002	1.2882e-009
Co-60	3.3118e-002	1.2254e+009	1.5423e-002	5.1076e-004
Cs-134	1.6559e-003	6.1268e+007	1.0179e-002	1.6855e-005
Cs-137	5.7596e+002	2.1311e+013	1.0122e-003	5.8301e-001
Eu-154	2.2318e+000	8.2578e+010	9.0517e-003	2.0202e-002
Eu-155	3.2398e-003	1.1987e+008	7.2543e-004	2.3502e-006
Np-237	2.2318e-004	8.2578e+006	2.8779e-002	6.4231e-006
Pa-233	2.2318e-004	8.2578e+006	2.4276e-003	5.4179e-007
Pm-147	3.4558e-001	1.2786e+010	3.6731e-004	1.2693e-004
Pr-144	3.7437e-010	1.3852e+001	7.3455e-003	2.7500e-012
Pu-238	8.6394e+000	3.1966e+011	3.2587e-002	2.8153e-001
Pu-239	1.3679e-001	5.0612e+009	3.0551e-002	4.1790e-003
Pu-240	1.2959e-001	4.7949e+009	3.0614e-002	3.9674e-003
Pu-241	4.0317e+000	1.4917e+011	3.1003e-005	1.2500e-004
Pu-242	2.8798e-004	1.0655e+007	2.9184e-002	8.4045e-006
Rh-106	3.4558e-008	1.2786e+003	9.5998e-003	3.3175e-010
Ru-106	3.4558e-008	1.2786e+003	5.9459e-005	2.0548e-012
Sb-125	1.0799e-002	3.9957e+008	3.1431e-003	3.3943e-005
Sm-151	1.2959e+001	4.7949e+011	1.1729e-004	1.5199e-003
Sr-90	7.1995e+002	2.6638e+013	1.1607e-003	8.3566e-001
Tc-99	1.7999e-001	6.6595e+009	5.0152e-004	9.0267e-005
Th-230	1.6559e-006	6.1268e+004	2.7809e-002	4.6049e-008
Th-231	4.3917e-005	1.6249e+006	1.0580e-003	4.6463e-008
U-232	4.3197e-007	1.5983e+004	3.1553e-002	1.3630e-008
U-233	2.7358e-008	1.0122e+003	2.8557e-002	7.8125e-010
U-234	6.9835e-003	2.5839e+008	2.8311e-002	1.9771e-004
U-235	4.3917e-005	1.6249e+006	2.7115e-002	1.1908e-006
U-236	1.1519e-004	4.2621e+006	2.6697e-002	3.0753e-006
U-237	1.0079e-004	3.7293e+006	1.9366e-003	1.9520e-007
U-238	2.1598e-006	7.9914e+004	2.4920e-002	5.3824e-008
Y-90	7.1995e+002	2.6638e+013	5.5411e-003	3.9893e+000

Total

Heat Generation:

7.8907e+000 ✓

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
DOS File: T9ZIR.MS5
Run Date: November 20, 1997
Run Time: 2:20:01 AM
Duration: 00:01:31

File Ref: HKP-26-97
Date: 12/4/97
By: J. H. Johnson
Checked: J. H. Johnson

Case Title: T9zir
Description: R/hr @ 1 cm from canister surf., Zirconia calcine (T-9)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions

Height 262.8 cm - 8 ft 7.5 in
Radius 29.53 cm - 11.6 in

Dose Points

1 X Y Z
31.48 cm 131.4 cm 0 cm
1 ft 0.4 in 4 ft 3.7 in 0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	7.20e+05 cm ³	Concrete	2.6
Shield 1	.95 cm	Iron	7.86
Transition	1.0 cm	Air	0.0011
Air Gap		Air	0.0011

Source Input

Grouping Method : Standard Indices

Number of Groups : 25

Lower Energy Cutoff : 0.015

Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Am-241	1.0079e+000	3.7293e+010	1.4000e+000	5.1800e+004
Am-243	1.6559e-008	6.1268e+002	2.3000e-008	8.5100e-004
Ba-137m	5.4500e+002	2.0165e+013	7.5700e+002	2.8009e+007
Ce-144	3.7437e-010	1.3852e+001	5.2000e-010	1.9240e-005
Cm-242	2.1598e-007	7.9914e+003	3.0000e-007	1.1100e-002
Cm-244	3.7437e-008	1.3852e+003	5.2000e-008	1.9240e-003
Co-60	3.3118e-002	1.2254e+009	4.6000e-002	1.7020e+003
Cs-134	1.6559e-003	6.1268e+007	2.3000e-003	8.5100e+001
Cs-137	5.7596e+002	2.1311e+013	8.0000e+002	2.9600e+007
Eu-154	2.2318e+000	8.2578e+010	3.1000e+000	1.1470e+005
Eu-155	3.2398e-003	1.1987e+008	4.5000e-003	1.6650e+002
Np-237	2.2318e-004	8.2578e+006	3.1000e-004	1.1470e+001
Pa-233	2.2318e-004	8.2578e+006	3.1000e-004	1.1470e+001
Pm-147	3.4558e-001	1.2786e+010	4.8000e-001	1.7760e+004
Pr-144	3.7437e-010	1.3852e+001	5.2000e-010	1.9240e-005
Pu-238	8.6394e+000	3.1966e+011	1.2000e+001	4.4400e+005
Pu-239	1.3679e-001	5.0612e+009	1.9000e-001	7.0300e+003
Pu-240	1.2959e-001	4.7949e+009	1.8000e-001	6.6600e+003
Pu-241	4.0317e+000	1.4917e+011	5.6000e+000	2.0720e+005
Pu-242	2.8798e-004	1.0655e+007	4.0000e-004	1.4800e+001
Rh-106	3.4558e-008	1.2786e+003	4.8000e-008	1.7760e-003
Ru-106	3.4558e-008	1.2786e+003	4.8000e-008	1.7760e-003
Sb-125	1.0799e-002	3.9957e+008	1.5000e-002	5.5500e+002
Sm-151	1.2959e+001	4.7949e+011	1.8000e+001	6.6600e+005
Sr-90	7.1995e+002	2.6638e+013	1.0000e+003	3.7000e+007

Page : 2
 DOS File: T9ZIR.MS5
 Run Date: November 20, 1997
 Run Time: 2:20:01 AM
 Duration: 00:01:31

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Tc-99	1.7999e-001	6.6595e+009	2.5000e-001	9.2500e+003
Th-230	1.6559e-006	6.1268e+004	2.3000e-006	8.5100e-002
Th-231	4.3917e-005	1.6249e+006	6.1000e-005	2.2570e+000
U-232	4.3197e-007	1.5983e+004	6.0000e-007	2.2200e-002
U-233	2.7358e-008	1.0122e+003	3.8000e-008	1.4060e-003
U-234	6.9835e-003	2.5839e+008	9.7000e-003	3.5890e+002
U-235	4.3917e-005	1.6249e+006	6.1000e-005	2.2570e+000
U-236	1.1519e-004	4.2621e+006	1.6000e-004	5.9200e+000
U-237	1.0079e-004	3.7293e+006	1.4000e-004	5.1800e+000
U-238	2.1598e-006	7.9914e+004	3.0000e-006	1.1100e-001
Y-90	7.1995e+002	2.6638e+013	1.0000e+003	3.7000e+007

Buildup
 The material reference is : Source

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Results</u>			
		<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
		<u>MeV/cm²/sec</u>	<u>MeV/cm²/sec</u>	<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.015	3.056e+03	2.244e-216	1.401e-29	1.925e-217	1.202e-30
0.02	1.418e+08	3.503e-95	1.023e-24	1.214e-96	3.543e-26
0.03	1.189e+12	1.410e-26	1.897e-20	1.397e-28	1.880e-22
0.04	2.971e+11	2.465e-10	9.261e-10	1.090e-12	4.096e-12
0.05	4.279e+09	6.499e-06	3.855e-05	1.731e-08	1.027e-07
0.06	1.361e+10	1.534e-02	1.213e-01	3.047e-05	2.410e-04
0.08	3.877e+07	1.200e-02	1.120e-01	1.900e-05	1.772e-04
0.1	3.345e+10	9.908e+01	9.077e+02	1.516e-01	1.389e+00
0.15	1.467e+06	3.631e-02	2.779e-01	5.979e-05	4.576e-04
0.2	5.672e+09	3.303e+02	2.203e+03	5.829e-01	3.888e+00
0.3	5.904e+06	8.452e-01	4.617e+00	1.603e-03	8.758e-03
0.4	7.146e+08	1.792e+02	8.460e+02	3.492e-01	1.648e+00
0.5	2.211e+08	8.436e+01	3.550e+02	1.656e-01	6.967e-01
0.6	1.815e+13	9.713e+06	3.715e+07	1.896e+04	7.252e+04
0.8	3.226e+10	2.937e+04	9.732e+04	5.587e+01	1.851e+02
1.0	2.663e+10	3.661e+04	1.091e+05	6.749e+01	2.012e+02
1.5	3.345e+10	9.672e+04	2.415e+05	1.627e+02	4.063e+02
2.0	1.072e-01	5.163e-07	1.162e-06	7.985e-10	1.796e-09
TOTALS:	1.979e+13	9.877e+06	3.761e+07	1.925e+04	7.332e+04

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
DOS File: T9ALUM.MS5
Run Date: November 20, 1997
Run Time: 2:15:06 AM
Duration: 00:01:30

File Ref: HKP-26-93
Date: 12/4/97
By: [Signature]
Checked: [Signature]

Case Title: T9zir
Description: R/hr @ 1 m from canister surf., Zirconia calcine (T-9)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions
Height 262.8 cm — 8 ft 7.5 in
Radius 29.53 cm — 11.6 in

Dose Points
1 X 130.48 cm — 4 ft 3.4 in Y 131.4 cm — 4 ft 3.7 in Z 0 cm — 0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	7.20e+05 cm ³	Concrete	2.6 —
Shield 1	.95 cm	Iron	7.86
Transition	100.0 cm	Air	0.0011
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Am-241	1.0079e+000	3.7293e+010	1.4000e+000	5.1800e+004
Am-243	1.6559e-008	6.1268e+002	2.3000e-008	8.5100e-004
Ba-137m	5.4500e+002	2.0165e+013	7.5700e+002	2.8009e+007
Ce-144	3.7437e-010	1.3852e+001	5.2000e-010	1.9240e-005
Cm-242	2.1598e-007	7.9914e+003	3.0000e-007	1.1100e-002
Cm-244	3.7437e-008	1.3852e+003	5.2000e-008	1.9240e-003
Co-60	3.3118e-002	1.2254e+009	4.6000e-002	1.7020e+003
Cs-134	1.6559e-003	6.1268e+007	2.3000e-003	8.5100e+001
Cs-137	5.7596e+002	2.1311e+013	8.0000e+002	2.9600e+007
Eu-154	2.2318e+000	8.2578e+010	3.1000e+000	1.1470e+005
Eu-155	3.2398e-003	1.1987e+008	4.5000e-003	1.6650e+002
Np-237	2.2318e-004	8.2578e+006	3.1000e-004	1.1470e+001
Pa-233	2.2318e-004	8.2578e+006	3.1000e-004	1.1470e+001
Pm-147	3.4558e-001	1.2786e+010	4.8000e-001	1.7760e+004
Pr-144	3.7437e-010	1.3852e+001	5.2000e-010	1.9240e-005
Pu-238	8.6394e+000	3.1966e+011	1.2000e+001	4.4400e+005
Pu-239	1.3679e-001	5.0612e+009	1.9000e-001	7.0300e+003
Pu-240	1.2959e-001	4.7949e+009	1.8000e-001	6.6600e+003
Pu-241	4.0317e+000	1.4917e+011	5.6000e+000	2.0720e+005
Pu-242	2.8798e-004	1.0655e+007	4.0000e-004	1.4800e+001
Rh-106	3.4558e-008	1.2786e+003	4.8000e-008	1.7760e-003
Ru-106	3.4558e-008	1.2786e+003	4.8000e-008	1.7760e-003
Sb-125	1.0799e-002	3.9957e+008	1.5000e-002	5.5500e+002
Sm-151	1.2959e+001	4.7949e+011	1.8000e+001	6.6600e+005
Sr-90	7.1995e+002	2.6638e+013	1.0000e+003	3.7000e+007

Page : 2
 DOS File: T9ALUM.MS5
 Run Date: November 20, 1997
 Run Time: 2:15:06 AM
 Duration: 00:01:30

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Tc-99	1.7999e-001	6.6595e+009	2.5000e-001	9.2500e+003
Th-230	1.6559e-006	6.1268e+004	2.3000e-006	8.5100e-002
Th-231	4.3917e-005	1.6249e+006	6.1000e-005	2.2570e+000
U-232	4.3197e-007	1.5983e+004	6.0000e-007	2.2200e-002
U-233	2.7358e-008	1.0122e+003	3.8000e-008	1.4060e-003
U-234	6.9835e-003	2.5839e+008	9.7000e-003	3.5890e+002
U-235	4.3917e-005	1.6249e+006	6.1000e-005	2.2570e+000
U-236	1.1519e-004	4.2621e+006	1.6000e-004	5.9200e+000
U-237	1.0079e-004	3.7293e+006	1.4000e-004	5.1800e+000
U-238	2.1598e-006	7.9914e+004	3.0000e-006	1.1100e-001
Y-90	7.1995e+002	2.6638e+013	1.0000e+003	3.7000e+007

Buildup

The material reference is : Transition

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

Results

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Fluence Rate</u> <u>MeV/cm²/sec</u> <u>No Buildup</u>	<u>Fluence Rate</u> <u>MeV/cm²/sec</u> <u>With Buildup</u>	<u>Exposure Rate</u> <u>mR/hr</u> <u>No Buildup</u>	<u>Exposure Rate</u> <u>mR/hr</u> <u>With Buildup</u>
0.015	3.056e+03	6.463e-193	2.778e-30	5.544e-194	2.383e-31
0.02	1.418e+08	3.934e-86	3.656e-25	1.363e-87	1.267e-26
0.03	1.189e+12	5.766e-25	5.812e-20	5.714e-27	5.760e-22
0.04	2.971e+11	2.322e-10	2.640e-08	1.027e-12	1.168e-10
0.05	4.279e+09	2.114e-06	3.496e-04	5.632e-09	9.314e-07
0.06	1.361e+10	3.581e-03	5.366e-01	7.113e-06	1.066e-03
0.08	3.877e+07	2.408e-03	1.941e-01	3.811e-06	3.072e-04
0.1	3.345e+10	1.934e+01	8.650e+02	2.959e-02	1.323e+00
0.15	1.467e+06	6.868e-03	1.272e-01	1.131e-05	2.094e-04
0.2	5.672e+09	6.125e+01	7.351e+02	1.081e-01	1.297e+00
0.3	5.904e+06	1.535e-01	1.174e+00	2.912e-04	2.227e-03
0.4	7.146e+08	3.216e+01	1.899e+02	6.266e-02	3.701e-01
0.5	2.211e+08	1.500e+01	7.428e+01	2.944e-02	1.458e-01
0.6	1.815e+13	1.714e+06	7.429e+06	3.345e+03	1.450e+04
0.8	3.226e+10	5.116e+03	1.832e+04	9.731e+00	3.484e+01
1.0	2.663e+10	6.310e+03	1.983e+04	1.163e+01	3.655e+01
1.5	3.345e+10	1.634e+04	4.172e+04	2.749e+01	7.018e+01
2.0	1.072e-01	8.611e-08	1.949e-07	1.332e-10	3.014e-10
TOTALS:	1.979e+13	1.741e+06	7.511e+06	3.394e+03	1.464e+04

MicroShield v5.01 (5.01-00121)
 Lockheed Martin Idaho Technologies Company
 Case File Heat Generation
 Case File: T9SBW16.MS5
 Case Title: T9sbw

<u>Isotope</u>	<u>Activity Curies</u>	<u>Activity Bequerels</u>	<u>Heat Generation Watts/Curie</u>	<u>Heat Generation Watts</u>
Ac-225	4.8483e-010	1.7939e+001	3.4574e-002	1.6762e-011
Ac-227	3.1997e-008	1.1839e+003	4.7208e-004	1.5105e-011
Ac-228	4.7712e-014	1.7653e-003	8.0395e-003	3.8358e-016
Am-241	1.4189e-001	5.2500e+009	3.2813e-002	4.6559e-003
At-217	4.8483e-010	1.7939e+001	4.1888e-002	2.0308e-011
Ba-137m	4.5193e+001	1.6722e+012	3.9212e-003	1.7721e-001
Bi-210	7.9869e-009	2.9552e+002	2.3060e-003	1.8418e-011
Bi-211	3.1689e-008	1.1725e+003	3.9163e-002	1.2411e-009
Bi-212	3.9419e-014	1.4585e-003	1.6753e-002	6.6040e-016
Bi-213	4.8482e-010	1.7939e+001	4.1771e-003	2.0252e-012
Bi-214	4.1274e-008	1.5272e+003	1.2767e-002	5.2695e-010
Ce-144	3.5732e-008	1.3221e+003	6.6284e-004	2.3685e-011
Co-60	3.1115e-002	1.1512e+009	1.5423e-002	4.7987e-004
Cs-134	1.3706e-003	5.0711e+007	1.0179e-002	1.3951e-005
Cs-137	4.7773e+001	1.7676e+012	1.0122e-003	4.8358e-002
Eu-154	8.3998e-002	3.1079e+009	9.0517e-003	7.6033e-004
Eu-155	3.6600e-002	1.3542e+009	7.2543e-004	2.6551e-005
Fr-221	4.8483e-010	1.7939e+001	3.7907e-002	1.8378e-011
Fr-223	4.4155e-010	1.6337e+001	2.5771e-003	1.1379e-012
Ni-63	8.0368e-002	2.9736e+009	1.0155e-004	8.1613e-006
Np-237	4.9686e-003	1.8384e+008	2.8779e-002	1.4299e-004
Pa-231	1.1389e-007	4.2141e+003	3.2329e-002	3.6821e-009
Pa-233	4.9685e-003	1.8384e+008	2.4276e-003	1.2061e-005
Pa-234	2.3038e-008	8.5242e+002	1.4604e-002	3.3645e-010
Pa-234m	1.4399e-005	5.3276e+005	4.9490e-003	7.1260e-008
Pb-209	4.8480e-010	1.7938e+001	1.1714e-003	5.6789e-013
Pb-210	8.0074e-009	2.9627e+002	2.3060e-004	1.8465e-012
Pb-211	3.1689e-008	1.1725e+003	2.9963e-003	9.4950e-011
Pb-212	3.9419e-014	1.4585e-003	1.9044e-003	7.5069e-017
Pb-214	4.1275e-008	1.5272e+003	3.1921e-003	1.3175e-010
Po-210	7.4465e-009	2.7552e+002	3.1446e-002	2.3416e-010
Po-211	8.6512e-011	3.2009e+000	4.4166e-002	3.8209e-012
Po-212	2.5255e-014	9.3445e-004	5.2078e-002	1.3152e-015
Po-213	4.7435e-010	1.7551e+001	4.9660e-002	2.3556e-011
Po-214	4.1266e-008	1.5268e+003	4.5570e-002	1.8805e-009
Po-215	3.1690e-008	1.1725e+003	4.3787e-002	1.3876e-009
Po-216	3.9424e-014	1.4587e-003	4.0184e-002	1.5842e-015
Po-218	4.1283e-008	1.5275e+003	3.5576e-002	1.4687e-009
Pr-144	3.5734e-008	1.3221e+003	7.3455e-003	2.6248e-010
Pr-144m	5.1098e-010	1.8906e+001	3.3653e-004	1.7196e-013
Pu-238	1.2707e+000	4.7017e+010	3.2587e-002	4.1409e-002
Pu-239	1.5829e-001	5.8567e+009	3.0551e-002	4.8358e-003
Pu-240	3.8069e-002	1.4085e+009	3.0614e-002	1.1655e-003
Pu-241	4.9937e-001	1.8477e+010	3.1003e-005	1.5482e-005
Pu-242	2.0158e-005	7.4584e+005	2.9184e-002	5.8829e-007
Ra-223	3.1690e-008	1.1725e+003	3.4973e-002	1.1083e-009
Ra-224	3.9424e-014	1.4587e-003	3.3714e-002	1.3291e-015
Ra-225	4.8659e-010	1.8004e+001	7.0678e-004	3.4391e-013
Ra-226	4.1340e-008	1.5296e+003	2.8394e-002	1.1738e-009
Ra-228	4.7715e-014	1.7655e-003	6.8576e-005	3.2721e-018

<u>Isotope</u>	<u>Activity Curies</u>	<u>Activity Bequerels</u>	<u>Heat Generation Watts/Curie</u>	<u>Heat Generation Watts</u>
Rh-106	1.3189e-006	4.8799e+004	9.5998e-003	1.2661e-008
Rn-219	3.1690e-008	1.1725e+003	4.0502e-002	1.2835e-009
Rn-220	3.9424e-014	1.4587e-003	3.7278e-002	1.4696e-015
Rn-222	4.1283e-008	1.5275e+003	3.2543e-002	1.3435e-009
Ru-106	1.3189e-006	4.8799e+004	5.9459e-005	7.8420e-011
Sb-125	3.8053e-003	1.4080e+008	3.1431e-003	1.1961e-005
Sr-90	4.6466e+001	1.7192e+012	1.1607e-003	5.3934e-002
Tc-99	2.1597e-002	7.9909e+008	5.0152e-004	1.0831e-005
Te-125m	9.3249e-004	3.4502e+007	9.4493e-004	8.8114e-007
Th-227	3.1365e-008	1.1605e+003	3.5868e-002	1.1250e-009
Th-228	3.9467e-014	1.4603e-003	3.2139e-002	1.2684e-015
Th-229	4.8919e-010	1.8100e+001	2.9977e-002	1.4664e-011
Th-230	8.7051e-006	3.2209e+005	2.7809e-002	2.4208e-007
Th-231	2.4479e-004	9.0571e+006	1.0580e-003	2.5898e-007
Th-232	7.3465e-014	2.7182e-003	2.3811e-002	1.7493e-015
Th-234	1.4399e-005	5.3276e+005	3.9682e-004	5.7138e-009
Tl-207	3.1603e-008	1.1693e+003	2.9369e-003	9.2815e-011
Tl-208	1.4163e-014	5.2403e-004	2.3467e-002	3.3236e-016
Tl-209	1.0472e-011	3.8747e-001	1.6632e-002	1.7418e-013
U-233	4.7355e-007	1.7521e+004	2.8557e-002	1.3523e-008
U-234	4.4001e-002	1.6280e+009	2.8311e-002	1.2457e-003
U-235	2.4479e-004	9.0571e+006	2.7115e-002	6.6375e-006
U-236	6.7700e-005	2.5049e+006	2.6697e-002	1.8074e-006
U-237	1.2250e-005	4.5326e+005	1.9366e-003	2.3724e-008
U-238	1.4399e-005	5.3276e+005	2.4920e-002	3.5883e-007
Y-90	4.6478e+001	1.7197e+012	5.5411e-003	2.5754e-001

Total

Heat Generation:

5.9185e-001 ✓

Handwritten signature

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
DOS File: T9SBW16.MS5
Run Date: November 25, 1997
Run Time: 8:56:35 PM
Duration: 00:01:39

File Ref: HKP-26-9
Date: 12/4/97
By: J. H. Johnson
Checked: J. H. Johnson

Case Title: T9sbw
Description: R/hr @ 1 cm from canister surf., SBW calcine (T-9)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions
Height 262.8 cm / 8 ft 7.5 in
Radius 29.53 cm / 11.6 in

Dose Points
1 X 31.48 cm / 1 ft 0.4 in Y 131.4 cm / 4 ft 3.7 in Z 0 cm / 0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	7.20e+05 cm ³	Concrete	2.6
Shield 1	.95 cm	Iron	7.86
Transition	1.0 cm	Air	0.0011
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Ac-225	4.8483e-010	1.7939e+001	6.7342e-010	2.4917e-005
Ac-227	3.1997e-008	1.1839e+003	4.4443e-008	1.6444e-003
Ac-228	4.7712e-014	1.7653e-003	6.6271e-014	2.4520e-009
Am-241	1.4189e-001	5.2500e+009	1.9709e-001	7.2922e+003
At-217	4.8483e-010	1.7939e+001	6.7342e-010	2.4917e-005
Ba-137m	4.5193e+001	1.6722e+012	6.2773e+001	2.3226e+006
Bi-210	7.9869e-009	2.9552e+002	1.1094e-008	4.1047e-004
Bi-211	3.1689e-008	1.1725e+003	4.4016e-008	1.6286e-003
Bi-212	3.9419e-014	1.4585e-003	5.4752e-014	2.0258e-009
Bi-213	4.8482e-010	1.7939e+001	6.7341e-010	2.4916e-005
Bi-214	4.1274e-008	1.5272e+003	5.7330e-008	2.1212e-003
Ce-144	3.5732e-008	1.3221e+003	4.9632e-008	1.8364e-003
Co-60	3.1115e-002	1.1512e+009	4.3218e-002	1.5991e+003
Cs-134	1.3706e-003	5.0711e+007	1.9037e-003	7.0437e+001
Cs-137	4.7773e+001	1.7676e+012	6.6356e+001	2.4552e+006
Eu-154	8.3998e-002	3.1079e+009	1.1667e-001	4.3169e+003
Eu-155	3.6600e-002	1.3542e+009	5.0837e-002	1.8810e+003
Fr-221	4.8483e-010	1.7939e+001	6.7342e-010	2.4917e-005
Fr-223	4.4155e-010	1.6337e+001	6.1331e-010	2.2692e-005
Ni-63	8.0368e-002	2.9736e+009	1.1163e-001	4.1303e+003
Np-237	4.9686e-003	1.8384e+008	6.9013e-003	2.5535e+002
Pa-231	1.1389e-007	4.2141e+003	1.5820e-007	5.8533e-003
Pa-233	4.9685e-003	1.8384e+008	6.9012e-003	2.5535e+002
Pa-234	2.3038e-008	8.5242e+002	3.2000e-008	1.1840e-003
Pa-234m	1.4399e-005	5.3276e+005	2.0000e-005	7.4000e-001

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<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Pb-209	4.8480e-010	1.7938e+001	6.7338e-010	2.4915e-005
Pb-210	8.0074e-009	2.9627e+002	1.1122e-008	4.1152e-004
Pb-211	3.1689e-008	1.1725e+003	4.4016e-008	1.6286e-003
Pb-212	3.9419e-014	1.4585e-003	5.4753e-014	2.0258e-009
Pb-214	4.1275e-008	1.5272e+003	5.7330e-008	2.1212e-003
Po-210	7.4465e-009	2.7552e+002	1.0343e-008	3.8270e-004
Po-211	8.6512e-011	3.2009e+000	1.2016e-010	4.4461e-006
Po-212	2.5255e-014	9.3445e-004	3.5079e-014	1.2979e-009
Po-213	4.7435e-010	1.7551e+001	6.5887e-010	2.4378e-005
Po-214	4.1266e-008	1.5268e+003	5.7318e-008	2.1208e-003
Po-215	3.1690e-008	1.1725e+003	4.4016e-008	1.6286e-003
Po-216	3.9424e-014	1.4587e-003	5.4760e-014	2.0261e-009
Po-218	4.1283e-008	1.5275e+003	5.7342e-008	2.1216e-003
Pr-144	3.5734e-008	1.3221e+003	4.9634e-008	1.8364e-003
Pr-144m	5.1098e-010	1.8906e+001	7.0975e-010	2.6261e-005
Pu-238	1.2707e+000	4.7017e+010	1.7650e+000	6.5305e+004
Pu-239	1.5829e-001	5.8567e+009	2.1986e-001	8.1349e+003
Pu-240	3.8069e-002	1.4085e+009	5.2877e-002	1.9565e+003
Pu-241	4.9937e-001	1.8477e+010	6.9362e-001	2.5664e+004
Pu-242	2.0158e-005	7.4584e+005	2.7999e-005	1.0360e+000
Ra-223	3.1690e-008	1.1725e+003	4.4016e-008	1.6286e-003
Ra-224	3.9424e-014	1.4587e-003	5.4760e-014	2.0261e-009
Ra-225	4.8659e-010	1.8004e+001	6.7586e-010	2.5007e-005
Ra-226	4.1340e-008	1.5296e+003	5.7421e-008	2.1246e-003
Ra-228	4.7715e-014	1.7655e-003	6.6276e-014	2.4522e-009
Rh-106	1.3189e-006	4.8799e+004	1.8319e-006	6.7782e-002
Rn-219	3.1690e-008	1.1725e+003	4.4016e-008	1.6286e-003
Rn-220	3.9424e-014	1.4587e-003	5.4760e-014	2.0261e-009
Rn-222	4.1283e-008	1.5275e+003	5.7342e-008	2.1216e-003
Ru-106	1.3189e-006	4.8799e+004	1.8319e-006	6.7781e-002
Sb-125	3.8053e-003	1.4080e+008	5.2856e-003	1.9557e+002
Sr-90	4.6466e+001	1.7192e+012	6.4540e+001	2.3880e+006
Tc-99	2.1597e-002	7.9909e+008	2.9998e-002	1.1099e+003
Te-125m	9.3249e-004	3.4502e+007	1.2952e-003	4.7923e+001
Th-227	3.1365e-008	1.1605e+003	4.3566e-008	1.6119e-003
Th-228	3.9467e-014	1.4603e-003	5.4819e-014	2.0283e-009
Th-229	4.8919e-010	1.8100e+001	6.7948e-010	2.5141e-005
Th-230	8.7051e-006	3.2209e+005	1.2091e-005	4.4738e-001
Th-231	2.4479e-004	9.0571e+006	3.4000e-004	1.2580e+001
Th-232	7.3465e-014	2.7182e-003	1.0204e-013	3.7756e-009
Th-234	1.4399e-005	5.3276e+005	2.0000e-005	7.4000e-001
Tl-207	3.1603e-008	1.1693e+003	4.3896e-008	1.6241e-003
Tl-208	1.4163e-014	5.2403e-004	1.9672e-014	7.2788e-010
Tl-209	1.0472e-011	3.8747e-001	1.4546e-011	5.3819e-007
U-233	4.7355e-007	1.7521e+004	6.5775e-007	2.4337e-002
U-234	4.4001e-002	1.6280e+009	6.1116e-002	2.2613e+003
U-235	2.4479e-004	9.0571e+006	3.4000e-004	1.2580e+001
U-236	6.7700e-005	2.5049e+006	9.4034e-005	3.4793e+000
U-237	1.2250e-005	4.5326e+005	1.7016e-005	6.2958e-001
U-238	1.4399e-005	5.3276e+005	2.0000e-005	7.4000e-001
Y-90	4.6478e+001	1.7197e+012	6.4557e+001	2.3886e+006

Buildup
 The material reference is : Source

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Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

Energy MeV	Activity photons/sec	Results			
		Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	1.704e+04	1.251e-215	7.812e-29	1.073e-216	6.701e-30
0.02	1.719e+01	4.249e-102	1.241e-31	1.472e-103	4.297e-33
0.03	9.876e+10	1.171e-27	1.576e-21	1.160e-29	1.562e-23
0.04	2.413e+10	2.001e-11	7.521e-11	8.851e-14	3.326e-13
0.05	2.434e+08	3.698e-07	2.193e-06	9.850e-10	5.842e-09
0.06	1.935e+09	2.181e-03	1.725e-02	4.332e-06	3.426e-05
0.08	4.508e+08	1.396e-01	1.302e+00	2.209e-04	2.061e-03
0.1	1.623e+09	4.809e+00	4.405e+01	7.357e-03	6.739e-02
0.15	4.921e+06	1.218e-01	9.322e-01	2.006e-04	1.535e-03
0.2	2.293e+08	1.335e+01	8.906e+01	2.357e-02	1.572e-01
0.3	9.265e+07	1.326e+01	7.245e+01	2.516e-02	1.374e-01
0.4	7.272e+07	1.824e+01	8.610e+01	3.554e-02	1.678e-01
0.5	2.206e+07	8.417e+00	3.542e+01	1.652e-02	6.952e-02
0.6	1.505e+12	8.054e+05	3.080e+06	1.572e+03	6.013e+03
0.8	1.260e+09	1.147e+03	3.800e+03	2.182e+00	7.228e+00
1.0	2.109e+09	2.899e+03	8.642e+03	5.344e+00	1.593e+01
1.5	2.365e+09	6.840e+03	1.708e+04	1.151e+01	2.874e+01
2.0	4.343e+02	2.092e-03	4.705e-03	3.234e-06	7.276e-06
3.0	5.230e-04	4.990e-09	9.848e-09	6.770e-12	1.336e-11
TOTALS:	1.638e+12	8.163e+05	3.110e+06	1.591e+03	6.065e+03

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

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File Ref: HKP-26
Date: 12/14/97
By: [Signature]
Checked: [Signature]

for 2016
[Signature]

Case Title: T9sbw
Description: R/hr @ 1 m from canister surf., SBW calcine (T-9)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions

Height 262.8 cm / 8 ft 7.5 in
Radius 29.53 cm / 11.6 in

Dose Points

	X	Y	Z
# 1	130.48 cm / 4 ft 3.4 in	131.4 cm / 4 ft 3.7 in	0 cm / 0.0 in

Shields

Shield Name	Dimension	Material	Densit
Source	7.20e+05 cm ³	Concrete	2.6
Shield 1	.95 cm	Iron	7.86
Transition	100.0 cm	Air	0.0011
Air Gap		Air	0.0012

Source Input

Grouping Method : Standard Indices

Number of Groups : 25

Lower Energy Cutoff : 0.015

Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Ac-225	4.8483e-010	1.7939e+001	6.7342e-010	2.4917e-005
Ac-227	3.1997e-008	1.1839e+003	4.4443e-008	1.6444e-003
Ac-228	4.7712e-014	1.7653e-003	6.6271e-014	2.4520e-009
Am-241	1.4189e-001	5.2500e+009	1.9709e-001	7.2922e+003
At-217	4.8483e-010	1.7939e+001	6.7342e-010	2.4917e-005
Ba-137m	4.5193e+001	1.6722e+012	6.2773e+001	2.3226e+006
Bi-210	7.9869e-009	2.9552e+002	1.1094e-008	4.1047e-004
Bi-211	3.1689e-008	1.1725e+003	4.4016e-008	1.6286e-003
Bi-212	3.9419e-014	1.4585e-003	5.4752e-014	2.0258e-009
Bi-213	4.8482e-010	1.7939e+001	6.7341e-010	2.4916e-005
Bi-214	4.1274e-008	1.5272e+003	5.7330e-008	2.1212e-003
Ce-144	3.5732e-008	1.3221e+003	4.9632e-008	1.8364e-003
Co-60	3.1115e-002	1.1512e+009	4.3218e-002	1.5991e+003
Cs-134	1.3706e-003	5.0711e+007	1.9037e-003	7.0437e+001
Cs-137	4.7773e+001	1.7676e+012	6.6356e+001	2.4552e+006
Eu-154	8.3998e-002	3.1079e+009	1.1667e-001	4.3169e+003
Eu-155	3.6600e-002	1.3542e+009	5.0837e-002	1.8810e+003
Fr-221	4.8483e-010	1.7939e+001	6.7342e-010	2.4917e-005
Fr-223	4.4155e-010	1.6337e+001	6.1331e-010	2.2692e-005
Ni-63	8.0368e-002	2.9736e+009	1.1163e-001	4.1303e+003
Np-237	4.9686e-003	1.8384e+008	6.9013e-003	2.5535e+002
Pa-231	1.1389e-007	4.2141e+003	1.5820e-007	5.8533e-003
Pa-233	4.9685e-003	1.8384e+008	6.9012e-003	2.5535e+002
Pa-234	2.3038e-008	8.5242e+002	3.2000e-008	1.1840e-003
Pa-234m	1.4399e-005	5.3276e+005	2.0000e-005	7.4000e-001

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<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Pb-209	4.8480e-010	1.7938e+001	6.7338e-010	2.4915e-005
Pb-210	8.0074e-009	2.9627e+002	1.1122e-008	4.1152e-004
Pb-211	3.1689e-008	1.1725e+003	4.4016e-008	1.6286e-003
Pb-212	3.9419e-014	1.4585e-003	5.4753e-014	2.0258e-009
Pb-214	4.1275e-008	1.5272e+003	5.7330e-008	2.1212e-003
Po-210	7.4465e-009	2.7552e+002	1.0343e-008	3.8270e-004
Po-211	8.6512e-011	3.2009e+000	1.2016e-010	4.4461e-006
Po-212	2.5255e-014	9.3445e-004	3.5079e-014	1.2979e-009
Po-213	4.7435e-010	1.7551e+001	6.5887e-010	2.4378e-005
Po-214	4.1266e-008	1.5268e+003	5.7318e-008	2.1208e-003
Po-215	3.1690e-008	1.1725e+003	4.4016e-008	1.6286e-003
Po-216	3.9424e-014	1.4587e-003	5.4760e-014	2.0261e-009
Po-218	4.1283e-008	1.5275e+003	5.7342e-008	2.1216e-003
Pr-144	3.5734e-008	1.3221e+003	4.9634e-008	1.8364e-003
Pr-144m	5.1098e-010	1.8906e+001	7.0975e-010	2.6261e-005
Pu-238	1.2707e+000	4.7017e+010	1.7650e+000	6.5305e+004
Pu-239	1.5829e-001	5.8567e+009	2.1986e-001	8.1349e+003
Pu-240	3.8069e-002	1.4085e+009	5.2877e-002	1.9565e+003
Pu-241	4.9937e-001	1.8477e+010	6.9362e-001	2.5664e+004
Pu-242	2.0158e-005	7.4584e+005	2.7999e-005	1.0360e+000
Ra-223	3.1690e-008	1.1725e+003	4.4016e-008	1.6286e-003
Ra-224	3.9424e-014	1.4587e-003	5.4760e-014	2.0261e-009
Ra-225	4.8659e-010	1.8004e+001	6.7586e-010	2.5007e-005
Ra-226	4.1340e-008	1.5296e+003	5.7421e-008	2.1246e-003
Ra-228	4.7715e-014	1.7655e-003	6.6276e-014	2.4522e-009
Rh-106	1.3189e-006	4.8799e+004	1.8319e-006	6.7782e-002
Rn-219	3.1690e-008	1.1725e+003	4.4016e-008	1.6286e-003
Rn-220	3.9424e-014	1.4587e-003	5.4760e-014	2.0261e-009
Rn-222	4.1283e-008	1.5275e+003	5.7342e-008	2.1216e-003
Ru-106	1.3189e-006	4.8799e+004	1.8319e-006	6.7781e-002
Sb-125	3.8053e-003	1.4080e+008	5.2856e-003	1.9557e+002
Sr-90	4.6466e+001	1.7192e+012	6.4540e+001	2.3880e+006
Tc-99	2.1597e-002	7.9909e+008	2.9998e-002	1.1099e+003
Te-125m	9.3249e-004	3.4502e+007	1.2952e-003	4.7923e+001
Th-227	3.1365e-008	1.1605e+003	4.3566e-008	1.6119e-003
Th-228	3.9467e-014	1.4603e-003	5.4819e-014	2.0283e-009
Th-229	4.8919e-010	1.8100e+001	6.7948e-010	2.5141e-005
Th-230	8.7051e-006	3.2209e+005	1.2091e-005	4.4738e-001
Th-231	2.4479e-004	9.0571e+006	3.4000e-004	1.2580e+001
Th-232	7.3465e-014	2.7182e-003	1.0204e-013	3.7756e-009
Th-234	1.4399e-005	5.3276e+005	2.0000e-005	7.4000e-001
Tl-207	3.1603e-008	1.1693e+003	4.3896e-008	1.6241e-003
Tl-208	1.4163e-014	5.2403e-004	1.9672e-014	7.2788e-010
Tl-209	1.0472e-011	3.8747e-001	1.4546e-011	5.3819e-007
U-233	4.7355e-007	1.7521e+004	6.5775e-007	2.4337e-002
U-234	4.4001e-002	1.6280e+009	6.1116e-002	2.2613e+003
U-235	2.4479e-004	9.0571e+006	3.4000e-004	1.2580e+001
U-236	6.7700e-005	2.5049e+006	9.4034e-005	3.4793e+000
U-237	1.2250e-005	4.5326e+005	1.7016e-005	6.2958e-001
U-238	1.4399e-005	5.3276e+005	2.0000e-005	7.4000e-001
Y-90	4.6478e+001	1.7197e+012	6.4557e+001	2.3886e+006

Buildup
 The material reference is : Transition

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 Run Time: 8:50:06 PM
 Duration: 00:01:37

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

<u>Energy</u> MeV	<u>Activity</u> photons/sec	<u>Results</u>			
		<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
		<u>MeV/cm²/sec</u>	<u>MeV/cm²/sec</u>	<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.015	1.704e+04	3.603e-192	1.549e-29	3.090e-193	1.328e-30
0.02	1.719e+01	4.771e-93	4.435e-32	1.653e-94	1.536e-33
0.03	9.876e+10	4.789e-26	4.828e-21	4.747e-28	4.785e-23
0.04	2.413e+10	1.886e-11	2.144e-09	8.340e-14	9.482e-12
0.05	2.434e+08	1.203e-07	1.989e-05	3.204e-10	5.299e-08
0.06	1.935e+09	5.092e-04	7.629e-02	1.011e-06	1.515e-04
0.08	4.508e+08	2.801e-02	2.258e+00	4.432e-05	3.573e-03
0.1	1.623e+09	9.386e-01	4.198e+01	1.436e-03	6.423e-02
0.15	4.921e+06	2.304e-02	4.266e-01	3.794e-05	7.025e-04
0.2	2.293e+08	2.477e+00	2.972e+01	4.371e-03	5.246e-02
0.3	9.265e+07	2.409e+00	1.843e+01	4.570e-03	3.495e-02
0.4	7.272e+07	3.273e+00	1.933e+01	6.376e-03	3.766e-02
0.5	2.206e+07	1.496e+00	7.412e+00	2.937e-03	1.455e-02
0.6	1.505e+12	1.421e+05	6.159e+05	2.773e+02	1.202e+03
0.8	1.260e+09	1.998e+02	7.153e+02	3.800e-01	1.361e+00
1.0	2.109e+09	4.996e+02	1.570e+03	9.210e-01	2.894e+00
1.5	2.365e+09	1.156e+03	2.950e+03	1.944e+00	4.963e+00
2.0	4.343e+02	3.488e-04	7.895e-04	5.394e-07	1.221e-06
3.0	5.230e-04	8.191e-10	1.602e-09	1.111e-12	2.173e-12
TOTALS:	1.638e+12	1.439e+05	6.213e+05	2.806e+02	1.212e+03

MicroShield v5.01 (5.01-00121)
 Lockheed Martin Idaho Technologies Company
 Case File Heat Generation
 Case File: T13CWO.MS5
 Case Title: t13Was

<u>Isotope</u>	<u>Activity</u> <u>Curies</u>	<u>Activity</u> <u>Bequerels</u>	<u>Heat Generation</u> <u>Watts/Curie</u>	<u>Heat Generation</u> <u>Watts</u>
Am-241	5.9036e-001	2.1843e+010	3.2813e-002	1.9371e-002
Am-243	2.2318e-006	8.2578e+004	3.1704e-002	7.0759e-008
Ba-137m	6.8107e+002	2.5200e+013	3.9212e-003	2.6706e+000
Ce-144	1.0799e+000	3.9957e+010	6.6284e-004	7.1582e-004
Cm-242	1.8719e-006	6.9259e+004	3.6240e-002	6.7837e-008
Cm-244	3.5278e-006	1.3053e+005	3.4409e-002	1.2139e-007
Co-60	6.9115e-002	2.5573e+009	1.5423e-002	1.0659e-003
Cs-134	2.0879e-001	7.7251e+009	1.0179e-002	2.1253e-003
Cs-137	7.1995e+002	2.6638e+013	1.0122e-003	7.2877e-001
Eu-154	1.4399e+000	5.3276e+010	9.0517e-003	1.3034e-002
Eu-155	8.6394e-002	3.1966e+009	7.2543e-004	6.2673e-005
Ni-63	8.6394e-003	3.1966e+008	1.0155e-004	8.7732e-007
Np-237	1.1519e-003	4.2621e+007	2.8779e-002	3.3151e-005
Pa-233	7.0555e-004	2.6105e+007	2.4276e-003	1.7128e-006
Pm-147	1.7999e-001	6.6595e+009	3.6731e-004	6.6112e-005
Pr-144	1.0645e+000	3.9386e+010	7.3455e-003	7.8191e-003
Pu-238	4.8957e+000	1.8114e+011	3.2587e-002	1.5953e-001
Pu-239	1.1519e-001	4.2621e+009	3.0551e-002	3.5192e-003
Pu-240	7.9194e-002	2.9302e+009	3.0614e-002	2.4245e-003
Pu-241	2.3758e+000	8.7906e+010	3.1003e-005	7.3659e-005
Pu-242	1.5119e-004	5.5940e+006	2.9184e-002	4.4124e-006
Rh-106	4.5357e-001	1.6782e+010	9.5998e-003	4.3542e-003
Ru-106	4.5357e-001	1.6782e+010	5.9459e-005	2.6969e-005
Sb-125	9.3593e-002	3.4630e+009	3.1431e-003	2.9417e-004
Sm-151	1.5119e+001	5.5940e+011	1.1729e-004	1.7733e-003
Sr-90	7.9194e+002	2.9302e+013	1.1607e-003	9.1923e-001
Tc-99	3.0958e-001	1.1454e+010	5.0152e-004	1.5526e-004
Th-230	5.8316e-005	2.1577e+006	2.7809e-002	1.6217e-006
Th-231	3.3118e-005	1.2254e+006	1.0580e-003	3.5037e-008
U-232	3.0238e-007	1.1188e+004	3.1553e-002	9.5410e-009
U-233	9.3593e-008	3.4630e+003	2.8557e-002	2.6727e-009
U-234	9.3593e-003	3.4630e+008	2.8311e-002	2.6498e-004
U-235	5.7596e-005	2.1311e+006	2.7115e-002	1.5617e-006
U-236	9.3593e-005	3.4630e+006	2.6697e-002	2.4987e-006
U-237	5.3996e-005	1.9979e+006	1.9366e-003	1.0457e-007
U-238	3.1678e-006	1.1721e+005	2.4920e-002	7.8942e-008
Y-90	7.9194e+002	2.9302e+013	5.5411e-003	4.3883e+000

Total

Heat Generation:

8.9236e+000

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
 DOS File: T13CWO.MS5
 Run Date: November 19, 1997
 Run Time: 5:05:47 PM
 Duration: 00:01:26

File Ref: HKP-24
 Date: 12/4/97
 By: HKP/MLK
 Checked: 98/5/97

Case Title: T-13CWO
Description: R/hr @ 1 cm from canister surf., CWO Process (T-13)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions

Height	262.8 cm	8 ft 7.5 in
Radius	29.53 cm	11.6 in

Dose Points

	<u>X</u>	<u>Y</u>	<u>Z</u>
# 1	31.48 cm	131.4 cm	.0 cm
	1 ft 0.4 in	4 ft 3.7 in	0.0 in

Shields

<u>Shield Name</u>	<u>Dimension</u>	<u>Material</u>	<u>Densit</u>
Source	7.20e+05 cm ³	Concrete	1.7 ✓
Shield 1	.95 cm	Iron	7.86
Transition	1.0 cm	Air	0.0011
Air Gap		Air	0.0011

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded
Library : Grove

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Am-241	5.9036e-001	2.1843e+010	8.2000e-001 ✓	3.0340e+004
Am-243	2.2318e-006	8.2578e+004	3.1000e-006 ✓	1.1470e-001
Ba-137m	6.8107e+002	2.5200e+013	9.4600e+002 ✓	3.5002e+007
Ce-144	1.0799e+000	3.9957e+010	1.5000e+000 ✓	5.5500e+004
Cm-242	1.8719e-006	6.9259e+004	2.6000e-006 ✓	9.6200e-002
Cm-244	3.5278e-006	1.3053e+005	4.9000e-006 ✓	1.8130e-001
Co-60	6.9115e-002	2.5573e+009	9.6000e-002 ✓	3.5520e+003
Cs-134	2.0879e-001	7.7251e+009	2.9000e-001 ✓	1.0730e+004
Cs-137	7.1995e+002	2.6638e+013	1.0000e+003 ✓	3.7000e+007
Eu-154	1.4399e+000	5.3276e+010	2.0000e+000 ✓	7.4000e+004
Eu-155	8.6394e-002	3.1966e+009	1.2000e-001 ✓	4.4400e+003
Ni-63	8.6394e-003	3.1966e+008	1.2000e-002 ✓	4.4400e+002
Np-237	1.1519e-003	4.2621e+007	1.6000e-003 ✓	5.9200e+001
Pm-147	1.7999e-001	6.6595e+009	2.5000e-001 ✓	9.2500e+003
Pr-144	1.0799e+000	3.9957e+010	1.5000e+000	5.5500e+004
Pu-238	4.8957e+000	1.8114e+011	6.8000e+000 ✓	2.5160e+005
Pu-239	1.1519e-001	4.2621e+009	1.6000e-001 ✓	5.9200e+003
Pu-240	7.9194e-002	2.9302e+009	1.1000e-001 ✓	4.0700e+003
Pu-241	2.3758e+000	8.7906e+010	3.3000e+000 ✓	1.2210e+005
Pu-242	1.5119e-004	5.5940e+006	2.1000e-004 ✓	7.7700e+000
Rh-106	4.5357e-001	1.6782e+010	6.3000e-001	2.3310e+004
Ru-106	4.5357e-001	1.6782e+010	6.3000e-001 ✓	2.3310e+004
Sb-125	9.3593e-002	3.4630e+009	1.3000e-001 ✓	4.8100e+003
Sr-90	7.9194e+002	2.9302e+013	1.1000e+003 ✓	4.0700e+007
Tc-99	3.0958e-001	1.1454e+010	4.3000e-001 ✓	1.5910e+004

Page : 2
 DOS File: T13CWO.MS5
 Run Date: November 19, 1997
 Run Time: 5:05:47 PM
 Duration: 00:01:26

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Th-230	5.8316e-005	2.1577e+006	8.1000e-005✓	2.9970e+000
Th-231	3.3118e-005	1.2254e+006	4.6000e-005✓	1.7020e+000
U-232	3.0238e-007	1.1188e+004	4.2000e-007✓	1.5540e-002
U-233	9.3593e-008	3.4630e+003	1.3000e-007✓	4.8100e-003
U-234	9.3593e-003	3.4630e+008	1.3000e-002✓	4.8100e+002
U-235	5.7596e-005	2.1311e+006	8.0000e-005✓	2.9600e+000
U-236	9.3593e-005	3.4630e+006	1.3000e-004✓	4.8100e+000
U-237	5.3996e-005	1.9979e+006	7.5000e-005✓	2.7750e+000
U-238	3.1678e-006	1.1721e+005	4.4000e-006✓	1.6280e-001
Y-90	7.9194e+002	2.9302e+013	1.1000e+003✓	4.0700e+007

Buildup

The material reference is : Source

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

Results

<u>Energy</u>	<u>Activity</u>	<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
<u>MeV</u>	<u>photons/sec</u>	<u>MeV/cm²/sec</u>	<u>MeV/cm²/sec</u>	<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.015	2.305e+03	1.621e-211	1.057e-29	1.390e-212	9.065e-31
0.03	1.487e+12	9.282e-26	2.372e-20	9.199e-28	2.351e-22
0.04	3.654e+11	6.920e-10	2.583e-09	3.060e-12	1.142e-11
0.05	2.945e+09	7.874e-06	4.624e-05	2.098e-08	1.232e-07
0.06	8.062e+09	1.451e-02	1.135e-01	2.883e-05	2.254e-04
0.08	1.637e+09	7.639e-01	7.075e+00	1.209e-03	1.120e-02
0.1	2.223e+10	9.850e+01	9.035e+02	1.507e-01	1.382e+00
0.15	4.325e+09	1.610e+02	1.243e+03	2.651e-01	2.046e+00
0.2	3.903e+09	3.430e+02	2.304e+03	6.055e-01	4.066e+00
0.3	1.722e+07	3.732e+00	2.043e+01	7.079e-03	3.875e-02
0.4	1.464e+09	5.564e+02	2.622e+03	1.084e+00	5.110e+00
0.5	4.044e+09	2.338e+03	9.794e+03	4.589e+00	1.923e+01
0.6	2.269e+13	1.839e+07	6.987e+07	3.590e+04	1.364e+05
0.8	2.812e+10	3.872e+04	1.269e+05	7.365e+01	2.413e+02
1.0	1.953e+10	4.052e+04	1.190e+05	7.469e+01	2.194e+02
1.5	2.382e+10	1.033e+05	2.524e+05	1.737e+02	4.247e+02
2.0	3.093e+08	2.216e+03	4.857e+03	3.427e+00	7.511e+00
TOTALS:	2.466e+13	1.858e+07	7.039e+07	3.623e+04	1.373e+05

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
 DOS File: T13CWO.MS5
 Run Date: November 19, 1997
 Run Time: 5:15:59 PM
 Duration: 00:01:23

File Ref: HRP-26
 Date: 12/4/9
 By: HRP
 Checked: HRP

Case Title: T-13CWO
Description: R/hr @ 1 m from canister surf., CWO Process (T-13)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions
 Height 262.8 cm / 8 ft 7.5 in
 Radius 29.53 cm / 11.6 in

Dose Points

	<u>X</u>	<u>Y</u>	<u>Z</u>
# 1	130.48 cm / 4 ft 3.4 in	131.4 cm / 4 ft 3.7 in	0 cm / 0.0 in

Shields

Shield Name	Dimension	Material	Densit
Source	7.20e+05 cm ³	Concrete	1.7 /
Shield 1	.95 cm	Iron	7.86
Transition	100.0 cm	Air	0.0011
Air Gap		Air	0.0011

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded

Library : Grove

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Am-241	5.9036e-001	2.1843e+010	8.2000e-001 /	3.0340e+004
Am-243	2.2318e-006	8.2578e+004	3.1000e-006 /	1.1470e-001
Ba-137m	6.8107e+002	2.5200e+013	9.4600e+002 /	3.5002e+007
Ce-144	1.0799e+000	3.9957e+010	1.5000e+000 /	5.5500e+004
Cm-242	1.8719e-006	6.9259e+004	2.6000e-006 /	9.6200e-002
Cm-244	3.5278e-006	1.3053e+005	4.9000e-006 /	1.8130e-001
Co-60	6.9115e-002	2.5573e+009	9.6000e-002 /	3.5520e+003
Cs-134	2.0879e-001	7.7251e+009	2.9000e-001 /	1.0730e+004
Cs-137	7.1995e+002	2.6638e+013	1.0000e+003 /	3.7000e+007
Eu-154	1.4399e+000	5.3276e+010	2.0000e+000 /	7.4000e+004
Eu-155	8.6394e-002	3.1966e+009	1.2000e-001 /	4.4400e+003
Ni-63	8.6394e-003	3.1966e+008	1.2000e-002 /	4.4400e+002
Np-237	1.1519e-003	4.2621e+007	1.6000e-003 /	5.9200e+001
Pm-147	1.7999e-001	6.6595e+009	2.5000e-001 /	9.2500e+003
Pr-144	1.0799e+000	3.9957e+010	1.5000e+000 /	5.5500e+004
Pu-238	4.8957e+000	1.8114e+011	6.8000e+000 /	2.5160e+005
Pu-239	1.1519e-001	4.2621e+009	1.6000e-001 /	5.9200e+003
Pu-240	7.9194e-002	2.9302e+009	1.1000e-001 /	4.0700e+003
Pu-241	2.3758e+000	8.7906e+010	3.3000e+000 /	1.2210e+005
Pu-242	1.5119e-004	5.5940e+006	2.1000e-004 /	7.7700e+000
Rh-106	4.5357e-001	1.6782e+010	6.3000e-001 /	2.3310e+004
Ru-106	4.5357e-001	1.6782e+010	6.3000e-001 /	2.3310e+004
Sb-125	9.3593e-002	3.4630e+009	1.3000e-001 /	4.8100e+003
Sr-90	7.9194e+002	2.9302e+013	1.1000e+003 /	4.0700e+007
Tc-99	3.0958e-001	1.1454e+010	4.3000e-001 /	1.5910e+004

Page : 2
 DOS File: T13CWO.MS5
 Run Date: November 19, 1997
 Run Time: 5:15:59 PM
 Duration: 00:01:23

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Th-230	5.8316e-005	2.1577e+006	8.1000e-005	2.9970e+000
Th-231	3.3118e-005	1.2254e+006	4.6000e-005	1.7020e+000
U-232	3.0238e-007	1.1188e+004	4.2000e-007	1.5540e-002
U-233	9.3593e-008	3.4630e+003	1.3000e-007	4.8100e-003
U-234	9.3593e-003	3.4630e+008	1.3000e-002	4.8100e+002
U-235	5.7596e-005	2.1311e+006	8.0000e-005	2.9600e+000
U-236	9.3593e-005	3.4630e+006	1.3000e-004	4.8100e+000
U-237	5.3996e-005	1.9979e+006	7.5000e-005	2.7750e+000
U-238	3.1678e-006	1.1721e+005	4.4000e-006	1.6280e-001
Y-90	7.9194e+002	2.9302e+013	1.1000e+003	4.0700e+007

Buildup

The material reference is : Transition

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

Results

<u>Energy</u>	<u>Activity</u>	<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
<u>MeV</u>	<u>photons/sec</u>	<u>MeV/cm²/sec</u>	<u>MeV/cm²/sec</u>	<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.015	2.305e+03	8.751e-193	2.095e-30	7.506e-194	1.797e-31
0.03	1.487e+12	1.103e-24	7.268e-20	1.093e-26	7.203e-22
0.04	3.654e+11	4.368e-10	4.966e-08	1.932e-12	2.196e-10
0.05	2.945e+09	2.225e-06	3.680e-04	5.928e-09	9.803e-07
0.06	8.062e+09	3.244e-03	4.861e-01	6.444e-06	9.655e-04
0.08	1.637e+09	1.555e-01	1.253e+01	2.461e-04	1.983e-02
0.1	2.223e+10	1.965e+01	8.775e+02	3.005e-02	1.342e+00
0.15	4.325e+09	3.091e+01	5.702e+02	5.091e-02	9.390e-01
0.2	3.903e+09	6.431e+01	7.670e+02	1.135e-01	1.354e+00
0.3	1.722e+07	6.824e-01	5.170e+00	1.294e-03	9.807e-03
0.4	1.464e+09	1.003e+02	5.854e+02	1.954e-01	1.141e+00
0.5	4.044e+09	4.170e+02	2.037e+03	8.185e-01	3.998e+00
0.6	2.269e+13	3.252e+06	1.388e+07	6.347e+03	2.709e+04
0.8	2.812e+10	6.749e+03	2.371e+04	1.284e+01	4.509e+01
1.0	1.953e+10	6.981e+03	2.145e+04	1.287e+01	3.954e+01
1.5	2.382e+10	1.741e+04	4.316e+04	2.929e+01	7.262e+01
2.0	3.093e+08	3.681e+02	8.054e+02	5.692e-01	1.245e+00
TOTALS:	2.466e+13	3.284e+06	1.397e+07	6.404e+03	2.725e+04

MicroShield v5.01 (5.01-00121)
 Lockheed Martin Idaho Technologies Company
 Case File Heat Generation
 Case File: T17ALUM.MS5
 Case Title: T17alum

<u>Isotope</u>	<u>Activity Curies</u>	<u>Activity Bequerels</u>	<u>Heat Generation Watts/Curie</u>	<u>Heat Generation Watts</u>
Am-241	2.3038e-001	8.5242e+009	3.2813e-002	7.5595e-003
Am-243	7.9194e-006	2.9302e+005	3.1704e-002	2.5108e-007
Ba-137m	1.4305e+003	5.2930e+013	3.9212e-003	5.6095e+000
Ce-144	1.9439e-017	7.1923e-007	6.6284e-004	1.2885e-020
Cm-242	6.4076e-006	2.3708e+005	3.6240e-002	2.3221e-007
Cm-244	1.2959e-005	4.7949e+005	3.4409e-002	4.4591e-007
Cs-134	7.9194e-006	2.9302e+005	1.0179e-002	8.0613e-008
Cs-137	1.5119e+003	5.5940e+013	1.0122e-003	1.5304e+000
Eu-154	6.8395e-001	2.5306e+010	9.0517e-003	6.1909e-003
Eu-155	4.1757e-002	1.5450e+009	7.2543e-004	3.0292e-005
Np-237	2.1598e-003	7.9914e+007	2.8779e-002	6.2159e-005
Pa-233	2.1598e-003	7.9914e+007	2.4276e-003	5.2432e-006
Pm-147	5.5436e-003	2.0511e+008	3.6731e-004	2.0362e-006
Pr-144	1.9439e-017	7.1923e-007	7.3455e-003	1.4279e-019
Pu-238	7.9194e-001	2.9302e+010	3.2587e-002	2.5807e-002
Pu-239	1.0079e-001	3.7293e+009	3.0551e-002	3.0793e-003
Pu-240	4.1037e-002	1.5184e+009	3.0614e-002	1.2563e-003
Pu-241	3.5997e-001	1.3319e+010	3.1003e-005	1.1160e-005
Pu-242	3.0958e-006	1.1454e+005	2.9184e-002	9.0349e-008
Rh-106	1.0799e-013	3.9957e-003	9.5998e-003	1.0367e-015
Ru-106	1.0799e-013	3.9957e-003	5.9459e-005	6.4211e-018
Sb-125	2.3038e-004	8.5242e+006	3.1431e-003	7.2412e-007
Sm-151	3.0238e+001	1.1188e+012	1.1729e-004	3.5465e-003
Sr-90	1.3679e+003	5.0612e+013	1.1607e-003	1.5878e+000
Tc-99	7.9194e-001	2.9302e+010	5.0152e-004	3.9718e-004
Th-230	2.0879e-004	7.7251e+006	2.7809e-002	5.8062e-006
Th-231	3.5997e-005	1.3319e+006	1.0580e-003	3.8084e-008
U-232	2.8798e-007	1.0655e+004	3.1553e-002	9.0867e-009
U-233	3.0238e-007	1.1188e+004	2.8557e-002	8.6349e-009
U-234	6.4076e-003	2.3708e+008	2.8311e-002	1.8141e-004
U-235	4.3197e-005	1.5983e+006	2.7115e-002	1.1713e-006
U-236	1.0079e-004	3.7293e+006	2.6697e-002	2.6909e-006
U-237	8.6394e-006	3.1966e+005	1.9366e-003	1.6731e-008
U-238	2.5198e-006	9.3233e+004	2.4920e-002	6.2794e-008
Y-90	1.3679e+003	5.0612e+013	5.5411e-003	7.5797e+000

Total

Heat Generation:

1.6355e+001

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
 DOS File: T17ALUM.MS5
 Run Date: November 20, 1997
 Run Time: 2:59:53 AM
 Duration: 00:01:31

File Ref: HKP-26-
 Date: 12/4/97
 By: [Signature]
 Checked: [Signature]

Case Title: T17alum
Description: R/hr @ 1 cm from canister surf., Alumina calcine (T-17)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions

Height	262.8 cm	8 ft 7.5 in
Radius	29.53 cm	11.6 in

Dose Points

	<u>X</u>	<u>Y</u>	<u>Z</u>
# 1	31.48 cm	131.4 cm	0 cm
	1 ft 0.4 in	4 ft 3.7 in	0.0 in

Shields

<u>Shield Name</u>	<u>Dimension</u>	<u>Material</u>	<u>Densit</u>
Source	7.20e+05 cm ³	Concrete	1.7
Shield 1	.95 cm	Iron	7.86
Transition	1.0 cm	Air	0.0011
Air Gap		Air	0.0011

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded

Library : Grove

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Am-241	2.3038e-001	8.5242e+009	3.2000e-001	1.1840e+004
Am-243	7.9194e-006	2.9302e+005	1.1000e-005	4.0700e-001
Ba-137m	1.4305e+003	5.2930e+013	1.9870e+003	7.3519e+007
Ce-144	1.9439e-017	7.1923e-007	2.7000e-017	9.9900e-013
Cm-242	6.4076e-006	2.3708e+005	8.9000e-006	3.2930e-001
Cm-244	1.2959e-005	4.7949e+005	1.8000e-005	6.6600e-001
Cs-134	7.9194e-006	2.9302e+005	1.1000e-005	4.0700e-001
Cs-137	1.5119e+003	5.5940e+013	2.1000e+003	7.7700e+007
Eu-154	6.8395e-001	2.5306e+010	9.5000e-001	3.5150e+004
Eu-155	4.1757e-002	1.5450e+009	5.8000e-002	2.1460e+003
Np-237	2.1598e-003	7.9914e+007	3.0000e-003	1.1100e+002
Pa-233	2.1598e-003	7.9914e+007	3.0000e-003	1.1100e+002
Pm-147	5.5436e-003	2.0511e+008	7.7000e-003	2.8490e+002
Pr-144	1.9439e-017	7.1923e-007	2.7000e-017	9.9900e-013
Pu-238	7.9194e-001	2.9302e+010	1.1000e+000	4.0700e+004
Pu-239	1.0079e-001	3.7293e+009	1.4000e-001	5.1800e+003
Pu-240	4.1037e-002	1.5184e+009	5.7000e-002	2.1090e+003
Pu-241	3.5997e-001	1.3319e+010	5.0000e-001	1.8500e+004
Pu-242	3.0958e-006	1.1454e+005	4.3000e-006	1.5910e-001
Rh-106	1.0799e-013	3.9957e-003	1.5000e-013	5.5500e-009
Ru-106	1.0799e-013	3.9957e-003	1.5000e-013	5.5500e-009
Sb-125	2.3038e-004	8.5242e+006	3.2000e-004	1.1840e+001
Sm-151	3.0238e+001	1.1188e+012	4.2000e+001	1.5540e+006
Sr-90	1.3679e+003	5.0612e+013	1.9000e+003	7.0300e+007
Tc-99	7.9194e-001	2.9302e+010	1.1000e+000	4.0700e+004

Page : 2
 DOS File: T17ALUM.MS5
 Run Date: November 20, 1997
 Run Time: 2:59:53 AM
 Duration: 00:01:31

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Th-230	2.0879e-004	7.7251e+006	2.9000e-004	1.0730e+001
Th-231	3.5997e-005	1.3319e+006	5.0000e-005	1.8500e+000
U-232	2.8798e-007	1.0655e+004	4.0000e-007	1.4800e-002
U-233	3.0238e-007	1.1188e+004	4.2000e-007	1.5540e-002
U-234	6.4076e-003	2.3708e+008	8.9000e-003	3.2930e+002
U-235	4.3197e-005	1.5983e+006	6.0000e-005	2.2200e+000
U-236	1.0079e-004	3.7293e+006	1.4000e-004	5.1800e+000
U-237	8.6394e-006	3.1966e+005	1.2000e-005	4.4400e-001
U-238	2.5198e-006	9.3233e+004	3.5000e-006	1.2950e-001
Y-90	1.3679e+003	5.0612e+013	1.9000e+003	7.0300e+007

Buildup
 The material reference is : Source

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Results</u>			
		<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
		<u>MeV/cm²/sec</u> <u>No Buildup</u>	<u>MeV/cm²/sec</u> <u>With Buildup</u>	<u>mR/hr</u> <u>No Buildup</u>	<u>mR/hr</u> <u>With Buildup</u>
0.015	2.505e+03	1.761e-211	1.149e-29	1.511e-212	9.853e-31
0.02	3.308e+08	1.261e-92	2.387e-24	4.369e-94	8.268e-26
0.03	3.118e+12	1.947e-25	4.974e-20	1.929e-27	4.930e-22
0.04	7.412e+11	1.404e-09	5.238e-09	6.207e-12	2.317e-11
0.05	1.400e+09	3.745e-06	2.199e-05	9.976e-09	5.859e-08
0.06	3.110e+09	5.598e-03	4.377e-02	1.112e-05	8.694e-05
0.08	4.930e+08	2.301e-01	2.131e+00	3.641e-04	3.372e-03
0.1	1.060e+10	4.694e+01	4.306e+02	7.182e-02	6.588e-01
0.15	1.650e+06	6.142e-02	4.740e-01	1.011e-04	7.806e-04
0.2	1.730e+09	1.521e+02	1.021e+03	2.684e-01	1.802e+00
0.3	4.005e+07	8.678e+00	4.750e+01	1.646e-02	9.011e-02
0.4	1.860e+08	7.068e+01	3.331e+02	1.377e-01	6.491e-01
0.5	5.568e+07	3.219e+01	1.349e+02	6.319e-02	2.647e-01
0.6	4.763e+13	3.860e+07	1.467e+08	7.535e+04	2.862e+05
0.8	9.869e+09	1.359e+04	4.453e+04	2.585e+01	8.471e+01
1.0	7.785e+09	1.615e+04	4.746e+04	2.977e+01	8.748e+01
1.5	9.874e+09	4.280e+04	1.046e+05	7.201e+01	1.760e+02
2.0	5.567e-09	3.989e-14	8.743e-14	6.168e-17	1.352e-16
TOTALS:	5.153e+13	3.867e+07	1.469e+08	7.547e+04	2.866e+05

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
DOS File: T17ALUM.MS5
Run Date: November 20, 1997
Run Time: 3:03:52 AM
Duration: 00:01:28

File Ref: HKP-26-
Date: 12/4/9
By: [Signature]
Checked: [Signature]

Case Title: T17alum
Description: R/hr @ 1 m from canister surf., Alumina calcine (T-17)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions
Height 262.8 cm — 8 ft 7.5 in
Radius 29.53 cm — 11.6 in

Dose Points
1 X Y Z
130.48 cm — 131.4 cm 0 cm
4 ft 3.4 in 4 ft 3.7 in 0.0 in

Shields

Shield Name	Dimension	Material	Densit
Source	7.20e+05 cm ³	Concrete	1.7 —
Shield 1	.95 cm	Iron	7.86
Transition	100.0 cm	Air	0.0011
Air Gap		Air	0.0011

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Am-241	2.3038e-001	8.5242e+009	3.2000e-001 /	1.1840e+004
Am-243	7.9194e-006	2.9302e+005	1.1000e-005 /	4.0700e-001
Ba-137m	1.4305e+003	5.2930e+013	1.9870e+003 /	7.3519e+007
Ce-144	1.9439e-017	7.1923e-007	2.7000e-017 /	9.9900e-013
Cm-242	6.4076e-006	2.3708e+005	8.9000e-006 /	3.2930e-001
Cm-244	1.2959e-005	4.7949e+005	1.8000e-005 /	6.6600e-001
Cs-134	7.9194e-006	2.9302e+005	1.1000e-005 /	4.0700e-001
Cs-137	1.5119e+003	5.5940e+013	2.1000e+003 /	7.7700e+007
Eu-154	6.8395e-001	2.5306e+010	9.5000e-001 /	3.5150e+004
Eu-155	4.1757e-002	1.5450e+009	5.8000e-002 /	2.1460e+003
Np-237	2.1598e-003	7.9914e+007	3.0000e-003 /	1.1100e+002
Pa-233	2.1598e-003	7.9914e+007	3.0000e-003 /	1.1100e+002
Pm-147	5.5436e-003	2.0511e+008	7.7000e-003 /	2.8490e+002
Pr-144	1.9439e-017	7.1923e-007	2.7000e-017 /	9.9900e-013
Pu-238	7.9194e-001	2.9302e+010	1.1000e+000 /	4.0700e+004
Pu-239	1.0079e-001	3.7293e+009	1.4000e-001 /	5.1800e+003
Pu-240	4.1037e-002	1.5184e+009	5.7000e-002 /	2.1090e+003
Pu-241	3.5997e-001	1.3319e+010	5.0000e-001 /	1.8500e+004
Pu-242	3.0958e-006	1.1454e+005	4.3000e-006 /	1.5910e-001
Rh-106	1.0799e-013	3.9957e-003	1.5000e-013 /	5.5500e-009
Ru-106	1.0799e-013	3.9957e-003	1.5000e-013 /	5.5500e-009
Sb-125	2.3038e-004	8.5242e+006	3.2000e-004 /	1.1840e+001
Sm-151	3.0238e+001	1.1188e+012	4.2000e+001 /	1.5540e+006
Sr-90	1.3679e+003	5.0612e+013	1.9000e+003 /	7.0300e+007
Tc-99	7.9194e-001	2.9302e+010	1.1000e+000 /	4.0700e+004

Page : 2
 DOS File: T17ALUM.MS5
 Run Date: November 20, 1997
 Run Time: 3:03:52 AM
 Duration: 00:01:28

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Th-230	2.0879e-004	7.7251e+006	2.9000e-004	1.0730e+001
Th-231	3.5997e-005	1.3319e+006	5.0000e-005	1.8500e+000
U-232	2.8798e-007	1.0655e+004	4.0000e-007	1.4800e-002
U-233	3.0238e-007	1.1188e+004	4.2000e-007	1.5540e-002
U-234	6.4076e-003	2.3708e+008	8.9000e-003	3.2930e+002
U-235	4.3197e-005	1.5983e+006	6.0000e-005	2.2200e+000
U-236	1.0079e-004	3.7293e+006	1.4000e-004	5.1800e+000
U-237	8.6394e-006	3.1966e+005	1.2000e-005	4.4400e-001
U-238	2.5198e-006	9.3233e+004	3.5000e-006	1.2950e-001
Y-90	1.3679e+003	5.0612e+013	1.9000e+003	7.0300e+007

Buildup
 The material reference is : Transition

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Results</u>			
		<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
		<u>MeV/cm²/sec</u>	<u>MeV/cm²/sec</u>	<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.015	2.505e+03	9.512e-193	2.277e-30	8.159e-194	1.953e-31
0.02	3.308e+08	1.408e-85	8.532e-25	4.878e-87	2.955e-26
0.03	3.118e+12	2.313e-24	1.524e-19	2.292e-26	1.511e-21
0.04	7.412e+11	8.859e-10	1.007e-07	3.918e-12	4.454e-10
0.05	1.400e+09	1.058e-06	1.750e-04	2.820e-09	4.662e-07
0.06	3.110e+09	1.252e-03	1.875e-01	2.486e-06	3.724e-04
0.08	4.930e+08	4.683e-02	3.774e+00	7.411e-05	5.972e-03
0.1	1.060e+10	9.363e+00	4.182e+02	1.432e-02	6.398e-01
0.15	1.650e+06	1.179e-02	2.175e-01	1.942e-05	3.582e-04
0.2	1.730e+09	2.851e+01	3.400e+02	5.031e-02	6.001e-01
0.3	4.005e+07	1.587e+00	1.202e+01	3.010e-03	2.281e-02
0.4	1.860e+08	1.274e+01	7.437e+01	2.483e-02	1.449e-01
0.5	5.568e+07	5.741e+00	2.805e+01	1.127e-02	5.505e-02
0.6	4.763e+13	6.825e+06	2.913e+07	1.332e+04	5.685e+04
0.8	9.869e+09	2.369e+03	8.320e+03	4.506e+00	1.583e+01
1.0	7.785e+09	2.783e+03	8.552e+03	5.130e+00	1.576e+01
1.5	9.874e+09	7.215e+03	1.789e+04	1.214e+01	3.010e+01
2.0	5.567e-09	6.626e-15	1.450e-14	1.025e-17	2.242e-17
TOTALS:	5.153e+13	6.838e+06	2.916e+07	1.334e+04	5.692e+04

MicroShield v5.01 (5.01-00121)
 Lockheed Martin Idaho Technologies Company
 Case File Heat Generation
 Case File: T17ZIR.MS5
 Case Title: T17zir

<u>Isotope</u>	<u>Activity Curies</u>	<u>Activity Bequerels</u>	<u>Heat Generation Watts/Curie</u>	<u>Heat Generation Watts</u>
Am-241	7.1995e-001	2.6638e+010	3.2813e-002	2.3624e-002
Am-243	1.2239e-008	4.5285e+002	3.1704e-002	3.8803e-010
Ba-137m	4.0173e+002	1.4864e+013	3.9212e-003	1.5753e+000
Ce-144	2.7358e-010	1.0122e+001	6.6284e-004	1.8134e-013
Cm-242	1.5839e-007	5.8604e+003	3.6240e-002	5.7400e-009
Cm-244	2.8078e-008	1.0389e+003	3.4409e-002	9.6614e-010
Co-60	2.4478e-002	9.0570e+008	1.5423e-002	3.7752e-004
Cs-134	1.2239e-003	4.5285e+007	1.0179e-002	1.2458e-005
Cs-137	4.2477e+002	1.5717e+013	1.0122e-003	4.2997e-001
Eu-154	1.6559e+000	6.1268e+010	9.0517e-003	1.4989e-002
Eu-155	2.3758e-003	8.7906e+007	7.2543e-004	1.7235e-006
Ni-63	0.0000e+000	0.0000e+000	1.0155e-004	0.0000e+000
Np-237	1.6559e-004	6.1268e+006	2.8779e-002	4.7655e-006
Pa-233	1.6559e-004	6.1268e+006	2.4276e-003	4.0198e-007
Pm-147	2.5198e-001	9.3233e+009	3.6731e-004	9.2556e-005
Pr-144	2.7358e-010	1.0122e+001	7.3455e-003	2.0096e-012
Pu-238	6.4076e+000	2.3708e+011	3.2587e-002	2.0880e-001
Pu-239	1.0079e-001	3.7293e+009	3.0551e-002	3.0793e-003
Pu-240	9.3593e-002	3.4630e+009	3.0614e-002	2.8653e-003
Pu-241	3.0238e+000	1.1188e+011	3.1003e-005	9.3748e-005
Pu-242	2.1598e-004	7.9914e+006	2.9184e-002	6.3034e-006
Rh-106	2.5918e-008	9.5897e+002	9.5998e-003	2.4881e-010
Ru-106	2.5918e-008	9.5897e+002	5.9459e-005	1.5411e-012
Sb-125	7.9194e-003	2.9302e+008	3.1431e-003	2.4892e-005
Sm-151	9.3593e+000	3.4630e+011	1.1729e-004	1.0977e-003
Sr-90	5.5436e+002	2.0511e+013	1.1607e-003	6.4346e-001
Tc-99	1.2959e-001	4.7949e+009	5.0152e-004	6.4993e-005
Th-230	1.2239e-006	4.5285e+004	2.7809e-002	3.4036e-008
Th-231	3.2398e-005	1.1987e+006	1.0580e-003	3.4276e-008
U-232	3.1678e-007	1.1721e+004	3.1553e-002	9.9954e-009
U-233	2.0159e-008	7.4587e+002	2.8557e-002	5.7566e-010
U-234	5.1116e-003	1.8913e+008	2.8311e-002	1.4472e-004
U-235	3.2398e-005	1.1987e+006	2.7115e-002	8.7848e-007
U-236	8.6394e-005	3.1966e+006	2.6697e-002	2.3065e-006
U-237	7.1995e-005	2.6638e+006	1.9366e-003	1.3943e-007
U-238	1.5839e-006	5.8604e+004	2.4920e-002	3.9471e-008
Y-90	5.5436e+002	2.0511e+013	5.5411e-003	3.0718e+000

Total

Heat Generation:

5.9758e+000 ✓

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
DOS File: T17ZIR.MS5
Run Date: November 20, 1997
Run Time: 2:39:51 AM
Duration: 00:01:30

File Ref: HKP-26-9
Date: 12/4/97
By: [Signature]
Checked: [Signature]

Case Title: T17zir

Description: R/hr @ 1 cm from canister surf., Zirconia calcine (T-17)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions

Height 262.8 cm / 8 ft 7.5 in
Radius 29.53 cm / 11.6 in

Dose Points

	X	Y	Z
# 1	31.48 cm / 1 ft 0.4 in	131.4 cm / 4 ft 3.7 in	0 cm / 0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	7.20e+05 cm ³	Concrete	1.7
Shield 1	.95 cm	Iron	7.86
Transition	1.0 cm	Air	0.0011
Air Gap		Air	0.0011

Source Input

Grouping Method : Standard Indices

Number of Groups : 25

Lower Energy Cutoff : 0.015

Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Am-241	7.1995e-001	2.6638e+010	1.0000e+000	3.7000e+004
Am-243	1.2239e-008	4.5285e+002	1.7000e-008	6.2900e-004
Ba-137m	4.0173e+002	1.4864e+013	5.5800e+002	2.0646e+007
Ce-144	2.7358e-010	1.0122e+001	3.8000e-010	1.4060e-005
Cm-242	1.5839e-007	5.8604e+003	2.2000e-007	8.1400e-003
Cm-244	2.8078e-008	1.0389e+003	3.9000e-008	1.4430e-003
Co-60	2.4478e-002	9.0570e+008	3.4000e-002	1.2580e+003
Cs-134	1.2239e-003	4.5285e+007	1.7000e-003	6.2900e+001
Cs-137	4.2477e+002	1.5717e+013	5.9000e+002	2.1830e+007
Eu-154	1.6559e+000	6.1268e+010	2.3000e+000	8.5100e+004
Eu-155	2.3758e-003	8.7906e+007	3.3000e-003	1.2210e+002
Ni-63				
Np-237	1.6559e-004	6.1268e+006	2.3000e-004	8.5100e+000
Pa-233	1.6559e-004	6.1268e+006	2.3000e-004	8.5100e+000
Pm-147	2.5198e-001	9.3233e+009	3.5000e-001	1.2950e+004
Pr-144	2.7358e-010	1.0122e+001	3.8000e-010	1.4060e-005
Pu-238	6.4076e+000	2.3708e+011	8.9000e+000	3.2930e+005
Pu-239	1.0079e-001	3.7293e+009	1.4000e-001	5.1800e+003
Pu-240	9.3593e-002	3.4630e+009	1.3000e-001	4.8100e+003
Pu-241	3.0238e+000	1.1188e+011	4.2000e+000	1.5540e+005
Pu-242	2.1598e-004	7.9914e+006	3.0000e-004	1.1100e+001
Rh-106	2.5918e-008	9.5897e+002	3.6000e-008	1.3320e-003
Ru-106	2.5918e-008	9.5897e+002	3.6000e-008	1.3320e-003
Sb-125	7.9194e-003	2.9302e+008	1.1000e-002	4.0700e+002
Sm-151	9.3593e+000	3.4630e+011	1.3000e+001	4.8100e+005

Page : 2
 DOS File: T17ZIR.MS5
 Run Date: November 20, 1997
 Run Time: 2:39:51 AM
 Duration: 00:01:30

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Sr-90	5.5436e+002	2.0511e+013	7.7000e+002 ✓	2.8490e+007
Tc-99	1.2959e-001	4.7949e+009	1.8000e-001 ✓	6.6600e+003
Th-230	1.2239e-006	4.5285e+004	1.7000e-006 ✓	6.2900e-002
Th-231	3.2398e-005	1.1987e+006	4.5000e-005 ✓	1.6650e+000
U-232	3.1678e-007	1.1721e+004	4.4000e-007 ✓	1.6280e-002
U-233	2.0159e-008	7.4587e+002	2.8000e-008 ✓	1.0360e-003
U-234	5.1116e-003	1.8913e+008	7.1000e-003 ✓	2.6270e+002
U-235	3.2398e-005	1.1987e+006	4.5000e-005 ✓	1.6650e+000
U-236	8.6394e-005	3.1966e+006	1.2000e-004 ✓	4.4400e+000
U-237	7.1995e-005	2.6638e+006	1.0000e-004 ✓	3.7000e+000
U-238	1.5839e-006	5.8604e+004	2.2000e-006 ✓	8.1400e-002
Y-90	5.5436e+002	2.0511e+013	7.7000e+002 ✓	2.8490e+007

Buildup
 The material reference is : Source

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Results</u>			
		<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
		<u>MeV/cm²/sec</u>	<u>MeV/cm²/sec</u>	<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.015	2.255e+03	1.585e-211	1.034e-29	1.360e-212	8.868e-31
0.02	1.024e+08	3.904e-93	7.388e-25	1.352e-94	2.559e-26
0.03	8.763e+11	5.472e-26	1.398e-20	5.423e-28	1.386e-22
0.04	2.191e+11	4.149e-10	1.548e-09	1.835e-12	6.848e-12
0.05	3.174e+09	8.489e-06	4.985e-05	2.261e-08	1.328e-07
0.06	9.725e+09	1.751e-02	1.369e-01	3.477e-05	2.719e-04
0.08	2.844e+07	1.327e-02	1.229e-01	2.100e-05	1.945e-04
0.1	2.482e+10	1.099e+02	1.008e+03	1.682e-01	1.543e+00
0.15	1.077e+06	4.008e-02	3.093e-01	6.600e-05	5.094e-04
0.2	4.208e+09	3.698e+02	2.483e+03	6.527e-01	4.383e+00
0.3	4.364e+06	9.455e-01	5.176e+00	1.794e-03	9.818e-03
0.4	5.291e+08	2.010e+02	9.475e+02	3.917e-01	1.846e+00
0.5	1.637e+08	9.461e+01	3.964e+02	1.857e-01	7.781e-01
0.6	1.338e+13	1.084e+07	4.120e+07	2.117e+04	8.041e+04
0.8	2.393e+10	3.296e+04	1.080e+05	6.269e+01	2.054e+02
1.0	1.976e+10	4.099e+04	1.204e+05	7.555e+01	2.220e+02
1.5	2.481e+10	1.075e+05	2.629e+05	1.809e+02	4.423e+02
2.0	7.835e-02	5.614e-07	1.231e-06	8.681e-10	1.903e-09
TOTALS:	1.459e+13	1.103e+07	4.169e+07	2.149e+04	8.129e+04

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
DOS File: T17ZIR.MS5
Run Date: November 20, 1997
Run Time: 2:43:57 AM
Duration: 00:01:27

File Ref: HKP-26-91
Date: 12/4/97
By: AKK/Adren
Checked: BBB

Case Title: T17zir

Description: R/hr @ 1 m from canister surf., Zirconia calcine (T-17)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions

Height 262.8 cm / 8 ft 7.5 in
Radius 29.53 cm / 11.6 in

Dose Points

	<u>X</u>	<u>Y</u>	<u>Z</u>
# 1	130.48 cm / 4 ft 3.4 in	131.4 cm / 4 ft 3.7 in	0 cm / 0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	7.20e+05 cm ³	Concrete	1.7
Shield 1	.95 cm	Iron	7.86
Transition	100.0 cm	Air	0.0011
Air Gap		Air	0.00122

Source Input

Grouping Method : Standard Indices

Number of Groups : 25

Lower Energy Cutoff : 0.015

Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μ Ci/cm ³	Bq/cm ³
Am-241	7.1995e-001	2.6638e+010	1.0000e+000	3.7000e+004
Am-243	1.2239e-008	4.5285e+002	1.7000e-008	6.2900e-004
Ba-137m	4.0173e+002	1.4864e+013	5.5800e+002	2.0646e+007
Ce-144	2.7358e-010	1.0122e+001	3.8000e-010	1.4060e-005
Cm-242	1.5839e-007	5.8604e+003	2.2000e-007	8.1400e-003
Cm-244	2.8078e-008	1.0389e+003	3.9000e-008	1.4430e-003
Co-60	2.4478e-002	9.0570e+008	3.4000e-002	1.2580e+003
Cs-134	1.2239e-003	4.5285e+007	1.7000e-003	6.2900e+001
Cs-137	4.2477e+002	1.5717e+013	5.9000e+002	2.1830e+007
Eu-154	1.6559e+000	6.1268e+010	2.3000e+000	8.5100e+004
Eu-155	2.3758e-003	8.7906e+007	3.3000e-003	1.2210e+002
Ni-63				
Np-237	1.6559e-004	6.1268e+006	2.3000e-004	8.5100e+000
Pa-233	1.6559e-004	6.1268e+006	2.3000e-004	8.5100e+000
Pm-147	2.5198e-001	9.3233e+009	3.5000e-001	1.2950e+004
Pr-144	2.7358e-010	1.0122e+001	3.8000e-010	1.4060e-005
Pu-238	6.4076e+000	2.3708e+011	8.9000e+000	3.2930e+005
Pu-239	1.0079e-001	3.7293e+009	1.4000e-001	5.1800e+003
Pu-240	9.3593e-002	3.4630e+009	1.3000e-001	4.8100e+003
Pu-241	3.0238e+000	1.1188e+011	4.2000e+000	1.5540e+005
Pu-242	2.1598e-004	7.9914e+006	3.0000e-004	1.1100e+001
Rh-106	2.5918e-008	9.5897e+002	3.6000e-008	1.3320e-003
Ru-106	2.5918e-008	9.5897e+002	3.6000e-008	1.3320e-003
Sb-125	7.9194e-003	2.9302e+008	1.1000e-002	4.0700e+002
Sm-151	9.3593e+000	3.4630e+011	1.3000e+001	4.8100e+005

Page : 2
 DOS File: T17ZIR.MS5
 Run Date: November 20, 1997
 Run Time: 2:43:57 AM
 Duration: 00:01:27

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Sr-90	5.5436e+002	2.0511e+013	7.7000e+002 ✓	2.8490e+007
Tc-99	1.2959e-001	4.7949e+009	1.8000e-001 ✓	6.6600e+003
Th-230	1.2239e-006	4.5285e+004	1.7000e-006 ✓	6.2900e-002
Th-231	3.2398e-005	1.1987e+006	4.5000e-005 ✓	1.6650e+000
U-232	3.1678e-007	1.1721e+004	4.4000e-007 ✓	1.6280e-002
U-233	2.0159e-008	7.4587e+002	2.8000e-008 ✓	1.0360e-003
U-234	5.1116e-003	1.8913e+008	7.1000e-003 ✓	2.6270e+002
U-235	3.2398e-005	1.1987e+006	4.5000e-005 ✓	1.6650e+000
U-236	8.6394e-005	3.1966e+006	1.2000e-004 ✓	4.4400e+000
U-237	7.1995e-005	2.6638e+006	1.0000e-004 ✓	3.7000e+000
U-238	1.5839e-006	5.8604e+004	2.2000e-006 ✓	8.1400e-002
Y-90	5.5436e+002	2.0511e+013	7.7000e+002 ✓	2.8490e+007

Buildup
 The material reference is : Transition

Integration Parameters
 Radial 23
 Circumferential 23
 Y Direction (axial) 23

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Fluence Rate</u> <u>MeV/cm²/sec</u>	<u>Results</u>		<u>Exposure Rate</u> <u>mR/hr</u>	<u>Exposure Rate</u> <u>mR/hr</u>
			<u>No Buildup</u>	<u>With Buildup</u>		
0.015	2.255e+03	8.561e-193	2.049e-30	7.343e-194	1.758e-31	
0.02	1.024e+08	4.359e-86	2.641e-25	1.510e-87	9.147e-27	
0.03	8.763e+11	6.500e-25	4.284e-20	6.442e-27	4.246e-22	
0.04	2.191e+11	2.619e-10	2.977e-08	1.158e-12	1.317e-10	
0.05	3.174e+09	2.399e-06	3.967e-04	6.391e-09	1.057e-06	
0.06	9.725e+09	3.914e-03	5.864e-01	7.774e-06	1.165e-03	
0.08	2.844e+07	2.702e-03	2.177e-01	4.275e-06	3.445e-04	
0.1	2.482e+10	2.193e+01	9.794e+02	3.355e-02	1.498e+00	
0.15	1.077e+06	7.695e-03	1.419e-01	1.267e-05	2.338e-04	
0.2	4.208e+09	6.933e+01	8.268e+02	1.224e-01	1.459e+00	
0.3	4.364e+06	1.729e-01	1.310e+00	3.280e-04	2.485e-03	
0.4	5.291e+08	3.624e+01	2.115e+02	7.061e-02	4.121e-01	
0.5	1.637e+08	1.688e+01	8.244e+01	3.312e-02	1.618e-01	
0.6	1.338e+13	1.917e+06	8.182e+06	3.742e+03	1.597e+04	
0.8	2.393e+10	5.745e+03	2.018e+04	1.093e+01	3.838e+01	
1.0	1.976e+10	7.062e+03	2.170e+04	1.302e+01	4.000e+01	
1.5	2.481e+10	1.813e+04	4.495e+04	3.050e+01	7.563e+01	
2.0	7.835e-02	9.325e-08	2.040e-07	1.442e-10	3.155e-10	
TOTALS:	1.459e+13	1.948e+06	8.271e+06	3.797e+03	1.613e+04	

MicroShield v5.01 (5.01-00121)
 Lockheed Martin Idaho Technologies Company
 Case File Heat Generation
 Case File: T17SBW16.MS5
 Case Title: T17sbw

<u>Isotope</u>	<u>Activity Curies</u>	<u>Activity Bequerels</u>	<u>Heat Generation Watts/Curie</u>	<u>Heat Generation Watts</u>
Ac-225	3.7241e-010	1.3779e+001	3.4574e-002	1.2875e-011
Ac-227	2.4468e-008	9.0532e+002	4.7208e-004	1.1551e-011
Ac-228	3.6038e-014	1.3334e-003	8.0395e-003	2.8973e-016
Am-241	1.0642e-001	3.9376e+009	3.2813e-002	3.4920e-003
At-217	3.7241e-010	1.3779e+001	4.1888e-002	1.5599e-011
Ba-137m	3.4100e+001	1.2617e+012	3.9212e-003	1.3372e-001
Bi-210	6.0229e-009	2.2285e+002	2.3060e-003	1.3889e-011
Bi-211	2.4233e-008	8.9662e+002	3.9163e-002	9.4904e-010
Bi-212	2.9774e-014	1.1016e-003	1.6753e-002	4.9881e-016
Bi-213	3.7240e-010	1.3779e+001	4.1771e-003	1.5556e-012
Bi-214	3.1125e-008	1.1516e+003	1.2767e-002	3.9738e-010
Ce-144	2.6799e-008	9.9158e+002	6.6284e-004	1.7764e-011
Co-60	2.3934e-002	8.8557e+008	1.5423e-002	3.6913e-004
Cs-134	1.0611e-003	3.9260e+007	1.0179e-002	1.0801e-005
Cs-137	3.6047e+001	1.3337e+012	1.0122e-003	3.6488e-002
Eu-154	6.3635e-002	2.3545e+009	9.0517e-003	5.7601e-004
Eu-155	2.7616e-002	1.0218e+009	7.2543e-004	2.0034e-005
Fr-221	3.7241e-010	1.3779e+001	3.7907e-002	1.4117e-011
Fr-223	3.3766e-010	1.2493e+001	2.5771e-003	8.7018e-013
Ni-63	6.1822e-002	2.2874e+009	1.0155e-004	6.2779e-006
Np-237	3.8164e-003	1.4121e+008	2.8779e-002	1.0983e-004
Pa-231	8.7096e-008	3.2226e+003	3.2329e-002	2.8157e-009
Pa-233	3.8164e-003	1.4121e+008	2.4276e-003	9.2646e-006
Pa-234	1.7279e-008	6.3932e+002	1.4604e-002	2.5234e-010
Pa-234m	1.0799e-005	3.9957e+005	4.9490e-003	5.3445e-008
Pb-209	3.7238e-010	1.3778e+001	1.1714e-003	4.3621e-013
Pb-210	6.0384e-009	2.2342e+002	2.3060e-004	1.3924e-012
Pb-211	2.4233e-008	8.9662e+002	2.9963e-003	7.2609e-011
Pb-212	2.9774e-014	1.1016e-003	1.9044e-003	5.6701e-017
Pb-214	3.1125e-008	1.1516e+003	3.1921e-003	9.9356e-011
Po-210	5.6155e-009	2.0777e+002	3.1446e-002	1.7658e-010
Po-211	6.6156e-011	2.4478e+000	4.4166e-002	2.9219e-012
Po-212	1.9076e-014	7.0581e-004	5.2078e-002	9.9343e-016
Po-213	3.6436e-010	1.3481e+001	4.9660e-002	1.8094e-011
Po-214	3.1119e-008	1.1514e+003	4.5570e-002	1.4181e-009
Po-215	2.4233e-008	8.9663e+002	4.3787e-002	1.0611e-009
Po-216	2.9778e-014	1.1018e-003	4.0184e-002	1.1966e-015
Po-218	3.1132e-008	1.1519e+003	3.5576e-002	1.1076e-009
Pr-144	2.6800e-008	9.9161e+002	7.3455e-003	1.9686e-010
Pr-144m	3.8324e-010	1.4180e+001	3.3653e-004	1.2897e-013
Pu-238	9.6817e-001	3.5822e+010	3.2587e-002	3.1549e-002
Pu-239	1.2231e-001	4.5256e+009	3.0551e-002	3.7368e-003
Pu-240	2.8731e-002	1.0631e+009	3.0614e-002	8.7959e-004
Pu-241	3.7453e-001	1.3858e+010	3.1003e-005	1.1612e-005
Pu-242	1.5118e-005	5.5938e+005	2.9184e-002	4.4122e-007
Ra-223	2.4233e-008	8.9663e+002	3.4973e-002	8.4750e-010
Ra-224	2.9778e-014	1.1018e-003	3.3714e-002	1.0039e-015
Ra-225	3.7376e-010	1.3829e+001	7.0678e-004	2.6416e-013
Ra-226	3.1175e-008	1.1535e+003	2.8394e-002	8.8516e-010
Ra-228	3.6040e-014	1.3335e-003	6.8576e-005	2.4715e-018

<u>Isotope</u>	<u>Activity Curies</u>	<u>Activity Bequerels</u>	<u>Heat Generation Watts/Curie</u>	<u>Heat Generation Watts</u>
Rh-106	1.0086e-006	3.7317e+004	9.5998e-003	9.6821e-009
Rn-219	2.4233e-008	8.9663e+002	4.0502e-002	9.8150e-010
Rn-220	2.9778e-014	1.1018e-003	3.7278e-002	1.1101e-015
Rn-222	3.1132e-008	1.1519e+003	3.2543e-002	1.0131e-009
Ru-106	1.0086e-006	3.7317e+004	5.9459e-005	5.9968e-011
Sb-125	2.9272e-003	1.0831e+008	3.1431e-003	9.2004e-006
Sr-90	3.5061e+001	1.2972e+012	1.1607e-003	4.0696e-002
Tc-99	1.6558e-002	6.1263e+008	5.0152e-004	8.3040e-006
Te-125m	7.1730e-004	2.6540e+007	9.4493e-004	6.7780e-007
Th-227	2.3985e-008	8.8746e+002	3.5868e-002	8.6030e-010
Th-228	2.9810e-014	1.1030e-003	3.2139e-002	9.5806e-016
Th-229	3.7576e-010	1.3903e+001	2.9977e-002	1.1264e-011
Th-230	6.5646e-006	2.4289e+005	2.7809e-002	1.8256e-007
Th-231	1.8719e-004	6.9260e+006	1.0580e-003	1.9804e-007
Th-232	5.5490e-014	2.0531e-003	2.3811e-002	1.3213e-015
Th-234	1.0799e-005	3.9957e+005	3.9682e-004	4.2853e-009
Tl-207	2.4167e-008	8.9417e+002	2.9369e-003	7.0976e-011
Tl-208	1.0698e-014	3.9581e-004	2.3467e-002	2.5104e-016
Tl-209	8.0439e-012	2.9762e-001	1.6632e-002	1.3379e-013
U-233	3.6374e-007	1.3458e+004	2.8557e-002	1.0387e-008
U-234	3.3182e-002	1.2277e+009	2.8311e-002	9.3942e-004
U-235	1.8719e-004	6.9260e+006	2.7115e-002	5.0757e-006
U-236	5.1135e-005	1.8920e+006	2.6697e-002	1.3652e-006
U-237	9.1878e-006	3.3995e+005	1.9366e-003	1.7793e-008
U-238	1.0799e-005	3.9957e+005	2.4920e-002	2.6912e-007
Y-90	3.5070e+001	1.2976e+012	5.5411e-003	1.9432e-001

Total

Heat Generation:

4.4696e-001 ✓

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
DOS File: T17SBW16.MS5
Run Date: November 25, 1997
Run Time: 9:42:40 PM
Duration: 00:01:38

File Ref: HKP-26-97
Date: 12/4/97
By: AKKednam
Checked: 28Bm

Case Title: T17sbw

Description: R/hr @ 1 cm from canister surf., SBW calcine (T-17)
Geometry: 7 - Cylinder Volume - Side Shields

decay
2016

Source Dimensions

Height 262.8 cm — 8 ft 7.5 in
Radius 29.53 cm — 11.6 in

Dose Points

1 X Y Z
 31.48 cm — 131.4 cm 0 cm
 1 ft 0.4 in — 4 ft 3.7 in 0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	7.20e+05 cm ³	Concrete	1.7 —
Shield 1	.95 cm	Iron	7.86
Transition	1.0 cm	Air	0.0011
Air Gap		Air	0.00122

Source Input

Grouping Method : Standard Indices

Number of Groups : 25

Lower Energy Cutoff : 0.015

Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Ac-225	3.7241e-010	1.3779e+001	5.1727e-010	1.9139e-005
Ac-227	2.4468e-008	9.0532e+002	3.3986e-008	1.2575e-003
Ac-228	3.6038e-014	1.3334e-003	5.0056e-014	1.8521e-009
Am-241	1.0642e-001	3.9376e+009	1.4782e-001	5.4692e+003
At-217	3.7241e-010	1.3779e+001	5.1727e-010	1.9139e-005
Ba-137m	3.4100e+001	1.2617e+012	4.7365e+001	1.7525e+006
Bi-210	6.0229e-009	2.2285e+002	8.3658e-009	3.0953e-004
Bi-211	2.4233e-008	8.9662e+002	3.3659e-008	1.2454e-003
Bi-212	2.9774e-014	1.1016e-003	4.1355e-014	1.5301e-009
Bi-213	3.7240e-010	1.3779e+001	5.1726e-010	1.9139e-005
Bi-214	3.1125e-008	1.1516e+003	4.3232e-008	1.5996e-003
Ce-144	2.6799e-008	9.9158e+002	3.7224e-008	1.3773e-003
Co-60	2.3934e-002	8.8557e+008	3.3244e-002	1.2300e+003
Cs-134	1.0611e-003	3.9260e+007	1.4738e-003	5.4532e+001
Cs-137	3.6047e+001	1.3337e+012	5.0069e+001	1.8525e+006
Eu-154	6.3635e-002	2.3545e+009	8.8388e-002	3.2704e+003
Eu-155	2.7616e-002	1.0218e+009	3.8359e-002	1.4193e+003
Fr-221	3.7241e-010	1.3779e+001	5.1727e-010	1.9139e-005
Fr-223	3.3766e-010	1.2493e+001	4.6900e-010	1.7353e-005
Ni-63	6.1822e-002	2.2874e+009	8.5870e-002	3.1772e+003
Np-237	3.8164e-003	1.4121e+008	5.3009e-003	1.9613e+002
Pa-231	8.7096e-008	3.2226e+003	1.2098e-007	4.4761e-003
Pa-233	3.8164e-003	1.4121e+008	5.3009e-003	1.9613e+002
Pa-234	1.7279e-008	6.3932e+002	2.4000e-008	8.8800e-004
Pa-234m	1.0799e-005	3.9957e+005	1.5000e-005	5.5500e-001

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 DOS File: T17SBW16.MS5
 Run Date: November 25, 1997
 Run Time: 9:42:40 PM
 Duration: 00:01:38

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Pb-209	3.7238e-010	1.3778e+001	5.1723e-010	1.9138e-005
Pb-210	6.0384e-009	2.2342e+002	8.3872e-009	3.1033e-004
Pb-211	2.4233e-008	8.9662e+002	3.3659e-008	1.2454e-003
Pb-212	2.9774e-014	1.1016e-003	4.1356e-014	1.5302e-009
Pb-214	3.1125e-008	1.1516e+003	4.3233e-008	1.5996e-003
Po-210	5.6155e-009	2.0777e+002	7.7998e-009	2.8859e-004
Po-211	6.6156e-011	2.4478e+000	9.1890e-011	3.3999e-006
Po-212	1.9076e-014	7.0581e-004	2.6496e-014	9.8036e-010
Po-213	3.6436e-010	1.3481e+001	5.0609e-010	1.8725e-005
Po-214	3.1119e-008	1.1514e+003	4.3223e-008	1.5993e-003
Po-215	2.4233e-008	8.9663e+002	3.3660e-008	1.2454e-003
Po-216	2.9778e-014	1.1018e-003	4.1361e-014	1.5304e-009
Po-218	3.1132e-008	1.1519e+003	4.3242e-008	1.5999e-003
Pr-144	2.6800e-008	9.9161e+002	3.7225e-008	1.3773e-003
Pr-144m	3.8324e-010	1.4180e+001	5.3231e-010	1.9696e-005
Pu-238	9.6817e-001	3.5822e+010	1.3448e+000	4.9756e+004
Pu-239	1.2231e-001	4.5256e+009	1.6989e-001	6.2860e+003
Pu-240	2.8731e-002	1.0631e+009	3.9907e-002	1.4766e+003
Pu-241	3.7453e-001	1.3858e+010	5.2022e-001	1.9248e+004
Pu-242	1.5118e-005	5.5938e+005	2.0999e-005	7.7697e-001
Ra-223	2.4233e-008	8.9663e+002	3.3660e-008	1.2454e-003
Ra-224	2.9778e-014	1.1018e-003	4.1361e-014	1.5304e-009
Ra-225	3.7376e-010	1.3829e+001	5.1914e-010	1.9208e-005
Ra-226	3.1175e-008	1.1535e+003	4.3301e-008	1.6021e-003
Ra-228	3.6040e-014	1.3335e-003	5.0059e-014	1.8522e-009
Rh-106	1.0086e-006	3.7317e+004	1.4009e-006	5.1833e-002
Rn-219	2.4233e-008	8.9663e+002	3.3660e-008	1.2454e-003
Rn-220	2.9778e-014	1.1018e-003	4.1361e-014	1.5304e-009
Rn-222	3.1132e-008	1.1519e+003	4.3242e-008	1.5999e-003
Ru-106	1.0086e-006	3.7317e+004	1.4009e-006	5.1833e-002
Sb-125	2.9272e-003	1.0831e+008	4.0658e-003	1.5044e+002
Sr-90	3.5061e+001	1.2972e+012	4.8699e+001	1.8018e+006
Tc-99	1.6558e-002	6.1263e+008	2.2998e-002	8.5094e+002
Te-125m	7.1730e-004	2.6540e+007	9.9632e-004	3.6864e+001
Th-227	2.3985e-008	8.8746e+002	3.3315e-008	1.2327e-003
Th-228	2.9810e-014	1.1030e-003	4.1406e-014	1.5320e-009
Th-229	3.7576e-010	1.3903e+001	5.2192e-010	1.9311e-005
Th-230	6.5646e-006	2.4289e+005	9.1181e-006	3.3737e-001
Th-231	1.8719e-004	6.9260e+006	2.6000e-004	9.6201e+000
Th-232	5.5490e-014	2.0531e-003	7.7074e-014	2.8517e-009
Th-234	1.0799e-005	3.9957e+005	1.5000e-005	5.5500e-001
Tl-207	2.4167e-008	8.9417e+002	3.3567e-008	1.2420e-003
Tl-208	1.0698e-014	3.9581e-004	1.4859e-014	5.4978e-010
Tl-209	8.0439e-012	2.9762e-001	1.1173e-011	4.1339e-007
U-233	3.6374e-007	1.3458e+004	5.0523e-007	1.8693e-002
U-234	3.3182e-002	1.2277e+009	4.6089e-002	1.7053e+003
U-235	1.8719e-004	6.9260e+006	2.6000e-004	9.6201e+000
U-236	5.1135e-005	1.8920e+006	7.1026e-005	2.6280e+000
U-237	9.1878e-006	3.3995e+005	1.2762e-005	4.7218e-001
U-238	1.0799e-005	3.9957e+005	1.5000e-005	5.5500e-001
Y-90	3.5070e+001	1.2976e+012	4.8711e+001	1.8023e+006

Buildup
 The material reference is : Source

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 File: T17SBW16.MS5
 Run Date: November 25, 1997
 Run Time: 9:42:40 PM
 Duration: 00:01:38

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

Energy MeV	Activity photons/sec	Results			
		Fluence Rate	Fluence Rate	Exposure Rate	Exposure Rate
		<u>MeV/cm²/sec</u>	<u>MeV/cm²/sec</u>	<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.015	1.303e+04	9.160e-211	5.974e-29	7.857e-212	5.124e-30
0.02	1.315e+01	5.014e-100	9.487e-32	1.737e-101	3.286e-33
0.03	7.452e+10	4.653e-27	1.189e-21	4.611e-29	1.178e-23
0.04	1.821e+10	3.448e-11	1.287e-10	1.525e-13	5.691e-13
0.05	1.842e+08	4.925e-07	2.892e-06	1.312e-09	7.705e-09
0.06	1.452e+09	2.613e-03	2.043e-02	5.191e-06	4.058e-05
0.08	3.406e+08	1.589e-01	1.472e+00	2.515e-04	2.329e-03
0.1	1.230e+09	5.449e+00	4.998e+01	8.336e-03	7.646e-02
0.15	3.775e+06	1.405e-01	1.085e+00	2.314e-04	1.786e-03
0.2	1.739e+08	1.528e+01	1.026e+02	2.697e-02	1.811e-01
0.3	7.116e+07	1.542e+01	8.441e+01	2.925e-02	1.601e-01
0.4	5.567e+07	2.115e+01	9.970e+01	4.121e-02	1.943e-01
0.5	1.689e+07	9.766e+00	4.091e+01	1.917e-02	8.031e-02
0.6	1.136e+12	9.204e+05	3.497e+06	1.796e+03	6.825e+03
0.8	9.551e+08	1.315e+03	4.310e+03	2.502e+00	8.198e+00
1.0	1.611e+09	3.343e+03	9.821e+03	6.161e+00	1.810e+01
1.5	1.805e+09	7.825e+03	1.913e+04	1.317e+01	3.219e+01
2.0	3.274e+02	2.346e-03	5.142e-03	3.627e-06	7.952e-06
3.0	3.950e-04	5.528e-09	1.058e-08	7.500e-12	1.435e-11
TOTALS:	1.236e+12	9.329e+05	3.530e+06	1.818e+03	6.884e+03

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
 DOS File: T17SBW.MS5
 Run Date: November 25, 1997
 Run Time: 9:36:47 PM
 Duration: 00:01:36

File Ref: HKP-26-
 Date: 12/14/97
 By: HH
 Checked: 283

Case Title: T17sbw

Description: R/hr @ 1 m from canister surf., SBW calcine (T-17)
Geometry: 7 - Cylinder Volume - Side Shields

*Derog 6
2016*

Source Dimensions

Height	262.8 cm	8 ft 7.5 in
Radius	29.53 cm	11.6 in

Dose Points

	<u>X</u>	<u>Y</u>	<u>Z</u>
# 1	130.48 cm	131.4 cm	0 cm
	4 ft 3.4 in	4 ft 3.7 in	0.0 ir

Shields

<u>Shield Name</u>	<u>Dimension</u>	<u>Material</u>	<u>Densit</u>
Source	7.20e+05 cm ³	Concrete	1.7
Shield 1	.95 cm	Iron	7.86
Transition	100.0 cm	Air	0.0011
Air Gap		Air	0.0012

Source Input

Grouping Method : Standard Indices

Number of Groups : 25

Lower Energy Cutoff : 0.015

Photons < 0.015 : Excluded

Library : Grove

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Ac-225	3.7241e-010	1.3779e+001	5.1727e-010	1.9139e-005
Ac-227	2.4468e-008	9.0532e+002	3.3986e-008	1.2575e-003
Ac-228	3.6038e-014	1.3334e-003	5.0056e-014	1.8521e-009
Am-241	1.0642e-001	3.9376e+009	1.4782e-001	5.4692e+003
At-217	3.7241e-010	1.3779e+001	5.1727e-010	1.9139e-005
Ba-137m	3.4100e+001	1.2617e+012	4.7365e+001	1.7525e+006
Bi-210	6.0229e-009	2.2285e+002	8.3658e-009	3.0953e-004
Bi-211	2.4233e-008	8.9662e+002	3.3659e-008	1.2454e-003
Bi-212	2.9774e-014	1.1016e-003	4.1355e-014	1.5301e-009
Bi-213	3.7240e-010	1.3779e+001	5.1726e-010	1.9139e-005
Bi-214	3.1125e-008	1.1516e+003	4.3232e-008	1.5996e-003
Ce-144	2.6799e-008	9.9158e+002	3.7224e-008	1.3773e-003
Co-60	2.3934e-002	8.8557e+008	3.3244e-002	1.2300e+003
Cs-134	1.0611e-003	3.9260e+007	1.4738e-003	5.4532e+001
Cs-137	3.6047e+001	1.3337e+012	5.0069e+001	1.8525e+006
Eu-154	6.3635e-002	2.3545e+009	8.8388e-002	3.2704e+003
Eu-155	2.7616e-002	1.0218e+009	3.8359e-002	1.4193e+003
Fr-221	3.7241e-010	1.3779e+001	5.1727e-010	1.9139e-005
Fr-223	3.3766e-010	1.2493e+001	4.6900e-010	1.7353e-005
Ni-63	6.1822e-002	2.2874e+009	8.5870e-002	3.1772e+003
Np-237	3.8164e-003	1.4121e+008	5.3009e-003	1.9613e+002
Pa-231	8.7096e-008	3.2226e+003	1.2098e-007	4.4761e-003
Pa-233	3.8164e-003	1.4121e+008	5.3009e-003	1.9613e+002
Pa-234	1.7279e-008	6.3932e+002	2.4000e-008	8.8800e-004
Pa-234m	1.0799e-005	3.9957e+005	1.5000e-005	5.5500e-001

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 Run Date: November 25, 1997
 Run Time: 9:36:47 PM
 Duration: 00:01:36

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Pb-209	3.7238e-010	1.3778e+001	5.1723e-010	1.9138e-005
Pb-210	6.0384e-009	2.2342e+002	8.3872e-009	3.1033e-004
Pb-211	2.4233e-008	8.9662e+002	3.3659e-008	1.2454e-003
Pb-212	2.9774e-014	1.1016e-003	4.1356e-014	1.5302e-009
Pb-214	3.1125e-008	1.1516e+003	4.3233e-008	1.5996e-003
Po-210	5.6155e-009	2.0777e+002	7.7998e-009	2.8859e-004
Po-211	6.6156e-011	2.4478e+000	9.1890e-011	3.3999e-006
Po-212	1.9076e-014	7.0581e-004	2.6496e-014	9.8036e-010
Po-213	3.6436e-010	1.3481e+001	5.0609e-010	1.8725e-005
Po-214	3.1119e-008	1.1514e+003	4.3223e-008	1.5993e-003
Po-215	2.4233e-008	8.9663e+002	3.3660e-008	1.2454e-003
Po-216	2.9778e-014	1.1018e-003	4.1361e-014	1.5304e-009
Po-218	3.1132e-008	1.1519e+003	4.3242e-008	1.5999e-003
Pr-144	2.6800e-008	9.9161e+002	3.7225e-008	1.3773e-003
Pr-144m	3.8324e-010	1.4180e+001	5.3231e-010	1.9696e-005
Pu-238	9.6817e-001	3.5822e+010	1.3448e+000	4.9756e+004
Pu-239	1.2231e-001	4.5256e+009	1.6989e-001	6.2860e+003
Pu-240	2.8731e-002	1.0631e+009	3.9907e-002	1.4766e+003
Pu-241	3.7453e-001	1.3858e+010	5.2022e-001	1.9248e+004
Pu-242	1.5118e-005	5.5938e+005	2.0999e-005	7.7697e-001
Ra-223	2.4233e-008	8.9663e+002	3.3660e-008	1.2454e-003
Ra-224	2.9778e-014	1.1018e-003	4.1361e-014	1.5304e-009
Ra-225	3.7376e-010	1.3829e+001	5.1914e-010	1.9208e-005
Ra-226	3.1175e-008	1.1535e+003	4.3301e-008	1.6021e-003
Ra-228	3.6040e-014	1.3335e-003	5.0059e-014	1.8522e-009
Rh-106	1.0086e-006	3.7317e+004	1.4009e-006	5.1833e-002
Rn-219	2.4233e-008	8.9663e+002	3.3660e-008	1.2454e-003
Rn-220	2.9778e-014	1.1018e-003	4.1361e-014	1.5304e-009
Rn-222	3.1132e-008	1.1519e+003	4.3242e-008	1.5999e-003
Ru-106	1.0086e-006	3.7317e+004	1.4009e-006	5.1833e-002
Sb-125	2.9272e-003	1.0831e+008	4.0658e-003	1.5044e+002
Sr-90	3.5061e+001	1.2972e+012	4.8699e+001	1.8018e+006
Tc-99	1.6558e-002	6.1263e+008	2.2998e-002	8.5094e+002
Te-125m	7.1730e-004	2.6540e+007	9.9632e-004	3.6864e+001
Th-227	2.3985e-008	8.8746e+002	3.3315e-008	1.2327e-003
Th-228	2.9810e-014	1.1030e-003	4.1406e-014	1.5320e-009
Th-229	3.7576e-010	1.3903e+001	5.2192e-010	1.9311e-005
Th-230	6.5646e-006	2.4289e+005	9.1181e-006	3.3737e-001
Th-231	1.8719e-004	6.9260e+006	2.6000e-004	9.6201e+000
Th-232	5.5490e-014	2.0531e-003	7.7074e-014	2.8517e-009
Th-234	1.0799e-005	3.9957e+005	1.5000e-005	5.5500e-001
Tl-207	2.4167e-008	8.9417e+002	3.3567e-008	1.2420e-003
Tl-208	1.0698e-014	3.9581e-004	1.4859e-014	5.4978e-010
Tl-209	8.0439e-012	2.9762e-001	1.1173e-011	4.1339e-007
U-233	3.6374e-007	1.3458e+004	5.0523e-007	1.8693e-002
U-234	3.3182e-002	1.2277e+009	4.6089e-002	1.7053e+003
U-235	1.8719e-004	6.9260e+006	2.6000e-004	9.6201e+000
U-236	5.1135e-005	1.8920e+006	7.1026e-005	2.6280e+000
U-237	9.1878e-006	3.3995e+005	1.2762e-005	4.7218e-001
U-238	1.0799e-005	3.9957e+005	1.5000e-005	5.5500e-001
Y-90	3.5070e+001	1.2976e+012	4.8711e+001	1.8023e+006

Buildup
 The material reference is : Transition

Page : 3
 DOS File: T17SBW.MS5
 Run Date: November 25, 1997
 Run Time: 9:36:47 PM
 Duration: 00:01:36

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

<u>Energy</u> MeV	<u>Activity</u> photons/sec	<u>Results</u>			
		<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
		<u>MeV/cm²/sec</u>	<u>MeV/cm²/sec</u>	<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.015	1.303e+04	4.947e-192	1.184e-29	4.243e-193	1.016e-30
0.02	1.315e+01	5.598e-93	3.391e-32	1.939e-94	1.175e-33
0.03	7.452e+10	5.527e-26	3.643e-21	5.478e-28	3.611e-23
0.04	1.821e+10	2.176e-11	2.474e-09	9.625e-14	1.094e-11
0.05	1.842e+08	1.392e-07	2.302e-05	3.708e-10	6.131e-08
0.06	1.452e+09	5.842e-04	8.753e-02	1.160e-06	1.738e-04
0.08	3.406e+08	3.235e-02	2.607e+00	5.120e-05	4.125e-03
0.1	1.230e+09	1.087e+00	4.854e+01	1.662e-03	7.426e-02
0.15	3.775e+06	2.698e-02	4.977e-01	4.444e-05	8.196e-04
0.2	1.739e+08	2.865e+00	3.417e+01	5.056e-03	6.031e-02
0.3	7.116e+07	2.820e+00	2.136e+01	5.349e-03	4.053e-02
0.4	5.567e+07	3.813e+00	2.226e+01	7.429e-03	4.336e-02
0.5	1.689e+07	1.742e+00	8.509e+00	3.419e-03	1.670e-02
0.6	1.136e+12	1.627e+05	6.944e+05	3.176e+02	1.355e+03
0.8	9.551e+08	2.293e+02	8.053e+02	4.361e-01	1.532e+00
1.0	1.611e+09	5.759e+02	1.770e+03	1.062e+00	3.262e+00
1.5	1.805e+09	1.319e+03	3.271e+03	2.220e+00	5.503e+00
2.0	3.274e+02	3.897e-04	8.526e-04	6.026e-07	1.318e-06
3.0	3.950e-04	9.014e-10	1.695e-09	1.223e-12	2.300e-12
TOTALS:	1.236e+12	1.649e+05	7.004e+05	3.214e+02	1.366e+03

MicroShield v5.01 (5.01-00121)
 Lockheed Martin Idaho Technologies Company
 Case File Heat Generation
 Case File: T24ALUM.MS5
 Case Title: T-24Alum

<u>Isotope</u>	<u>Activity Curies</u>	<u>Activity Bequerels</u>	<u>Heat Generation Watts/Curie</u>	<u>Heat Generation Watts</u>
Am-241	3.0310e+000	1.1215e+011	3.2813e-002	9.9455e-002
Am-243	1.0655e-004	3.9424e+006	3.1704e-002	3.3782e-006
Ba-137m	1.8791e+004	6.9526e+014	3.9212e-003	7.3682e+001
Ce-144	2.4334e-016	9.0037e-006	6.6284e-004	1.6130e-019
Cm-242	8.4234e-005	3.1167e+006	3.6240e-002	3.0527e-006
Cm-244	1.6847e-004	6.2333e+006	3.4409e-002	5.7969e-006
Cs-134	1.0223e-004	3.7826e+006	1.0179e-002	1.0406e-006
Cs-137	1.9871e+004	7.3521e+014	1.0122e-003	2.0114e+001
Eu-154	8.9994e+000	3.3298e+011	9.0517e-003	8.1460e-002
Eu-155	5.4500e-001	2.0165e+010	7.2543e-004	3.9536e-004
Np-237	2.8438e-002	1.0522e+009	2.8779e-002	8.1843e-004
Pm-147	7.2715e-002	2.6905e+009	3.6731e-004	2.6709e-005
Pr-144	2.4334e-016	9.0037e-006	7.3455e-003	1.7875e-018
Pu-238	1.0799e+001	3.9957e+011	3.2587e-002	3.5191e-001
Pu-239	1.3679e+000	5.0612e+010	3.0551e-002	4.1790e-002
Pu-240	5.4572e-001	2.0192e+010	3.0614e-002	1.6707e-002
Pu-241	4.7733e+000	1.7661e+011	3.1003e-005	1.4799e-004
Pu-242	4.0965e-005	1.5157e+006	2.9184e-002	1.1955e-006
Rh-106	9.5753e-014	3.5429e-003	9.5998e-003	9.1921e-016
Ru-106	9.5753e-014	3.5429e-003	5.9459e-005	5.6934e-018
Sm-151	3.8157e+002	1.4118e+013	1.1729e-004	4.4754e-002
Sr-90	1.8215e+004	6.7394e+014	1.1607e-003	2.1142e+001
Tc-99	2.5846e+000	9.5631e+010	5.0152e-004	1.2962e-003
Th-230	1.0583e-004	3.9158e+006	2.7809e-002	2.9431e-006
Th-231	1.8143e-005	6.7128e+005	1.0580e-003	1.9194e-008
U-232	3.8085e-006	1.4092e+005	3.1553e-002	1.2017e-007
U-233	3.9813e-006	1.4731e+005	2.8557e-002	1.1369e-007
U-234	8.4954e-002	3.1433e+009	2.8311e-002	2.4052e-003
U-235	5.6876e-004	2.1044e+007	2.7115e-002	1.5422e-005
U-236	1.3679e-003	5.0612e+007	2.6697e-002	3.6519e-005
U-237	1.1951e-004	4.4219e+006	1.9366e-003	2.3145e-007
U-238	3.2974e-005	1.2200e+006	2.4920e-002	8.2171e-007
Y-90	1.8215e+004	6.7394e+014	5.5411e-003	1.0093e+002
Total			Heat Generation:	2.1651e+002

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
File: T24ALUM.MS5
Run Date: December 4, 1997
Run Time: 5:47:24 PM
Duration: 00:01:36

File Ref: HKP-26
Date: 12/4/97
By: AKB
Checked: AKB

Case Title: T-24Alum

Description: R/hr @ 1 cm from canister surf., Alumina calcine (NT-24)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions
Height 262.8 cm 8 ft 7.5 in
Radius 29.53 cm 11.6 in

Dose Points
1 X 31.48 cm 131.4 cm Z 0 cm
1 ft 0.4 in 4 ft 3.7 in 0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	7.20e+05 cm ³	Concrete	2.6
Shield 1	.95 cm	Iron	7.86
Transition	1.0 cm	Air	0.0011
Air Gap		Air	0.0012

Source Input
Grouping Method : Standard Indices

Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Am-241	3.0310e+000	1.1215e+011	4.2100e+000	1.5577e+005
Am-243	1.0655e-004	3.9424e+006	1.4800e-004	5.4760e+000
Ba-137m	1.8791e+004	6.9526e+014	2.6100e+004	9.6570e+008
Ce-144	2.4334e-016	9.0037e-006	3.3800e-016	1.2506e-011
Cm-242	8.4234e-005	3.1167e+006	1.1700e-004	4.3290e+000
Cm-244	1.6847e-004	6.2333e+006	2.3400e-004	8.6580e+000
Cs-134	1.0223e-004	3.7826e+006	1.4200e-004	5.2540e+000
Cs-137	1.9871e+004	7.3521e+014	2.7600e+004	1.0212e+009
Eu-154	8.9994e+000	3.3298e+011	1.2500e+001	4.6250e+005
Eu-155	5.4500e-001	2.0165e+010	7.5700e-001	2.8009e+004
Np-237	2.8438e-002	1.0522e+009	3.9500e-002	1.4615e+003
Pm-147	7.2715e-002	2.6905e+009	1.0100e-001	3.7370e+003
Pr-144	2.4334e-016	9.0037e-006	3.3800e-016	1.2506e-011
Pu-238	1.0799e+001	3.9957e+011	1.5000e+001	5.5500e+005
Pu-239	1.3679e+000	5.0612e+010	1.9000e+000	7.0300e+004
Pu-240	5.4572e-001	2.0192e+010	7.5800e-001	2.8046e+004
Pu-241	4.7733e+000	1.7661e+011	6.6300e+000	2.4531e+005
Pu-242	4.0965e-005	1.5157e+006	5.6900e-005	2.1053e+000
Rh-106	9.5753e-014	3.5429e-003	1.3300e-013	4.9210e-009
Ru-106	9.5753e-014	3.5429e-003	1.3300e-013	4.9210e-009
Sm-151	3.8157e+002	1.4118e+013	5.3000e+002	1.9610e+007
Sr-90	1.8215e+004	6.7394e+014	2.5300e+004	9.3610e+008
Tc-99	2.5846e+000	9.5631e+010	3.5900e+000	1.3283e+005
Th-230	1.0583e-004	3.9158e+006	1.4700e-004	5.4390e+000
Th-231	1.8143e-005	6.7128e+005	2.5200e-005	9.3240e-001

Page : 2
 DOS File: T24ALUM.MS5
 Run Date: December 4, 1997
 Run Time: 5:47:24 PM
 Duration: 00:01:36

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
U-232	3.8085e-006	1.4092e+005	5.2900e-006	1.9573e-001
U-233	3.9813e-006	1.4731e+005	5.5300e-006	2.0461e-001
U-234	8.4954e-002	3.1433e+009	1.1800e-001	4.3660e+003
U-235	5.6876e-004	2.1044e+007	7.9000e-004	2.9230e+001
U-236	1.3679e-003	5.0612e+007	1.9000e-003	7.0300e+001
U-237	1.1951e-004	4.4219e+006	1.6600e-004	6.1420e+000
U-238	3.2974e-005	1.2200e+006	4.5800e-005	1.6946e+000
Y-90	1.8215e+004	6.7394e+014	2.5300e+004	9.3610e+008

Buildup

The material reference is : Source

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Results</u>			
		<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
		<u>MeV/cm²/sec</u>	<u>MeV/cm²/sec</u>	<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.015	1.263e+03	9.269e-217	5.790e-30	7.951e-218	4.966e-31
0.02	4.174e+09	1.032e-93	3.012e-23	3.573e-95	1.043e-24
0.03	4.095e+13	4.856e-25	6.534e-19	4.812e-27	6.476e-21
0.04	9.735e+12	8.075e-09	3.034e-08	3.571e-11	1.342e-10
0.05	1.842e+10	2.798e-05	1.659e-04	7.453e-08	4.420e-07
0.06	4.092e+10	4.612e-02	3.648e-01	9.161e-05	7.246e-04
0.08	6.400e+09	1.982e+00	1.849e+01	3.136e-03	2.925e-02
0.1	1.390e+11	4.117e+02	3.772e+03	6.299e-01	5.771e+00
0.15	2.135e+07	5.285e-01	4.045e+00	8.704e-04	6.661e-03
0.2	2.276e+10	1.325e+03	8.839e+03	2.339e+00	1.560e+01
0.3	9.825e+04	1.407e-02	7.683e-02	2.668e-05	1.457e-04
0.4	2.376e+09	5.958e+02	2.813e+03	1.161e+00	5.481e+00
0.5	7.210e+08	2.751e+02	1.158e+03	5.401e-01	2.273e+00
0.6	6.256e+14	3.348e+08	1.281e+09	6.535e+05	2.499e+06
0.8	1.299e+11	1.182e+05	3.917e+05	2.249e+02	7.451e+02
1.0	1.024e+11	1.408e+05	4.198e+05	2.596e+02	7.738e+02
1.5	1.299e+11	3.757e+05	9.381e+05	6.321e+02	1.578e+03
2.0	6.969e-08	3.356e-13	7.550e-13	5.190e-16	1.168e-15
TOTALS:	6.769e+14	3.354e+08	1.282e+09	6.546e+05	2.503e+06

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
 DOS File: T24ALUM.MS5
 Run Date: December 4, 1997
 Run Time: 5:51:20 PM
 Duration: 00:01:30

File Ref: HKP-26-9
 Date: 12/4/97
 By: Mike Moran
 Checked: Joe Spahn

Case Title: T-24Alum
Description: R/hr @ 1 m from canister surf., Alumina calcine (NT-24)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions

Height	262.8 cm	8 ft 7.5 in
Radius	29.53 cm	11.6 in

Dose Points

	<u>X</u>	<u>Y</u>	<u>Z</u>
# 1	130.48 cm	131.4 cm	0 cm
	4 ft 3.4 in	4 ft 3.7 in	0.0 in

Shields

<u>Shield Name</u>	<u>Dimension</u>	<u>Material</u>	<u>Density</u>
Source	7.20e+05 cm ³	Concrete	2.6
Shield 1	.95 cm	Iron	7.86
Transition	100.0 cm	Air	0.0011
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded

Library : Grove

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Am-241	3.0310e+000	1.1215e+011	4.2100e+000	1.5577e+005
Am-243	1.0655e-004	3.9424e+006	1.4800e-004	5.4760e+000
Ba-137m	1.8791e+004	6.9526e+014	2.6100e+004	9.6570e+008
Ce-144	2.4334e-016	9.0037e-006	3.3800e-016	1.2506e-011
Cm-242	8.4234e-005	3.1167e+006	1.1700e-004	4.3290e+000
Cm-244	1.6847e-004	6.2333e+006	2.3400e-004	8.6580e+000
Cs-134	1.0223e-004	3.7826e+006	1.4200e-004	5.2540e+000
Cs-137	1.9871e+004	7.3521e+014	2.7600e+004	1.0212e+009
Eu-154	8.9994e+000	3.3298e+011	1.2500e+001	4.6250e+005
Eu-155	5.4500e-001	2.0165e+010	7.5700e-001	2.8009e+004
Np-237	2.8438e-002	1.0522e+009	3.9500e-002	1.4615e+003
Pm-147	7.2715e-002	2.6905e+009	1.0100e-001	3.7370e+003
Pr-144	2.4334e-016	9.0037e-006	3.3800e-016	1.2506e-011
Pu-238	1.0799e+001	3.9957e+011	1.5000e+001	5.5500e+005
Pu-239	1.3679e+000	5.0612e+010	1.9000e+000	7.0300e+004
Pu-240	5.4572e-001	2.0192e+010	7.5800e-001	2.8046e+004
Pu-241	4.7733e+000	1.7661e+011	6.6300e+000	2.4531e+005
Pu-242	4.0965e-005	1.5157e+006	5.6900e-005	2.1053e+000
Rh-106	9.5753e-014	3.5429e-003	1.3300e-013	4.9210e-009
Ru-106	9.5753e-014	3.5429e-003	1.3300e-013	4.9210e-009
Sm-151	3.8157e+002	1.4118e+013	5.3000e+002	1.9610e+007
Sr-90	1.8215e+004	6.7394e+014	2.5300e+004	9.3610e+008
Tc-99	2.5846e+000	9.5631e+010	3.5900e+000	1.3283e+005
Th-230	1.0583e-004	3.9158e+006	1.4700e-004	5.4390e+000
Th-231	1.8143e-005	6.7128e+005	2.5200e-005	9.3240e-001

Page : 2
 DOS File: T24ALUM.MS5
 Run Date: December 4, 1997
 Run Time: 5:51:20 PM
 Duration: 00:01:30

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
U-232	3.8085e-006	1.4092e+005	5.2900e-006	1.9573e-001
U-233	3.9813e-006	1.4731e+005	5.5300e-006	2.0461e-001
U-234	8.4954e-002	3.1433e+009	1.1800e-001	4.3660e+003
U-235	5.6876e-004	2.1044e+007	7.9000e-004	2.9230e+001
U-236	1.3679e-003	5.0612e+007	1.9000e-003	7.0300e+001
U-237	1.1951e-004	4.4219e+006	1.6600e-004	6.1420e+000
U-238	3.2974e-005	1.2200e+006	4.5800e-005	1.6946e+000
Y-90	1.8215e+004	6.7394e+014	2.5300e+004	9.3610e+008

Buildup
 The material reference is : Transition

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Results</u>			
		<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
		<u>MeV/cm²/sec</u>	<u>MeV/cm²/sec</u>	<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.015	1.263e+03	2.670e-193	1.148e-30	2.290e-194	9.844e-32
0.02	4.174e+09	1.158e-84	1.077e-23	4.013e-86	3.729e-25
0.03	4.095e+13	1.986e-23	2.002e-18	1.968e-25	1.984e-20
0.04	9.735e+12	7.608e-09	8.650e-07	3.365e-11	3.826e-09
0.05	1.842e+10	9.101e-06	1.505e-03	2.424e-08	4.009e-06
0.06	4.092e+10	1.077e-02	1.613e+00	2.139e-05	3.204e-03
0.08	6.400e+09	3.976e-01	3.205e+01	6.292e-04	5.072e-02
0.1	1.390e+11	8.036e+01	3.595e+03	1.229e-01	5.499e+00
0.15	2.135e+07	9.998e-02	1.851e+00	1.646e-04	3.048e-03
0.2	2.276e+10	2.458e+02	2.950e+03	4.338e-01	5.206e+00
0.3	9.825e+04	2.555e-03	1.954e-02	4.847e-06	3.707e-05
0.4	2.376e+09	1.069e+02	6.315e+02	2.083e-01	1.230e+00
0.5	7.210e+08	4.891e+01	2.423e+02	9.601e-02	4.756e-01
0.6	6.256e+14	5.906e+07	2.560e+08	1.153e+05	4.998e+05
0.8	1.299e+11	2.059e+04	7.374e+04	3.917e+01	1.403e+02
1.0	1.024e+11	2.427e+04	7.627e+04	4.474e+01	1.406e+02
1.5	1.299e+11	6.348e+04	1.620e+05	1.068e+02	2.726e+02
2.0	6.969e-08	5.597e-14	1.267e-13	8.655e-17	1.959e-16
TOTALS:	6.769e+14	5.917e+07	2.564e+08	1.155e+05	5.003e+05

MicroShield v5.01 (5.01-00121)
 Lockheed Martin Idaho Technologies Company
 Case File Heat Generation
 Case File: T24ZIR.MS5
 Case Title: T-24zir

<u>Isotope</u>	<u>Activity Curies</u>	<u>Activity Bequerels</u>	<u>Heat Generation Watts/Curie</u>	<u>Heat Generation Watts</u>
Am-241	1.9799e+001	7.3255e+011	3.2813e-002	6.4965e-001
Am-243	3.3766e-007	1.2493e+004	3.1704e-002	1.0705e-008
Ba-137m	1.1015e+004	4.0756e+014	3.9212e-003	4.3193e+001
Ce-144	7.1707e-009	2.6532e+002	6.6284e-004	4.7531e-012
Cm-242	4.3125e-006	1.5956e+005	3.6240e-002	1.5629e-007
Cm-244	7.5595e-007	2.7970e+004	3.4409e-002	2.6012e-008
Cs-134	3.4198e-002	1.2653e+009	1.0179e-002	3.4810e-004
Cs-137	1.1663e+004	4.3154e+014	1.0122e-003	1.1806e+001
Eu-154	4.5429e+001	1.6809e+012	9.0517e-003	4.1121e-001
Eu-155	6.5227e-002	2.4134e+009	7.2543e-004	4.7318e-005
Np-237	4.4853e-003	1.6596e+008	2.8779e-002	1.2908e-004
Pm-147	6.8755e+000	2.5439e+011	3.6731e-004	2.5255e-003
Pr-144	7.1707e-009	2.6532e+002	7.3455e-003	5.2672e-011
Pu-238	1.7711e+002	6.5530e+012	3.2587e-002	5.7714e+000
Pu-239	2.8294e+000	1.0469e+011	3.0551e-002	8.6440e-002
Pu-240	2.5918e+000	9.5897e+010	3.0614e-002	7.9347e-002
Pu-241	8.2794e+001	3.0634e+012	3.1003e-005	2.5669e-003
Pu-242	5.8964e-003	2.1817e+008	2.9184e-002	1.7208e-004
Rh-106	4.6005e-008	1.7022e+003	9.5998e-003	4.4164e-010
Ru-106	4.6005e-008	1.7022e+003	5.9459e-005	2.7354e-012
Sm-151	2.4550e+002	9.0836e+012	1.1729e-004	2.8794e-002
Sr-90	1.5335e+004	5.6739e+014	1.1607e-003	1.7800e+001
Tc-99	9.2154e-001	3.4097e+010	5.0152e-004	4.6217e-004
Th-230	1.3031e-006	4.8215e+004	2.7809e-002	3.6238e-008
Th-231	3.4054e-005	1.2600e+006	1.0580e-003	3.6028e-008
U-232	8.7114e-006	3.2232e+005	3.1553e-002	2.7487e-007
U-233	5.5436e-007	2.0511e+004	2.8557e-002	1.5831e-008
U-234	1.4183e-001	5.2477e+009	2.8311e-002	4.0154e-003
U-235	8.9994e-004	3.3298e+007	2.7115e-002	2.4402e-005
U-236	2.3614e-003	8.7373e+007	2.6697e-002	6.3043e-005
U-237	2.0087e-003	7.4320e+007	1.9366e-003	3.8900e-006
U-238	4.3629e-005	1.6143e+006	2.4920e-002	1.0872e-006
Y-90	1.5335e+004	5.6739e+014	5.5411e-003	8.4972e+001
		Total	Heat Generation:	1.6481e+002

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
DOS File: T24ZIR.MS5
Run Date: December 4, 1997
Run Time: 6:06:10 PM
Duration: 00:01:34

File Ref: HKP-26-97
Date: 12/4/97
By: [Signature]
Checked: [Signature]

Case Title: T-24zir

Description: R/hr @ 1 cm from canister surf., Zirconia calcine (T-24)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions
Height 262.8 cm 8 ft 7.5 in
Radius 29.53 cm 11.6 in

Dose Points
1 X Y Z
31.48 cm 131.4 cm 0 cm
1 ft 0.4 in 4 ft 3.7 in 0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	7.20e+05 cm ³	Concrete	2.6
Shield 1	.95 cm	Iron	7.86
Transition	1.0 cm	Air	0.0011
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Am-241	1.9799e+001	7.3255e+011	2.7500e+001	1.0175e+006
Am-243	3.3766e-007	1.2493e+004	4.6900e-007	1.7353e-002
Ba-137m	1.1015e+004	4.0756e+014	1.5300e+004	5.6610e+008
Ce-144	7.1707e-009	2.6532e+002	9.9600e-009	3.6852e-004
Cm-242	4.3125e-006	1.5956e+005	5.9900e-006	2.2163e-001
Cm-244	7.5595e-007	2.7970e+004	1.0500e-006	3.8850e-002
Cs-134	3.4198e-002	1.2653e+009	4.7500e-002	1.7575e+003
Cs-137	1.1663e+004	4.3154e+014	1.6200e+004	5.9940e+008
Eu-154	4.5429e+001	1.6809e+012	6.3100e+001	2.3347e+006
Eu-155	6.5227e-002	2.4134e+009	9.0600e-002	3.3522e+003
Np-237	4.4853e-003	1.6596e+008	6.2300e-003	2.3051e+002
Pm-147	6.8755e+000	2.5439e+011	9.5500e+000	3.5335e+005
Pr-144	7.1707e-009	2.6532e+002	9.9600e-009	3.6852e-004
Pu-238	1.7711e+002	6.5530e+012	2.4600e+002	9.1020e+006
Pu-239	2.8294e+000	1.0469e+011	3.9300e+000	1.4541e+005
Pu-240	2.5918e+000	9.5897e+010	3.6000e+000	1.3320e+005
Pu-241	8.2794e+001	3.0634e+012	1.1500e+002	4.2550e+006
Pu-242	5.8964e-003	2.1817e+008	8.1900e-003	3.0303e+002
Rh-106	4.6005e-008	1.7022e+003	6.3900e-008	2.3643e-003
Ru-106	4.6005e-008	1.7022e+003	6.3900e-008	2.3643e-003
Sm-151	2.4550e+002	9.0836e+012	3.4100e+002	1.2617e+007
Sr-90	1.5335e+004	5.6739e+014	2.1300e+004	7.8810e+008
Tc-99	9.2154e-001	3.4097e+010	1.2800e+000	4.7360e+004
Th-230	1.3031e-006	4.8215e+004	1.8100e-006	6.6970e-002
Th-231	3.4054e-005	1.2600e+006	4.7300e-005	1.7501e+000

Page : 2
 DOS File: T24ZIR.MS5
 Run Date: December 4, 1997
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 Duration: 00:01:34

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
U-232	8.7114e-006	3.2232e+005	1.2100e-005	4.4770e-001
U-233	5.5436e-007	2.0511e+004	7.7000e-007	2.8490e-002
U-234	1.4183e-001	5.2477e+009	1.9700e-001	7.2890e+003
U-235	8.9994e-004	3.3298e+007	1.2500e-003	4.6250e+001
U-236	2.3614e-003	8.7373e+007	3.2800e-003	1.2136e+002
U-237	2.0087e-003	7.4320e+007	2.7900e-003	1.0323e+002
U-238	4.3629e-005	1.6143e+006	6.0600e-005	2.2422e+000
Y-90	1.5335e+004	5.6739e+014	2.1300e+004	7.8810e+008

Buildup
 The material reference is : Source

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Results</u>		<u>Exposure Rate</u>	
		<u>Fluence Rate</u> <u>MeV/cm²/sec</u> <u>No Buildup</u>	<u>Fluence Rate</u> <u>MeV/cm²/sec</u> <u>With Buildup</u>	<u>mR/hr</u> <u>No Buildup</u>	<u>mR/hr</u> <u>With Buildup</u>
0.015	2.370e+03	1.740e-216	1.087e-29	1.492e-217	9.321e-31
0.02	2.686e+09	6.637e-94	1.938e-23	2.299e-95	6.713e-25
0.03	2.402e+13	2.848e-25	3.833e-19	2.823e-27	3.799e-21
0.04	6.008e+12	4.983e-09	1.872e-08	2.204e-11	8.281e-11
0.05	8.709e+10	1.323e-04	7.846e-04	3.524e-07	2.090e-06
0.06	2.675e+11	3.015e-01	2.384e+00	5.988e-04	4.736e-03
0.08	7.718e+08	2.390e-01	2.230e+00	3.782e-04	3.528e-03
0.1	6.808e+11	2.016e+03	1.847e+04	3.085e+00	2.826e+01
0.15	9.362e+06	2.317e-01	1.774e+00	3.816e-04	2.921e-03
0.2	1.148e+11	6.686e+03	4.460e+04	1.180e+01	7.872e+01
0.3	2.077e+06	2.973e-01	1.624e+00	5.640e-04	3.081e-03
0.4	1.199e+10	3.008e+03	1.420e+04	5.861e+00	2.767e+01
0.5	3.658e+09	1.396e+03	5.874e+03	2.740e+00	1.153e+01
0.6	3.669e+14	1.963e+08	7.509e+08	3.832e+05	1.466e+06
0.8	6.567e+11	5.979e+05	1.981e+06	1.137e+03	3.768e+03
1.0	5.171e+11	7.109e+05	2.119e+06	1.310e+03	3.906e+03
1.5	6.559e+11	1.897e+06	4.736e+06	3.191e+03	7.968e+03
2.0	2.054e+00	9.890e-06	2.225e-05	1.529e-08	3.440e-08
TOTALS:	3.999e+14	1.995e+08	7.598e+08	3.889e+05	1.481e+06

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
DOS File: T24ZIR.MS5
Run Date: December 4, 1997
Run Time: 6:12:12 PM
Duration: 00:01:31

File Ref: HKP-26-97
Date: 12/4/97
By: [Signature]
Checked: [Signature]

Case Title: T-24zir
Description: R/hr @ 1 m from canister surf., Zirconia calcine (T-24)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions
Height 262.8 cm 8 ft 7.5 in
Radius 29.53 cm 11.6 in

Dose Points
1 X Y Z
130.48 cm 131.4 cm 0 cm
4 ft 3.4 in 4 ft 3.7 in 0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	7.20e+05 cm ³	Concrete	2.6
Shield 1	.95 cm	Iron	7.86
Transition	100.0 cm	Air	0.0011
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded
Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Am-241	1.9799e+001	7.3255e+011	2.7500e+001	1.0175e+006
Am-243	3.3766e-007	1.2493e+004	4.6900e-007	1.7353e-002
Ba-137m	1.1015e+004	4.0756e+014	1.5300e+004	5.6610e+008
Ce-144	7.1707e-009	2.6532e+002	9.9600e-009	3.6852e-004
Cm-242	4.3125e-006	1.5956e+005	5.9900e-006	2.2163e-001
Cm-244	7.5595e-007	2.7970e+004	1.0500e-006	3.8850e-002
Cs-134	3.4198e-002	1.2653e+009	4.7500e-002	1.7575e+003
Cs-137	1.1663e+004	4.3154e+014	1.6200e+004	5.9940e+008
Eu-154	4.5429e+001	1.6809e+012	6.3100e+001	2.3347e+006
Eu-155	6.5227e-002	2.4134e+009	9.0600e-002	3.3522e+003
Np-237	4.4853e-003	1.6596e+008	6.2300e-003	2.3051e+002
Pm-147	6.8755e+000	2.5439e+011	9.5500e+000	3.5335e+005
Pr-144	7.1707e-009	2.6532e+002	9.9600e-009	3.6852e-004
Pu-238	1.7711e+002	6.5530e+012	2.4600e+002	9.1020e+006
Pu-239	2.8294e+000	1.0469e+011	3.9300e+000	1.4541e+005
Pu-240	2.5918e+000	9.5897e+010	3.6000e+000	1.3320e+005
Pu-241	8.2794e+001	3.0634e+012	1.1500e+002	4.2550e+006
Pu-242	5.8964e-003	2.1817e+008	8.1900e-003	3.0303e+002
Rh-106	4.6005e-008	1.7022e+003	6.3900e-008	2.3643e-003
Ru-106	4.6005e-008	1.7022e+003	6.3900e-008	2.3643e-003
Sm-151	2.4550e+002	9.0836e+012	3.4100e+002	1.2617e+007
Sr-90	1.5335e+004	5.6739e+014	2.1300e+004	7.8810e+008
Tc-99	9.2154e-001	3.4097e+010	1.2800e+000	4.7360e+004
Th-230	1.3031e-006	4.8215e+004	1.8100e-006	6.6970e-002
Th-231	3.4054e-005	1.2600e+006	4.7300e-005	1.7501e+000

Page : 2
 DOS File: T24ZIR.MS5
 Run Date: December 4, 1997
 Run Time: 6:12:12 PM
 Duration: 00:01:31

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
U-232	8.7114e-006	3.2232e+005	1.2100e-005	4.4770e-001
U-233	5.5436e-007	2.0511e+004	7.7000e-007	2.8490e-002
U-234	1.4183e-001	5.2477e+009	1.9700e-001	7.2890e+003
U-235	8.9994e-004	3.3298e+007	1.2500e-003	4.6250e+001
U-236	2.3614e-003	8.7373e+007	3.2800e-003	1.2136e+002
U-237	2.0087e-003	7.4320e+007	2.7900e-003	1.0323e+002
U-238	4.3629e-005	1.6143e+006	6.0600e-005	2.2422e+000
Y-90	1.5335e+004	5.6739e+014	2.1300e+004	7.8810e+008

Buildup
 The material reference is : Transition

Integration Parameters	
Radial	23
Circumferential	23
Y Direction (axial)	23

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Fluence Rate</u>		<u>Exposure Rate</u>	
		<u>MeV/cm²/sec</u>	<u>MeV/cm²/sec</u>	<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.015	2.370e+03	5.012e-193	2.154e-30	4.299e-194	1.848e-31
0.02	2.686e+09	7.453e-85	6.927e-24	2.582e-86	2.399e-25
0.03	2.402e+13	1.165e-23	1.175e-18	1.155e-25	1.164e-20
0.04	6.008e+12	4.695e-09	5.338e-07	2.076e-11	2.361e-09
0.05	8.709e+10	4.304e-05	7.117e-03	1.146e-07	1.896e-05
0.06	2.675e+11	7.038e-02	1.054e+01	1.398e-04	2.094e-02
0.08	7.718e+08	4.795e-02	3.866e+00	7.589e-05	6.117e-03
0.1	6.808e+11	3.936e+02	1.760e+04	6.021e-01	2.693e+01
0.15	9.362e+06	4.383e-02	8.116e-01	7.218e-05	1.337e-03
0.2	1.148e+11	1.240e+03	1.488e+04	2.189e+00	2.627e+01
0.3	2.077e+06	5.401e-02	4.130e-01	1.024e-04	7.835e-04
0.4	1.199e+10	5.397e+02	3.188e+03	1.052e+00	6.211e+00
0.5	3.658e+09	2.481e+02	1.229e+03	4.871e-01	2.413e+00
0.6	3.669e+14	3.463e+07	1.501e+08	6.760e+04	2.931e+05
0.8	6.567e+11	1.041e+05	3.729e+05	1.981e+02	7.093e+02
1.0	5.171e+11	1.225e+05	3.850e+05	2.258e+02	7.097e+02
1.5	6.559e+11	3.204e+05	8.180e+05	5.391e+02	1.376e+03
2.0	2.054e+00	1.649e-06	3.733e-06	2.550e-09	5.773e-09
TOTALS:	3.999e+14	3.518e+07	1.518e+08	6.857e+04	2.959e+05

MicroShield v5.01 (5.01-00121)
 Lockheed Martin Idaho Technologies Company
 Case File Heat Generation
 Case File: T24SBW.MS5
 Case Title: T-24SBW

<u>Isotope</u>	<u>Activity</u> <u>Curies</u>	<u>Activity</u> <u>Bequerels</u>	<u>Heat Generation</u> <u>Watts/Curie</u>	<u>Heat Generation</u> <u>Watts</u>
Ac-225	2.3129e-005	8.5578e+005	3.4574e-002	7.9966e-007
Ac-227	1.3723e-007	5.0774e+003	4.7208e-004	6.4782e-011
Ac-228	4.9556e-014	1.8336e-003	8.0395e-003	3.9840e-016
Am-241	1.0499e+001	3.8846e+011	3.2813e-002	3.4450e-001
At-217	2.3129e-005	8.5578e+005	4.1888e-002	9.6883e-007
Ba-137m	1.8927e-004	7.0030e+006	3.9212e-003	7.4217e-007
Bi-210	1.2176e-009	4.5051e+001	2.3060e-003	2.8078e-012
Bi-211	1.3568e-007	5.0202e+003	3.9163e-002	5.3137e-009
Bi-212	3.9404e-014	1.4580e-003	1.6753e-002	6.6016e-016
Bi-213	2.3129e-005	8.5577e+005	4.1771e-003	9.6613e-008
Bi-214	7.4496e-009	2.7564e+002	1.2767e-002	9.5109e-011
Ce-144	2.8422e-005	1.0516e+006	6.6284e-004	1.8839e-008
Co-60	3.8469e-005	1.4234e+006	1.5423e-002	5.9330e-007
Cs-134	9.6961e-009	3.5875e+002	1.0179e-002	9.8698e-011
Cs-137	2.0007e-004	7.4028e+006	1.0122e-003	2.0252e-007
Eu-154	6.6090e+000	2.4453e+011	9.0517e-003	5.9822e-002
Eu-155	2.8337e+000	1.0485e+011	7.2543e-004	2.0556e-003
Fr-221	2.3129e-005	8.5578e+005	3.7907e-002	8.7676e-007
Fr-223	1.8937e-009	7.0068e+001	2.5771e-003	4.8803e-012
Ni-63	6.9431e-005	2.5690e+006	1.0155e-004	7.0507e-009
Np-237	2.5924e-001	9.5919e+009	2.8779e-002	7.4608e-003
Pa-231	5.4972e-007	2.0340e+004	3.2329e-002	1.7772e-008
Pa-233	2.5924e-001	9.5919e+009	2.4276e-003	6.2932e-004
Pa-234	3.2254e-006	1.1934e+005	1.4604e-002	4.7103e-008
Pa-234m	2.0159e-003	7.4587e+007	4.9490e-003	9.9764e-006
Pb-209	2.3128e-005	8.5575e+005	1.1714e-003	2.7092e-008
Pb-210	1.2214e-009	4.5192e+001	2.3060e-004	2.8165e-013
Pb-211	1.3568e-007	5.0202e+003	2.9963e-003	4.0654e-010
Pb-212	3.9405e-014	1.4580e-003	1.9044e-003	7.5042e-017
Pb-214	7.4497e-009	2.7564e+002	3.1921e-003	2.3780e-011
Pm-147	7.6069e-049	2.8146e-038	3.6731e-004	2.7941e-052
Po-210	1.1178e-009	4.1358e+001	3.1446e-002	3.5150e-011
Po-211	3.7041e-010	1.3705e+001	4.4166e-002	1.6359e-011
Po-212	2.5246e-014	9.3412e-004	5.2078e-002	1.3148e-015
Po-213	2.2629e-005	8.3729e+005	4.9660e-002	1.1238e-006
Po-214	7.4480e-009	2.7558e+002	4.5570e-002	3.3941e-010
Po-215	1.3568e-007	5.0202e+003	4.3787e-002	5.9411e-009
Po-216	3.9411e-014	1.4582e-003	4.0184e-002	1.5837e-015
Po-218	7.4512e-009	2.7569e+002	3.5576e-002	2.6509e-010
Pr-144	2.8423e-005	1.0517e+006	7.3455e-003	2.0878e-007
Pr-144m	4.0644e-007	1.5038e+004	3.3653e-004	1.3678e-010
Pu-238	9.9138e+001	3.6681e+012	3.2587e-002	3.2306e+000
Pu-239	1.2232e+001	4.5260e+011	3.0551e-002	3.7371e-001
Pu-240	2.8740e+000	1.0634e+011	3.0614e-002	8.7987e-002
Pu-241	4.3271e+001	1.6010e+012	3.1003e-005	1.3416e-003
Pu-242	7.9192e-004	2.9301e+007	2.9184e-002	2.3112e-005
Ra-223	1.3568e-007	5.0202e+003	3.4973e-002	4.7451e-009
Ra-224	3.9411e-014	1.4582e-003	3.3714e-002	1.3287e-015
Ra-225	2.3178e-005	8.5757e+005	7.0678e-004	1.6381e-008
Ra-226	7.4641e-009	2.7617e+002	2.8394e-002	2.1193e-010

<u>Isotope</u>	<u>Activity Curies</u>	<u>Activity Bequerels</u>	<u>Heat Generation Watts/Curie</u>	<u>Heat Generation Watts</u>
Ra-228	4.9560e-014	1.8337e-003	6.8576e-005	3.3986e-018
Rh-106	1.2513e-005	4.6299e+005	9.5998e-003	1.2012e-007
Rn-219	1.3568e-007	5.0202e+003	4.0502e-002	5.4954e-009
Rn-220	3.9411e-014	1.4582e-003	3.7278e-002	1.4692e-015
Rn-222	7.4512e-009	2.7570e+002	3.2543e-002	2.4248e-010
Ru-106	1.2513e-005	4.6299e+005	5.9459e-005	7.4403e-010
Sb-125	6.8213e-006	2.5239e+005	3.1431e-003	2.1440e-008
Sm-147	2.8321e-057	1.0479e-046	1.3324e-002	3.7734e-059
Sr-90	3.0891e+003	1.1430e+014	1.1607e-003	3.5855e+000
Tc-99	4.2474e-001	1.5716e+010	5.0152e-004	2.1302e-004
Te-125m	1.6715e-006	6.1847e+004	9.4493e-004	1.5795e-009
Th-227	1.3438e-007	4.9720e+003	3.5868e-002	4.8199e-009
Th-228	3.9464e-014	1.4602e-003	3.2139e-002	1.2683e-015
Th-229	2.3249e-005	8.6022e+005	2.9977e-002	6.9693e-007
Th-230	1.9825e-006	7.3352e+004	2.7809e-002	5.5132e-008
Th-231	1.3681e-003	5.0621e+007	1.0580e-003	1.4474e-006
Th-232	8.1740e-014	3.0244e-003	2.3811e-002	1.9463e-015
Th-234	2.0159e-003	7.4587e+007	3.9682e-004	7.9993e-007
Tl-207	1.3531e-007	5.0064e+003	2.9369e-003	3.9739e-010
Tl-208	1.4158e-014	5.2385e-004	2.3467e-002	3.3224e-016
Tl-209	4.9959e-007	1.8485e+004	1.6632e-002	8.3093e-009
U-233	1.2979e-002	4.8024e+008	2.8557e-002	3.7065e-004
U-234	1.4400e-002	5.3282e+008	2.8311e-002	4.0770e-004
U-235	1.3681e-003	5.0621e+007	2.7115e-002	3.7097e-005
U-236	8.8012e-005	3.2564e+006	2.6697e-002	2.3497e-006
U-237	1.0615e-003	3.9276e+007	1.9366e-003	2.0557e-006
U-238	2.0159e-003	7.4587e+007	2.4920e-002	5.0236e-005
Y-90	3.0898e+003	1.1432e+014	5.5411e-003	1.7121e+001

Total

Heat Generation:

2.4816e+001 ✓

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
DOS File: T24ZIR.MS5
Run Date: November 25, 1997
Run Time: 3:16:17 PM
Duration: 00:01:33

File Ref: HKP-26-97
Date: 12/14/97
By: [Signature]
Checked: [Signature]

for 2016
[Signature]

Case Title: T-24SBW
Description: R/hr @ 1 cm from canister surf., SBW calcine (T-24)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions
Height 262.8 cm / 8 ft 7.5 in
Radius 29.53 cm / 11.6 in

Dose Points
1 X 31.48 cm / 1 ft 0.4 in Y 131.4 cm / 4 ft 3.7 in Z 0 cm / 0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	7.20e+05 cm ³	Concrete	2.6
Shield 1	.95 cm	Iron	7.86
Transition	1.0 cm	Air	0.0011
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Ac-225	2.3129e-005	8.5578e+005	3.2126e-005	1.1887e+000
Ac-227	1.3723e-007	5.0774e+003	1.9061e-007	7.0524e-003
Ac-228	4.9556e-014	1.8336e-003	6.8832e-014	2.5468e-009
Am-241	1.0499e+001	3.8846e+011	1.4583e+001	5.3957e+005
At-217	2.3129e-005	8.5578e+005	3.2126e-005	1.1887e+000
Ba-137m	1.8927e-004	7.0030e+006	2.6289e-004	9.7271e+000
Bi-210	1.2176e-009	4.5051e+001	1.6912e-009	6.2575e-005
Bi-211	1.3568e-007	5.0202e+003	1.8846e-007	6.9729e-003
Bi-212	3.9404e-014	1.4580e-003	5.4732e-014	2.0251e-009
Bi-213	2.3129e-005	8.5577e+005	3.2126e-005	1.1887e+000
Bi-214	7.4496e-009	2.7564e+002	1.0347e-008	3.8285e-004
Ce-144	2.8422e-005	1.0516e+006	3.9478e-005	1.4607e+000
Co-60	3.8469e-005	1.4234e+006	5.3433e-005	1.9770e+000
Cs-134	9.6961e-009	3.5875e+002	1.3468e-008	4.9830e-004
Cs-137	2.0007e-004	7.4028e+006	2.7790e-004	1.0282e+001
Eu-154	6.6090e+000	2.4453e+011	9.1798e+000	3.3965e+005
Eu-155	2.8337e+000	1.0485e+011	3.9359e+000	1.4563e+005
Fr-221	2.3129e-005	8.5578e+005	3.2126e-005	1.1887e+000
Fr-223	1.8937e-009	7.0068e+001	2.6303e-009	9.7323e-005
Ni-63	6.9431e-005	2.5690e+006	9.6439e-005	3.5683e+000
Np-237	2.5924e-001	9.5919e+009	3.6008e-001	1.3323e+004
Pa-231	5.4972e-007	2.0340e+004	7.6356e-007	2.8252e-002
Pa-233	2.5924e-001	9.5919e+009	3.6008e-001	1.3323e+004
Pa-234	3.2254e-006	1.1934e+005	4.4800e-006	1.6576e-001
Pa-234m	2.0159e-003	7.4587e+007	2.8000e-003	1.0360e+002

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 DOS File: T24ZIR.MS5
 Run Date: November 25, 1997
 Run Time: 3:16:17 PM
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<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Pb-209	2.3128e-005	8.5575e+005	3.2125e-005	1.1886e+000
Pb-210	1.2214e-009	4.5192e+001	1.6965e-009	6.2771e-005
Pb-211	1.3568e-007	5.0202e+003	1.8846e-007	6.9729e-003
Pb-212	3.9405e-014	1.4580e-003	5.4733e-014	2.0251e-009
Pb-214	7.4497e-009	2.7564e+002	1.0347e-008	3.8286e-004
Pm-147	7.6069e-049	2.8146e-038	1.0566e-048	3.9094e-044
Po-210	1.1178e-009	4.1358e+001	1.5526e-009	5.7446e-005
Po-211	3.7041e-010	1.3705e+001	5.1449e-010	1.9036e-005
Po-212	2.5246e-014	9.3412e-004	3.5067e-014	1.2975e-009
Po-213	2.2629e-005	8.3729e+005	3.1432e-005	1.1630e+000
Po-214	7.4480e-009	2.7558e+002	1.0345e-008	3.8277e-004
Po-215	1.3568e-007	5.0202e+003	1.8846e-007	6.9730e-003
Po-216	3.9411e-014	1.4582e-003	5.4742e-014	2.0255e-009
Po-218	7.4512e-009	2.7569e+002	1.0350e-008	3.8294e-004
Pr-144	2.8423e-005	1.0517e+006	3.9479e-005	1.4607e+000
Pr-144m	4.0644e-007	1.5038e+004	5.6454e-007	2.0888e-002
Pu-238	9.9138e+001	3.6681e+012	1.3770e+002	5.0950e+006
Pu-239	1.2232e+001	4.5260e+011	1.6991e+001	6.2866e+005
Pu-240	2.8740e+000	1.0634e+011	3.9920e+000	1.4770e+005
Pu-241	4.3271e+001	1.6010e+012	6.0103e+001	2.2238e+006
Pu-242	7.9192e-004	2.9301e+007	1.1000e-003	4.0699e+001
Ra-223	1.3568e-007	5.0202e+003	1.8846e-007	6.9730e-003
Ra-224	3.9411e-014	1.4582e-003	5.4742e-014	2.0255e-009
Ra-225	2.3178e-005	8.5757e+005	3.2193e-005	1.1912e+000
Ra-226	7.4641e-009	2.7617e+002	1.0368e-008	3.8360e-004
Ra-228	4.9560e-014	1.8337e-003	6.8838e-014	2.5470e-009
Rh-106	1.2513e-005	4.6299e+005	1.7381e-005	6.4309e-001
Rn-219	1.3568e-007	5.0202e+003	1.8846e-007	6.9730e-003
Rn-220	3.9411e-014	1.4582e-003	5.4742e-014	2.0255e-009
Rn-222	7.4512e-009	2.7570e+002	1.0350e-008	3.8294e-004
Ru-106	1.2513e-005	4.6299e+005	1.7381e-005	6.4309e-001
Sb-125	6.8213e-006	2.5239e+005	9.4747e-006	3.5056e-001
Sm-147	2.8321e-057	1.0479e-046	3.9337e-057	1.4555e-052
Sr-90	3.0891e+003	1.1430e+014	4.2907e+003	1.5875e+008
Tc-99	4.2474e-001	1.5716e+010	5.8996e-001	2.1829e+004
Te-125m	1.6715e-006	6.1847e+004	2.3218e-006	8.5905e-002
Th-227	1.3438e-007	4.9720e+003	1.8665e-007	6.9060e-003
Th-228	3.9464e-014	1.4602e-003	5.4815e-014	2.0281e-009
Th-229	2.3249e-005	8.6022e+005	3.2293e-005	1.1948e+000
Th-230	1.9825e-006	7.3352e+004	2.7537e-006	1.0189e-001
Th-231	1.3681e-003	5.0621e+007	1.9003e-003	7.0312e+001
Th-232	8.1740e-014	3.0244e-003	1.1354e-013	4.2008e-009
Th-234	2.0159e-003	7.4587e+007	2.8000e-003	1.0360e+002
Tl-207	1.3531e-007	5.0064e+003	1.8794e-007	6.9539e-003
Tl-208	1.4158e-014	5.2385e-004	1.9665e-014	7.2761e-010
Tl-209	4.9959e-007	1.8485e+004	6.9392e-007	2.5675e-002
U-233	1.2979e-002	4.8024e+008	1.8028e-002	6.6704e+002
U-234	1.4400e-002	5.3282e+008	2.0002e-002	7.4007e+002
U-235	1.3681e-003	5.0621e+007	1.9003e-003	7.0312e+001
U-236	8.8012e-005	3.2564e+006	1.2225e-004	4.5232e+000
U-237	1.0615e-003	3.9276e+007	1.4744e-003	5.4554e+001
U-238	2.0159e-003	7.4587e+007	2.8000e-003	1.0360e+002
Y-90	3.0898e+003	1.1432e+014	4.2918e+003	1.5879e+008

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 DOS File: T24ZIR.MS5
 Run Date: November 25, 1997
 Run Time: 3:16:17 PM
 Duration: 00:01:33

Buildup
 The material reference is : Source

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Results</u>			
		<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
		<u>MeV/cm²/sec</u>	<u>MeV/cm²/sec</u>	<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.015	9.671e+04	7.100e-215	4.435e-28	6.090e-216	3.804e-29
0.02	8.167e+01	2.018e-101	5.892e-31	6.991e-103	2.041e-32
0.03	1.142e+10	1.354e-28	1.822e-22	1.342e-30	1.806e-24
0.04	6.877e+10	5.704e-11	2.143e-10	2.523e-13	9.480e-13
0.05	1.889e+10	2.870e-05	1.702e-04	7.645e-08	4.534e-07
0.06	1.433e+11	1.615e-01	1.278e+00	3.208e-04	2.538e-03
0.08	3.409e+10	1.056e+01	9.847e+01	1.670e-02	1.558e-01
0.1	1.251e+11	3.705e+02	3.394e+03	5.668e-01	5.193e+00
0.15	1.731e+08	4.284e+00	3.279e+01	7.055e-03	5.399e-02
0.2	1.678e+10	9.768e+02	6.516e+03	1.724e+00	1.150e+01
0.3	4.803e+09	6.876e+02	3.756e+03	1.304e+00	7.125e+00
0.4	2.082e+09	5.222e+02	2.465e+03	1.017e+00	4.803e+00
0.5	5.296e+08	2.021e+02	8.504e+02	3.967e-01	1.669e+00
0.6	1.973e+10	1.056e+04	4.038e+04	2.061e+01	7.883e+01
0.8	9.536e+10	8.683e+04	2.877e+05	1.652e+02	5.472e+02
1.0	7.523e+10	1.034e+05	3.083e+05	1.906e+02	5.683e+02
1.5	9.542e+10	2.759e+05	6.889e+05	4.642e+02	1.159e+03
2.0	1.037e+04	4.993e-02	1.123e-01	7.722e-05	1.737e-04
3.0	5.228e-04	4.988e-09	9.844e-09	6.768e-12	1.336e-11
TOTALS:		7.117e+11	4.795e+05	1.342e+06	8.456e+02
					2.384e+03

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
DOS File: T24SBW.MS5
Run Date: November 25, 1997
Run Time: 3:29:59 PM
Duration: 00:01:35

File Ref: HKP-26
Date: 12/4/97
By: HT/606
Checked: SD/3

Case Title: T-24SBW
Description: R/hr @ 1 m from canister surf., SBW calcine (T-24)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions
Height 262.8 cm ✓ 8 ft 7.5 in
Radius 29.53 cm ✓ 11.6 in

Dose Points
1 X Y Z
 130.48 cm ✓ 131.4 cm 0 cm
 4 ft 3.4 in 4 ft 3.7 in 0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	7.20e+05 cm ³	Concrete	2.6
Shield 1	.95 cm	Iron	7.86
Transition	100.0 cm ✓	Air	0.0011
Air Gap		Air	0.0012

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Ac-225	2.3129e-005	8.5578e+005	3.2126e-005	1.1887e+000
Ac-227	1.3723e-007	5.0774e+003	1.9061e-007	7.0524e-003
Ac-228	4.9556e-014	1.8336e-003	6.8832e-014	2.5468e-009
Am-241	1.0499e+001	3.8846e+011	1.4583e+001	5.3957e+005
At-217	2.3129e-005	8.5578e+005	3.2126e-005	1.1887e+000
Ba-137m	1.8927e-004	7.0030e+006	2.6289e-004	9.7271e+000
Bi-210	1.2176e-009	4.5051e+001	1.6912e-009	6.2575e-005
Bi-211	1.3568e-007	5.0202e+003	1.8846e-007	6.9729e-003
Bi-212	3.9404e-014	1.4580e-003	5.4732e-014	2.0251e-009
Bi-213	2.3129e-005	8.5577e+005	3.2126e-005	1.1887e+000
Bi-214	7.4496e-009	2.7564e+002	1.0347e-008	3.8285e-004
Ce-144	2.8422e-005	1.0516e+006	3.9478e-005	1.4607e+000
Co-60	3.8469e-005	1.4234e+006	5.3433e-005	1.9770e+000
Cs-134	9.6961e-009	3.5875e+002	1.3468e-008	4.9830e-004
Cs-137	2.0007e-004	7.4028e+006	2.7790e-004	1.0282e+001
Eu-154	6.6090e+000	2.4453e+011	9.1798e+000	3.3965e+005
Eu-155	2.8337e+000	1.0485e+011	3.9359e+000	1.4563e+005
Fr-221	2.3129e-005	8.5578e+005	3.2126e-005	1.1887e+000
Fr-223	1.8937e-009	7.0068e+001	2.6303e-009	9.7323e-005
Ni-63	6.9431e-005	2.5690e+006	9.6439e-005	3.5683e+000
Np-237	2.5924e-001	9.5919e+009	3.6008e-001	1.3323e+004
Pa-231	5.4972e-007	2.0340e+004	7.6356e-007	2.8252e-002
Pa-233	2.5924e-001	9.5919e+009	3.6008e-001	1.3323e+004
Pa-234	3.2254e-006	1.1934e+005	4.4800e-006	1.6576e-001
Pa-234m	2.0159e-003	7.4587e+007	2.8000e-003	1.0360e+002

Page : 2
 DOS File: T24SBW.MS5
 Run Date: November 25, 1997
 Run Time: 3:29:59 PM
 Duration: 00:01:35

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Pb-209	2.3128e-005	8.5575e+005	3.2125e-005	1.1886e+000
Pb-210	1.2214e-009	4.5192e+001	1.6965e-009	6.2771e-005
Pb-211	1.3568e-007	5.0202e+003	1.8846e-007	6.9729e-003
Pb-212	3.9405e-014	1.4580e-003	5.4733e-014	2.0251e-009
Pb-214	7.4497e-009	2.7564e+002	1.0347e-008	3.8286e-004
Pm-147	7.6069e-049	2.8146e-038	1.0566e-048	3.9094e-044
Po-210	1.1178e-009	4.1358e+001	1.5526e-009	5.7446e-005
Po-211	3.7041e-010	1.3705e+001	5.1449e-010	1.9036e-005
Po-212	2.5246e-014	9.3412e-004	3.5067e-014	1.2975e-009
Po-213	2.2629e-005	8.3729e+005	3.1432e-005	1.1630e+000
Po-214	7.4480e-009	2.7558e+002	1.0345e-008	3.8277e-004
Po-215	1.3568e-007	5.0202e+003	1.8846e-007	6.9730e-003
Po-216	3.9411e-014	1.4582e-003	5.4742e-014	2.0255e-009
Po-218	7.4512e-009	2.7569e+002	1.0350e-008	3.8294e-004
Pr-144	2.8423e-005	1.0517e+006	3.9479e-005	1.4607e+000
Pr-144m	4.0644e-007	1.5038e+004	5.6454e-007	2.0888e-002
Pu-238	9.9138e+001	3.6681e+012	1.3770e+002	5.0950e+006
Pu-239	1.2232e+001	4.5260e+011	1.6991e+001	6.2866e+005
Pu-240	2.8740e+000	1.0634e+011	3.9920e+000	1.4770e+005
Pu-241	4.3271e+001	1.6010e+012	6.0103e+001	2.2238e+006
Pu-242	7.9192e-004	2.9301e+007	1.1000e-003	4.0699e+001
Ra-223	1.3568e-007	5.0202e+003	1.8846e-007	6.9730e-003
Ra-224	3.9411e-014	1.4582e-003	5.4742e-014	2.0255e-009
Ra-225	2.3178e-005	8.5757e+005	3.2193e-005	1.1912e+000
Ra-226	7.4641e-009	2.7617e+002	1.0368e-008	3.8360e-004
Ra-228	4.9560e-014	1.8337e-003	6.8838e-014	2.5470e-009
Rh-106	1.2513e-005	4.6299e+005	1.7381e-005	6.4309e-001
Rn-219	1.3568e-007	5.0202e+003	1.8846e-007	6.9730e-003
Rn-220	3.9411e-014	1.4582e-003	5.4742e-014	2.0255e-009
Rn-222	7.4512e-009	2.7570e+002	1.0350e-008	3.8294e-004
Ru-106	1.2513e-005	4.6299e+005	1.7381e-005	6.4309e-001
Sb-125	6.8213e-006	2.5239e+005	9.4747e-006	3.5056e-001
Sm-147	2.8321e-057	1.0479e-046	3.9337e-057	1.4555e-052
Sr-90	3.0891e+003	1.1430e+014	4.2907e+003	1.5875e+008
Tc-99	4.2474e-001	1.5716e+010	5.8996e-001	2.1829e+004
Te-125m	1.6715e-006	6.1847e+004	2.3218e-006	8.5905e-002
Th-227	1.3438e-007	4.9720e+003	1.8665e-007	6.9060e-003
Th-228	3.9464e-014	1.4602e-003	5.4815e-014	2.0281e-009
Th-229	2.3249e-005	8.6022e+005	3.2293e-005	1.1948e+000
Th-230	1.9825e-006	7.3352e+004	2.7537e-006	1.0189e-001
Th-231	1.3681e-003	5.0621e+007	1.9003e-003	7.0312e+001
Th-232	8.1740e-014	3.0244e-003	1.1354e-013	4.2008e-009
Th-234	2.0159e-003	7.4587e+007	2.8000e-003	1.0360e+002
Tl-207	1.3531e-007	5.0064e+003	1.8794e-007	6.9539e-003
Tl-208	1.4158e-014	5.2385e-004	1.9665e-014	7.2761e-010
Tl-209	4.9959e-007	1.8485e+004	6.9392e-007	2.5675e-002
U-233	1.2979e-002	4.8024e+008	1.8028e-002	6.6704e+002
U-234	1.4400e-002	5.3282e+008	2.0002e-002	7.4007e+002
U-235	1.3681e-003	5.0621e+007	1.9003e-003	7.0312e+001
U-236	8.8012e-005	3.2564e+006	1.2225e-004	4.5232e+000
U-237	1.0615e-003	3.9276e+007	1.4744e-003	5.4554e+001
U-238	2.0159e-003	7.4587e+007	2.8000e-003	1.0360e+002
Y-90	3.0898e+003	1.1432e+014	4.2918e+003	1.5879e+008

Page : 3
 DOS File: T24SBW.MS5
 Run Date: November 25, 1997
 Run Time: 3:29:59 PM
 Duration: 00:01:35

Buildup
The material reference is : Transition

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Results</u>		<u>Exposure Rate</u>	
		<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
		<u>MeV/cm²/sec</u>	<u>MeV/cm²/sec</u>	<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.015	9.671e+04	2.045e-191	8.790e-29	1.754e-192	7.540e-30
0.02	8.167e+01	2.266e-92	2.106e-31	7.850e-94	7.296e-33
0.03	1.142e+10	5.538e-27	5.583e-22	5.488e-29	5.533e-24
0.04	6.877e+10	5.375e-11	6.110e-09	2.377e-13	2.702e-11
0.05	1.889e+10	9.336e-06	1.544e-03	2.487e-08	4.112e-06
0.06	1.433e+11	3.771e-02	5.650e+00	7.490e-05	1.122e-02
0.08	3.409e+10	2.118e+00	1.707e+02	3.352e-03	2.702e-01
0.1	1.251e+11	7.232e+01	3.235e+03	1.106e-01	4.949e+00
0.15	1.731e+08	8.104e-01	1.500e+01	1.334e-03	2.471e-02
0.2	1.678e+10	1.812e+02	2.174e+03	3.198e-01	3.837e+00
0.3	4.803e+09	1.249e+02	9.552e+02	2.369e-01	1.812e+00
0.4	2.082e+09	9.370e+01	5.534e+02	1.826e-01	1.078e+00
0.5	5.296e+08	3.593e+01	1.780e+02	7.052e-02	3.493e-01
0.6	1.973e+10	1.863e+03	8.075e+03	3.635e+00	1.576e+01
0.8	9.536e+10	1.512e+04	5.415e+04	2.876e+01	1.030e+02
1.0	7.523e+10	1.782e+04	5.601e+04	3.285e+01	1.032e+02
1.5	9.542e+10	4.662e+04	1.190e+05	7.843e+01	2.002e+02
2.0	1.037e+04	8.327e-03	1.885e-02	1.288e-05	2.914e-05
3.0	5.228e-04	8.188e-10	1.601e-09	1.111e-12	2.172e-12
TOTALS:	7.117e+11	8.194e+04	2.445e+05	1.446e+02	4.345e+02

MicroShield v5.01 (5.01-00121)
 Lockheed Martin Idaho Technologies Company
 Case File Heat Generation
 Case File: T25ALUM.MS5
 Case Title: T25Alum

<u>Isotope</u>	<u>Activity</u> <u>Curies</u>	<u>Activity</u> <u>Becquerels</u>	<u>Heat Generation</u> <u>Watts/Curie</u>	<u>Heat Generation</u> <u>Watts</u>
Am-241	1.3878e-003	5.1348e+007	3.2813e-002	4.5537e-005
Am-243	4.9106e-008	1.8169e+003	3.1704e-002	1.5569e-009
Ba-137m	6.7681e-001	2.5042e+010	3.9212e-003	2.6539e-003
Ce-144	4.5903e-019	1.6984e-008	6.6284e-004	3.0427e-022
Cm-242	3.8431e-008	1.4219e+003	3.6240e-002	1.3927e-009
Cm-244	7.6861e-008	2.8439e+003	3.4409e-002	2.6447e-009
Cs-134	3.7363e-009	1.3824e+002	1.0179e-002	3.8033e-011
Cs-137	7.1524e-001	2.6464e+010	1.0122e-003	7.2400e-004
Eu-154	4.1633e-003	1.5404e+008	9.0517e-003	3.7685e-005
Eu-155	2.4553e-004	9.0846e+006	7.2543e-004	1.7811e-007
Np-237	9.1807e-016	3.3968e-005	2.8779e-002	2.6421e-017
Pa-233	1.0248e-003	3.7918e+007	2.4276e-003	2.4878e-006
Pm-147	3.3093e-005	1.2244e+006	3.6731e-004	1.2156e-008
Pr-144	4.5903e-019	1.6984e-008	7.3455e-003	3.3718e-021
Pu-238	4.8038e-022	1.7774e-011	3.2587e-002	1.5654e-023
Pu-239	6.0849e-023	2.2514e-012	3.0551e-002	1.8590e-024
Pu-240	2.4553e-023	9.0846e-013	3.0614e-002	7.5167e-025
Pu-241	2.1350e-022	7.8996e-012	3.1003e-005	6.6193e-027
Pu-242	1.8148e-027	6.7147e-017	2.9184e-002	5.2963e-029
Rh-106	5.0173e-014	1.8564e-003	9.5998e-003	4.8165e-016
Ru-106	5.0173e-014	1.8564e-003	5.9459e-005	2.9833e-018
Sb-125	1.0675e-004	3.9498e+006	3.1431e-003	3.3553e-007
Sm-151	7.8996e-001	2.9229e+010	1.1729e-004	9.2653e-005
Sr-90	2.8823e-007	1.0665e+004	1.1607e-003	3.3456e-010
Tc-99	2.7756e-001	1.0270e+010	5.0152e-004	1.3920e-004
Th-230	9.7144e-005	3.5943e+006	2.7809e-002	2.7015e-006
Th-231	1.7080e-005	6.3197e+005	1.0580e-003	1.8070e-008
U-232	1.6013e-031	5.9247e-021	3.1553e-002	5.0526e-033
U-233	1.7080e-031	6.3197e-021	2.8557e-002	4.8776e-033
U-234	3.6296e-027	1.3429e-016	2.8311e-002	1.0276e-028
U-235	2.4553e-029	9.0846e-019	2.7115e-002	6.6576e-031
U-236	5.7646e-029	2.1329e-018	2.6697e-002	1.5390e-030
U-237	5.1241e-030	1.8959e-019	1.9366e-003	9.9233e-033
U-238	1.3878e-030	5.1348e-020	2.4920e-002	3.4584e-032
Y-90	2.8823e-007	1.0665e+004	5.5411e-003	1.5971e-009

Total

Heat Generation:

3.6987e-003

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
 DOS File: T25ALUM.MS5
 Run Date: November 20, 1997
 Run Time: 5:48:50 AM
 Duration: 00:01:27

File Ref: HKP-26-
 Date: 12/14/97
 By: JH/MS
 Checked: JH/MS

Case Title: T25Alum

Description: R/hr @ 1 cm from culvert with Alum. Grout from PP Sep. (T25)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions

Height 162.56 cm / 5 ft 4.0 in
 Radius 45.72 cm / 1 ft 6.0 in

Dose Points

	<u>X</u>	<u>Y</u>	<u>Z</u>
# 1	56.88 cm /	81.28 cm	0 cm
	1 ft 10.4 in	2 ft 8.0 in	0.0 in

Shields

<u>Shield Name</u>	<u>Dimension</u>	<u>Material</u>	<u>Density</u>
Source	1.07e+06 cm ³	Concrete	1.8
Shield 1	10.16 cm	Concrete	2.35
Transition	1.0 cm	Air	0.0011
Air Gap		Air	0.00122

Source Input

Grouping Method : Standard Indices

Number of Groups : 25

Lower Energy Cutoff : 0.015

Photons < 0.015 : Excluded

Library : Grove

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Am-241	1.3878e-003	5.1348e+007	1.3000e-003 /	4.8100e+001
Am-243	4.9106e-008	1.8169e+003	4.6000e-008 /	1.7020e-003
Ba-137m	6.7681e-001	2.5042e+010	6.3400e-001 /	2.3458e+004
Ce-144	4.5903e-019	1.6984e-008	4.3000e-019 /	1.5910e-014
Cm-242	3.8431e-008	1.4219e+003	3.6000e-008 /	1.3320e-003
Cm-244	7.6861e-008	2.8439e+003	7.2000e-008 /	2.6640e-003
Cs-134	3.7363e-009	1.3824e+002	3.5000e-009 /	1.2950e-004
Cs-137	7.1524e-001	2.6464e+010	6.7000e-001 /	2.4790e+004
Eu-154	4.1633e-003	1.5404e+008	3.9000e-003 /	1.4430e+002
Eu-155	2.4553e-004	9.0846e+006	2.3000e-004 /	8.5100e+000
Np-237	9.1807e-016	3.3968e-005	8.6000e-016 /	3.1820e-011
Pa-233	1.0248e-003	3.7918e+007	9.6000e-004 /	3.5520e+001
Pm-147	3.3093e-005	1.2244e+006	3.1000e-005 /	1.1470e+000
Pr-144	4.5903e-019	1.6984e-008	4.3000e-019	1.5910e-014
Pu-238	4.8038e-022	1.7774e-011	4.5000e-022 /	1.6650e-017
Pu-239	6.0849e-023	2.2514e-012	5.7000e-023 /	2.1090e-018
Pu-240	2.4553e-023	9.0846e-013	2.3000e-023 /	8.5100e-019
Pu-241	2.1350e-022	7.8996e-012	2.0000e-022 /	7.4000e-018
Pu-242	1.8148e-027	6.7147e-017	1.7000e-027 /	6.2900e-023
Rh-106	5.0173e-014	1.8564e-003	4.7000e-014	1.7390e-009
Ru-106	5.0173e-014	1.8564e-003	4.7000e-014 /	1.7390e-009
Sb-125	1.0675e-004	3.9498e+006	1.0000e-004 /	3.7000e+000
Sm-151	7.8996e-001	2.9229e+010	7.4000e-001 /	2.7380e+004
Sr-90	2.8823e-007	1.0665e+004	2.7000e-007 /	9.9900e-003
Tc-99	2.7756e-001	1.0270e+010	2.6000e-001 /	9.6200e+003

Page : 2
 DOS File: T25ALUM.MS5
 Run Date: November 20, 1997
 Run Time: 5:48:50 AM
 Duration: 00:01:27

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Th-230	9.7144e-005	3.5943e+006	9.1000e-005	3.3670e+000
Th-231	1.7080e-005	6.3197e+005	1.6000e-005	5.9200e-001
U-232	1.6013e-031	5.9247e-021	1.5000e-031	5.5500e-027
U-233	1.7080e-031	6.3197e-021	1.6000e-031	5.9200e-027
U-234	3.6296e-027	1.3429e-016	3.4000e-027	1.2580e-022
U-235	2.4553e-029	9.0846e-019	2.3000e-029	8.5100e-025
U-236	5.7646e-029	2.1329e-018	5.4000e-029	1.9980e-024
U-237	5.1241e-030	1.8959e-019	4.8000e-030	1.7760e-025
U-238	1.3878e-030	5.1348e-020	1.3000e-030	4.8100e-026
Y-90	2.8823e-007	1.0665e+004	2.7000e-007	9.9900e-003

Buildup

The material reference is : Source

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

Results

<u>Energy</u>	<u>Activity</u>	<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
<u>MeV</u>	<u>photons/sec</u>	<u>MeV/cm²/sec</u>	<u>MeV/cm²/sec</u>	<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.015	1.189e+03	5.759e-93	3.429e-30	4.939e-94	2.941e-31
0.02	8.642e+06	6.478e-41	3.922e-26	2.244e-42	1.359e-27
0.03	1.478e+09	4.174e-13	8.070e-13	4.137e-15	7.998e-15
0.04	3.812e+08	5.103e-07	1.535e-06	2.257e-09	6.789e-09
0.05	8.499e+06	4.160e-06	1.924e-05	1.108e-08	5.125e-08
0.06	1.866e+07	1.579e-04	1.045e-03	3.136e-07	2.076e-06
0.08	4.132e+06	4.815e-04	4.961e-03	7.620e-07	7.851e-06
0.1	7.847e+07	3.083e-02	4.057e-01	4.716e-05	6.207e-04
0.15	1.336e+04	2.276e-05	3.511e-04	3.749e-08	5.781e-07
0.2	1.082e+07	4.213e-02	6.220e-01	7.437e-05	1.098e-03
0.3	1.900e+07	2.173e-01	2.615e+00	4.122e-04	4.961e-03
0.4	3.668e+06	8.823e-02	8.709e-01	1.719e-04	1.697e-03
0.5	7.425e+05	3.160e-02	2.630e-01	6.203e-05	5.162e-04
0.6	2.255e+10	1.523e+03	1.098e+04	2.973e+00	2.143e+01
0.8	6.007e+07	8.363e+00	4.824e+01	1.591e-02	9.175e-02
1.0	4.739e+07	1.150e+01	5.609e+01	2.119e-02	1.034e-01
1.5	6.011e+07	3.920e+01	1.445e+02	6.596e-02	2.432e-01
2.0	1.315e-10	1.674e-16	5.219e-16	2.588e-19	8.070e-19
TOTALS:	2.473e+10	1.583e+03	1.123e+04	3.077e+00	2.188e+01

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
 DOS File: T25ALUM.MS5
 Run Date: November 20, 1997
 Run Time: 5:53:09 AM
 Duration: 00:01:34

File Ref: HKP-26-
 Date: 12/4/97
 By: [Signature]
 Checked: [Signature]

Case Title: T25Alum

Description: R/hr @ 1 m from culvert with Alum. Grout from PP Sep. (T25)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions

Height	162.56 cm	5 ft 4.0 in
Radius	45.72 cm	1 ft 6.0 in

Dose Points

	<u>X</u>	<u>Y</u>	<u>Z</u>
# 1	155.88 cm	81.28 cm	0 cm
	5 ft 1.4 in	2 ft 8.0 in	0.0 in

Shields

<u>Shield Name</u>	<u>Dimension</u>	<u>Material</u>	<u>Densit</u>
Source	1.07e+06 cm ³	Concrete	1.8
Shield 1	10.16 cm	Concrete	2.35
Transition	100.0 cm	Air	0.0011
Air Gap		Air	0.0011

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded

Library : Grove

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Am-241	1.3878e-003	5.1348e+007	1.3000e-003	4.8100e+001
Am-243	4.9106e-008	1.8169e+003	4.6000e-008	1.7020e-003
Ba-137m	6.7681e-001	2.5042e+010	6.3400e-001	2.3458e+004
Ce-144	4.5903e-019	1.6984e-008	4.3000e-019	1.5910e-014
Cm-242	3.8431e-008	1.4219e+003	3.6000e-008	1.3320e-003
Cm-244	7.6861e-008	2.8439e+003	7.2000e-008	2.6640e-003
Cs-134	3.7363e-009	1.3824e+002	3.5000e-009	1.2950e-004
Cs-137	7.1524e-001	2.6464e+010	6.7000e-001	2.4790e+004
Eu-154	4.1633e-003	1.5404e+008	3.9000e-003	1.4430e+002
Eu-155	2.4553e-004	9.0846e+006	2.3000e-004	8.5100e+000
Np-237	9.1807e-016	3.3968e-005	8.6000e-016	3.1820e-011
Pa-233	1.0248e-003	3.7918e+007	9.6000e-004	3.5520e+001
Pm-147	3.3093e-005	1.2244e+006	3.1000e-005	1.1470e+000
Pr-144	4.5903e-019	1.6984e-008	4.3000e-019	1.5910e-014
Pu-238	4.8038e-022	1.7774e-011	4.5000e-022	1.6650e-017
Pu-239	6.0849e-023	2.2514e-012	5.7000e-023	2.1090e-018
Pu-240	2.4553e-023	9.0846e-013	2.3000e-023	8.5100e-019
Pu-241	2.1350e-022	7.8996e-012	2.0000e-022	7.4000e-018
Pu-242	1.8148e-027	6.7147e-017	1.7000e-027	6.2900e-023
Rh-106	5.0173e-014	1.8564e-003	4.7000e-014	1.7390e-009
Ru-106	5.0173e-014	1.8564e-003	4.7000e-014	1.7390e-009
Sb-125	1.0675e-004	3.9498e+006	1.0000e-004	3.7000e+000
Sm-151	7.8996e-001	2.9229e+010	7.4000e-001	2.7380e+004
Sr-90	2.8823e-007	1.0665e+004	2.7000e-007	9.9900e-003
Tc-99	2.7756e-001	1.0270e+010	2.6000e-001	9.6200e+003

Page : 2
 DOS File: T25ALUM.MS5
 Run Date: November 20, 1997
 Run Time: 5:53:09 AM
 Duration: 00:01:34

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Th-230	9.7144e-005	3.5943e+006	9.1000e-005	3.3670e+000
Th-231	1.7080e-005	6.3197e+005	1.6000e-005	5.9200e-001
U-232	1.6013e-031	5.9247e-021	1.5000e-031	5.5500e-027
U-233	1.7080e-031	6.3197e-021	1.6000e-031	5.9200e-027
U-234	3.6296e-027	1.3429e-016	3.4000e-027	1.2580e-022
U-235	2.4553e-029	9.0846e-019	2.3000e-029	8.5100e-025
U-236	5.7646e-029	2.1329e-018	5.4000e-029	1.9980e-024
U-237	5.1241e-030	1.8959e-019	4.8000e-030	1.7760e-025
U-238	1.3878e-030	5.1348e-020	1.3000e-030	4.8100e-026
Y-90	2.8823e-007	1.0665e+004	2.7000e-007	9.9900e-003

Buildup
 The material reference is : Transition

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Results</u>			
		<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
		<u>MeV/cm²/sec</u>	<u>MeV/cm²/sec</u>	<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.015	1.189e+03	1.170e-93	9.093e-31	1.004e-94	7.799e-32
0.02	8.642e+06	1.778e-41	1.876e-26	6.160e-43	6.497e-28
0.03	1.478e+09	1.534e-13	3.212e-12	1.520e-15	3.183e-14
0.04	3.812e+08	1.763e-07	8.977e-06	7.799e-10	3.970e-08
0.05	8.499e+06	1.402e-06	1.171e-04	3.736e-09	3.120e-07
0.06	1.866e+07	5.194e-05	5.190e-03	1.032e-07	1.031e-05
0.08	4.132e+06	1.523e-04	1.472e-02	2.410e-07	2.330e-05
0.1	7.847e+07	9.512e-03	7.714e-01	1.455e-05	1.180e-03
0.15	1.336e+04	6.796e-06	3.417e-04	1.119e-08	5.628e-07
0.2	1.082e+07	1.233e-02	4.220e-01	2.176e-05	7.447e-04
0.3	1.900e+07	6.181e-02	1.231e+00	1.172e-04	2.336e-03
0.4	3.668e+06	2.455e-02	3.391e-01	4.783e-05	6.608e-04
0.5	7.425e+05	8.631e-03	9.152e-02	1.694e-05	1.796e-04
0.6	2.255e+10	4.093e+02	3.533e+03	7.990e-01	6.896e+00
0.8	6.007e+07	2.187e+00	1.404e+01	4.160e-03	2.670e-02
1.0	4.739e+07	2.939e+00	1.530e+01	5.417e-03	2.820e-02
1.5	6.011e+07	9.583e+00	3.589e+01	1.612e-02	6.038e-02
2.0	1.315e-10	3.961e-17	1.224e-16	6.125e-20	1.893e-19
TOTALS:	2.473e+10	4.242e+02	3.601e+03	8.249e-01	7.017e+00

MicroShield v5.01 (5.01-00121)
 Lockheed Martin Idaho Technologies Company
 Case File Heat Generation
 Case File: T25ZIR.MS5
 Case Title: T25Zir

<u>Isotope</u>	<u>Activity</u> <u>Curies</u>	<u>Activity</u> <u>Bequerels</u>	<u>Heat Generation</u> <u>Watts/Curie</u>	<u>Heat Generation</u> <u>Watts</u>
Am-241	8.5402e-003	3.1599e+008	3.2813e-002	2.8023e-004
Am-242	0.0000e+000	0.0000e+000	1.1352e-003	0.0000e+000
Am-243	1.4945e-010	5.5298e+000	3.1704e-002	4.7383e-012
Ba-137m	3.7363e-001	1.3824e+010	3.9212e-003	1.4651e-003
Ce-144	1.2810e-011	4.7398e-001	6.6284e-004	8.4912e-015
Cm-242	1.8148e-009	6.7147e+001	3.6240e-002	6.5768e-011
Cm-244	3.2026e-010	1.1849e+001	3.4409e-002	1.1020e-011
Co-60	0.0000e+000	0.0000e+000	1.5423e-002	0.0000e+000
Cs-134	1.1743e-006	4.3448e+004	1.0179e-002	1.1953e-008
Cs-137	3.9498e-001	1.4614e+010	1.0122e-003	3.9982e-004
Eu-154	1.9215e-002	7.1097e+008	9.0517e-003	1.7393e-004
Eu-155	2.7756e-005	1.0270e+006	7.2543e-004	2.0135e-008
Np-237	1.3878e-016	5.1348e-006	2.8779e-002	3.9939e-018
Pa-233	1.4945e-004	5.5298e+006	2.4276e-003	3.6281e-007
Pm-147	2.9891e-003	1.1060e+008	3.6731e-004	1.0979e-006
Pr-144	1.2810e-011	4.7398e-001	7.3455e-003	9.4098e-014
Pu-238	7.3659e-021	2.7254e-010	3.2587e-002	2.4003e-022
Pu-239	1.1743e-022	4.3448e-012	3.0551e-002	3.5875e-024
Pu-240	1.0675e-022	3.9498e-012	3.0614e-002	3.2682e-024
Pu-241	3.4161e-021	1.2639e-010	3.1003e-005	1.0591e-025
Pu-242	2.4553e-025	9.0846e-015	2.9184e-002	7.1656e-027
Rh-106	2.2418e-008	8.2946e+002	9.5998e-003	2.1521e-010
Ru-106	2.2418e-008	8.2946e+002	5.9459e-005	1.3329e-012
Sb-125	7.1524e-003	2.6464e+008	3.1431e-003	2.2481e-005
Sm-151	4.8038e-001	1.7774e+010	1.1729e-004	5.6343e-005
Sr-90	7.3659e-007	2.7254e+004	1.1607e-003	8.5498e-010
Tc-99	9.2874e-002	3.4363e+009	5.0152e-004	4.6578e-005
Th-230	1.0675e-006	3.9498e+004	2.7809e-002	2.9687e-008
Th-231	2.8823e-005	1.0665e+006	1.0580e-003	3.0494e-008
U-232	3.5228e-031	1.3034e-020	3.1553e-002	1.1116e-032
U-233	2.2418e-032	8.2946e-022	2.8557e-002	6.4018e-034
U-234	5.6579e-027	2.0934e-016	2.8311e-002	1.6018e-028
U-235	3.5228e-029	1.3034e-018	2.7115e-002	9.5522e-031
U-236	9.3942e-029	3.4758e-018	2.6697e-002	2.5080e-030
U-237	8.0064e-029	2.9624e-018	1.9366e-003	1.5505e-031
U-238	1.7080e-030	6.3197e-020	2.4920e-002	4.2564e-032
Y-90	7.3659e-007	2.7254e+004	5.5411e-003	4.0815e-009

Total Heat Generation: 2.4460e-003 ✓

Handwritten signature

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
 DOS File: T25ZIR.MS5
 Run Date: November 26, 1997
 Run Time: 8:16:07 AM
 Duration: 00:01:27

File Ref: HKP-26-9
 Date: 12/4/97
 By: AKK/Johnson
 Checked: SA/Sm

Case Title: T25Zir

Description: R/hr @ 1 cm from culvert with Zir. Grout from PP Sep. (T25)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions

Height	162.56 cm	5 ft 4.0 in
Radius	45.72 cm	1 ft 6.0 in ✓

Dose Points

	<u>X</u>	<u>Y</u>	<u>Z</u>
# 1	56.88 cm ✓	81.28 cm	0 cm
	1 ft 10.4 in	2 ft 8.0 in	0.0 in

Shields

<u>Shield Name</u>	<u>Dimension</u>	<u>Material</u>	<u>Density</u>
Source	1.07e+06 cm ³	Concrete	1.8
Shield 1	10.16 cm	Concrete	2.35
Transition	1.0 cm	Air	0.0011
Air Gap		Air	0.00122

Source Input

Grouping Method : Standard Indices

Number of Groups : 25

Lower Energy Cutoff : 0.015

Photons < 0.015 : Excluded

Library : Grove

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Am-241	8.5402e-003	3.1599e+008	8.0000e-003 ✓	2.9600e+002
Am-242				
Am-243	1.4945e-010	5.5298e+000	1.4000e-010 ✓	5.1800e-006
Ba-137m	3.7363e-001	1.3824e+010	3.5000e-001 ✓	1.2950e+004
Ce-144	1.2810e-011	4.7398e-001	1.2000e-011 ✓	4.4400e-007
Cm-242	1.8148e-009	6.7147e+001	1.7000e-009 ✓	6.2900e-005
Cm-244	3.2026e-010	1.1849e+001	3.0000e-010 ✓	1.1100e-005
Co-60				
Cs-134	1.1743e-006	4.3448e+004	1.1000e-006 ✓	4.0700e-002
Cs-137	3.9498e-001	1.4614e+010	3.7000e-001 ✓	1.3690e+004
Eu-154	1.9215e-002	7.1097e+008	1.8000e-002 ✓	6.6600e+002
Eu-155	2.7756e-005	1.0270e+006	2.6000e-005 ✓	9.6200e-001
Np-237	1.3878e-016	5.1348e-006	1.3000e-016 ✓	4.8100e-012
Pa-233	1.4945e-004	5.5298e+006	1.4000e-004 ✓	5.1800e+000
Pm-147	2.9891e-003	1.1060e+008	2.8000e-003 ✓	1.0360e+002
Pr-144	1.2810e-011	4.7398e-001	1.2000e-011 ✓	4.4400e-007
Pu-238	7.3659e-021	2.7254e-010	6.9000e-021 ✓	2.5530e-016
Pu-239	1.1743e-022	4.3448e-012	1.1000e-022 ✓	4.0700e-018
Pu-240	1.0675e-022	3.9498e-012	1.0000e-022 ✓	3.7000e-018
Pu-241	3.4161e-021	1.2639e-010	3.2000e-021 ✓	1.1840e-016
Pu-242	2.4553e-025	9.0846e-015	2.3000e-025 ✓	8.5100e-021
Rh-106	2.2418e-008	8.2946e+002	2.1000e-008 ✓	7.7700e-004
Ru-106	2.2418e-008	8.2946e+002	2.1000e-008 ✓	7.7700e-004
Sb-125	7.1524e-003	2.6464e+008	6.7000e-003 ✓	2.4790e+002
Sm-151	4.8038e-001	1.7774e+010	4.5000e-001 ✓	1.6650e+004

Page : 2
 LOS File: T25ZIR.MS5
 Run Date: November 26, 1997
 Run Time: 8:16:07 AM
 Duration: 00:01:27

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Sr-90	7.3659e-007	2.7254e+004	6.9000e-007	2.5530e-002
Tc-99	9.2874e-002	3.4363e+009	8.7000e-002	3.2190e+003
Th-230	1.0675e-006	3.9498e+004	1.0000e-006	3.7000e-002
Th-231	2.8823e-005	1.0665e+006	2.7000e-005	9.9900e-001
U-232	3.5228e-031	1.3034e-020	3.3000e-031	1.2210e-026
U-233	2.2418e-032	8.2946e-022	2.1000e-032	7.7700e-028
U-234	5.6579e-027	2.0934e-016	5.3000e-027	1.9610e-022
U-235	3.5228e-029	1.3034e-018	3.3000e-029	1.2210e-024
U-236	9.3942e-029	3.4758e-018	8.8000e-029	3.2560e-024
U-237	8.0064e-029	2.9624e-018	7.5000e-029	2.7750e-024
U-238	1.7080e-030	6.3197e-020	1.6000e-030	5.9200e-026
Y-90	7.3659e-007	2.7254e+004	6.9000e-007	2.5530e-002

Buildup
 The material reference is : Source

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Fluence Rate</u> <u>MeV/cm²/sec</u> <u>No Buildup</u>	<u>Results</u>		<u>Exposure Rate</u> <u>mR/hr</u> <u>No Buildup</u>	<u>Exposure Rate</u> <u>mR/hr</u> <u>With Buildup</u>
			<u>Fluence Rate</u> <u>MeV/cm²/sec</u> <u>With Buildup</u>			
0.015	2.006e+03	9.718e-93	5.786e-30	8.335e-94	4.963e-31	
0.02	5.255e+06	3.939e-41	2.385e-26	1.364e-42	8.262e-28	
0.03	9.412e+08	2.658e-13	5.139e-13	2.634e-15	5.093e-15	
0.04	3.481e+08	4.659e-07	1.401e-06	2.060e-09	6.198e-09	
0.05	3.681e+07	1.802e-05	8.333e-05	4.800e-08	2.220e-07	
0.06	1.140e+08	9.647e-04	6.388e-03	1.916e-06	1.269e-05	
0.08	6.078e+05	7.083e-05	7.298e-04	1.121e-07	1.155e-06	
0.1	2.907e+08	1.142e-01	1.503e+00	1.747e-04	2.299e-03	
0.15	6.659e+05	1.134e-03	1.749e-02	1.868e-06	2.881e-05	
0.2	6.864e+07	2.673e-01	3.946e+00	4.718e-04	6.964e-03	
0.3	3.872e+06	4.429e-02	5.330e-01	8.401e-05	1.011e-03	
0.4	8.812e+07	2.120e+00	2.093e+01	4.131e-03	4.077e-02	
0.5	2.894e+07	1.232e+00	1.025e+01	2.418e-03	2.012e-02	
0.6	1.259e+10	8.506e+02	6.131e+03	1.660e+00	1.197e+01	
0.8	2.773e+08	3.861e+01	2.227e+02	7.343e-02	4.235e-01	
1.0	2.187e+08	5.306e+01	2.589e+02	9.781e-02	4.772e-01	
1.5	2.774e+08	1.809e+02	6.671e+02	3.044e-01	1.122e+00	
2.0	3.669e-03	4.671e-09	1.456e-08	7.223e-12	2.252e-11	
TOTALS:	1.529e+10	1.127e+03	7.317e+03	2.143e+00	1.406e+01	

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
S File: T25ZIR.MS5
Run Date: November 26, 1997
Run Time: 8:12:24 AM
Duration: 00:01:26

File Ref: HKP-26-97
Date: 12/14/97
By: J. H. H. H. H.
Checked: J. H. H. H. H.

Case Title: T25Zir

Description: R/hr @ 1 m from culvert with Zir. Grout from PP Sep. (T25)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions
Height 162.56 cm 5 ft 4.0 in
Radius 45.72 cm 1 ft 6.0 in

Dose Points
1 X 155.88 cm 81.28 cm Z 0 cm
5 ft 1.4 in 2 ft 8.0 in 0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	1.07e+06 cm ³	Concrete	1.8
Shield 1	10.16 cm	Concrete	2.35
Transition	100.0 cm	Air	0.0011
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Am-241	8.5402e-003	3.1599e+008	8.0000e-003	2.9600e+002
Am-242				
Am-243	1.4945e-010	5.5298e+000	1.4000e-010	5.1800e-006
Ba-137m	3.7363e-001	1.3824e+010	3.5000e-001	1.2950e+004
Ce-144	1.2810e-011	4.7398e-001	1.2000e-011	4.4400e-007
Cm-242	1.8148e-009	6.7147e+001	1.7000e-009	6.2900e-005
Cm-244	3.2026e-010	1.1849e+001	3.0000e-010	1.1100e-005
Co-60				
Cs-134	1.1743e-006	4.3448e+004	1.1000e-006	4.0700e-002
Cs-137	3.9498e-001	1.4614e+010	3.7000e-001	1.3690e+004
Eu-154	1.9215e-002	7.1097e+008	1.8000e-002	6.6600e+002
Eu-155	2.7756e-005	1.0270e+006	2.6000e-005	9.6200e-001
Np-237	1.3878e-016	5.1348e-006	1.3000e-016	4.8100e-012
Pa-233	1.4945e-004	5.5298e+006	1.4000e-004	5.1800e+000
Pm-147	2.9891e-003	1.1060e+008	2.8000e-003	1.0360e+002
Pr-144	1.2810e-011	4.7398e-001	1.2000e-011	4.4400e-007
Pu-238	7.3659e-021	2.7254e-010	6.9000e-021	2.5530e-016
Pu-239	1.1743e-022	4.3448e-012	1.1000e-022	4.0700e-018
Pu-240	1.0675e-022	3.9498e-012	1.0000e-022	3.7000e-018
Pu-241	3.4161e-021	1.2639e-010	3.2000e-021	1.1840e-016
Pu-242	2.4553e-025	9.0846e-015	2.3000e-025	8.5100e-021
Rh-106	2.2418e-008	8.2946e+002	2.1000e-008	7.7700e-004
Ru-106	2.2418e-008	8.2946e+002	2.1000e-008	7.7700e-004
Sb-125	7.1524e-003	2.6464e+008	6.7000e-003	2.4790e+002
Sm-151	4.8038e-001	1.7774e+010	4.5000e-001	1.6650e+004

Page : 2
 DOS File: T25ZIR.MS5
 Run Date: November 26, 1997
 Run Time: 8:12:24 AM
 Duration: 00:01:26

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Sr-90	7.3659e-007	2.7254e+004	6.9000e-007	2.5530e-002
Tc-99	9.2874e-002	3.4363e+009	8.7000e-002	3.2190e+003
Th-230	1.0675e-006	3.9498e+004	1.0000e-006	3.7000e-002
Th-231	2.8823e-005	1.0665e+006	2.7000e-005	9.9900e-001
U-232	3.5228e-031	1.3034e-020	3.3000e-031	1.2210e-026
U-233	2.2418e-032	8.2946e-022	2.1000e-032	7.7700e-028
U-234	5.6579e-027	2.0934e-016	5.3000e-027	1.9610e-022
U-235	3.5228e-029	1.3034e-018	3.3000e-029	1.2210e-024
U-236	9.3942e-029	3.4758e-018	8.8000e-029	3.2560e-024
U-237	8.0064e-029	2.9624e-018	7.5000e-029	2.7750e-024
U-238	1.7080e-030	6.3197e-020	1.6000e-030	5.9200e-026
Y-90	7.3659e-007	2.7254e+004	6.9000e-007	2.5530e-002

Buildup
 The material reference is : Transition

Integration Parameters	
Radial	23
Circumferential	23
Y Direction (axial)	23

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	Results			
		<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
		<u>MeV/cm²/sec</u> <u>No Buildup</u>	<u>MeV/cm²/sec</u> <u>With Buildup</u>	<u>mR/hr</u> <u>No Buildup</u>	<u>mR/hr</u> <u>With Buildup</u>
0.015	2.006e+03	1.975e-93	1.534e-30	1.694e-94	1.316e-31
0.02	5.255e+06	1.081e-41	1.141e-26	3.746e-43	3.951e-28
0.03	9.412e+08	9.765e-14	2.045e-12	9.678e-16	2.027e-14
0.04	3.481e+08	1.610e-07	8.196e-06	7.120e-10	3.625e-08
0.05	3.681e+07	6.075e-06	5.073e-04	1.618e-08	1.352e-06
0.06	1.140e+08	3.174e-04	3.171e-02	6.304e-07	6.299e-05
0.08	6.078e+05	2.240e-05	2.166e-03	3.544e-08	3.427e-06
0.1	2.907e+08	3.524e-02	2.858e+00	5.391e-05	4.372e-03
0.15	6.659e+05	3.387e-04	1.703e-02	5.577e-07	2.804e-05
0.2	6.864e+07	7.823e-02	2.677e+00	1.381e-04	4.724e-03
0.3	3.872e+06	1.260e-02	2.509e-01	2.390e-05	4.760e-04
0.4	8.812e+07	5.898e-01	8.148e+00	1.149e-03	1.588e-02
0.5	2.894e+07	3.364e-01	3.567e+00	6.603e-04	7.002e-03
0.6	1.259e+10	2.286e+02	1.973e+03	4.462e-01	3.851e+00
0.8	2.773e+08	1.010e+01	6.479e+01	1.920e-02	1.232e-01
1.0	2.187e+08	1.356e+01	7.062e+01	2.500e-02	1.302e-01
1.5	2.774e+08	4.423e+01	1.656e+02	7.442e-02	2.787e-01
2.0	3.669e-03	1.105e-09	3.416e-09	1.709e-12	5.282e-12
TOTALS:	1.529e+10	2.975e+02	2.292e+03	5.668e-01	4.416e+00

MicroShield v5.01 (5.01-00121)
 Lockheed Martin Idaho Technologies Company
 Case File Heat Generation
 Case File: T25SBW16.MS5
 Case Title: T25SBW

<u>Isotope</u>	<u>Activity</u> <u>Curies</u>	<u>Activity</u> <u>Bequerels</u>	<u>Heat Generation</u> <u>Watts/Curie</u>	<u>Heat Generation</u> <u>Watts</u>
Ac-225	2.0509e-019	7.5882e-009	3.4574e-002	7.0906e-021
Ac-227	4.8195e-022	1.7832e-011	4.7208e-004	2.2752e-025
Ac-228	1.7920e-028	6.6306e-018	8.0395e-003	1.4407e-030
Am-241	7.3519e-007	2.7202e+004	3.2813e-002	2.4124e-008
At-217	2.0509e-019	7.5882e-009	4.1888e-002	8.5906e-021
Ba-137m	1.1748e-001	4.3467e+009	3.9212e-003	4.6066e-004
Bi-210	5.0457e-024	1.8669e-013	2.3060e-003	1.1636e-026
Bi-211	4.7652e-022	1.7631e-011	3.9163e-002	1.8662e-023
Bi-212	1.4234e-028	5.2665e-018	1.6753e-002	2.3847e-030
Bi-213	2.0508e-019	7.5881e-009	4.1771e-003	8.5666e-022
Bi-214	3.2071e-023	1.1866e-012	1.2767e-002	4.0946e-025
Ce-144	1.8677e-010	6.9106e+000	6.6284e-004	1.2380e-013
Co-60	2.3694e-002	8.7668e+008	1.5423e-002	3.6542e-004
Cs-134	5.9305e-006	2.1943e+005	1.0179e-002	6.0368e-008
Cs-137	1.2419e-001	4.5949e+009	1.0122e-003	1.2571e-004
Eu-154	5.7364e-007	2.1225e+004	9.0517e-003	5.1924e-009
Eu-155	2.4760e-007	9.1612e+003	7.2543e-004	1.7962e-010
Fr-221	2.0509e-019	7.5882e-009	3.7907e-002	7.7742e-021
Fr-223	6.6509e-024	2.4608e-013	2.5771e-003	1.7140e-026
Np-237	4.7649e-012	1.7630e-001	2.8779e-002	1.3713e-013
Pa-231	1.9307e-021	7.1437e-011	3.2329e-002	6.2419e-023
Pa-233	4.7395e-012	1.7536e-001	2.4276e-003	1.1505e-014
Pa-234	1.1615e-020	4.2974e-010	1.4604e-002	1.6962e-022
Pa-234m	7.2591e-018	2.6859e-007	4.9490e-003	3.5925e-020
Pb-209	2.0507e-019	7.5876e-009	1.1714e-003	2.4022e-022
Pb-210	5.0623e-024	1.8731e-013	2.3060e-004	1.1673e-027
Pb-211	4.7652e-022	1.7631e-011	2.9963e-003	1.4278e-024
Pb-212	1.4234e-028	5.2666e-018	1.9044e-003	2.7107e-031
Pb-214	3.2072e-023	1.1866e-012	3.1921e-003	1.0238e-025
Pm-147	0.0000e+000	0.0000e+000	3.6731e-004	0.0000e+000
Po-210	4.6149e-024	1.7075e-013	3.1446e-002	1.4512e-025
Po-211	1.3009e-024	4.8133e-014	4.4166e-002	5.7456e-026
Po-212	9.1196e-029	3.3742e-018	5.2078e-002	4.7493e-030
Po-213	2.0065e-019	7.4242e-009	4.9660e-002	9.9644e-021
Po-214	3.2065e-023	1.1864e-012	4.5570e-002	1.4612e-024
Po-215	4.7653e-022	1.7631e-011	4.3787e-002	2.0866e-023
Po-216	1.4236e-028	5.2674e-018	4.0184e-002	5.7207e-030
Po-218	3.2078e-023	1.1869e-012	3.5576e-002	1.1412e-024
Pr-144	1.8678e-010	6.9108e+000	7.3455e-003	1.3720e-012
Pr-144m	2.6709e-012	9.8823e-002	3.3653e-004	8.9883e-016
Pu-238	7.9012e-013	2.9235e-002	3.2587e-002	2.5748e-014
Pu-239	9.8158e-014	3.6319e-003	3.0551e-002	2.9988e-015
Pu-240	2.3438e-014	8.6722e-004	3.0614e-002	7.1755e-016
Pu-241	3.5075e-013	1.2978e-002	3.1003e-005	1.0874e-017
Pu-242	6.7251e-018	2.4883e-007	2.9184e-002	1.9627e-019
Ra-223	4.7653e-022	1.7631e-011	3.4973e-002	1.6665e-023
Ra-224	1.4236e-028	5.2674e-018	3.3714e-002	4.7996e-030
Ra-225	2.0601e-019	7.6223e-009	7.0678e-004	1.4560e-022
Ra-226	3.2138e-023	1.1891e-012	2.8394e-002	9.1251e-025
Ra-228	1.7922e-028	6.6311e-018	6.8576e-005	1.2290e-032

<u>Isotope</u>	<u>Activity</u> <u>Curies</u>	<u>Activity</u> <u>Bequerels</u>	<u>Heat Generation</u> <u>Watts/Curie</u>	<u>Heat Generation</u> <u>Watts</u>
Rh-106	5.2043e-006	1.9256e+005	9.5998e-003	4.9960e-008
Rn-219	4.7653e-022	1.7631e-011	4.0502e-002	1.9300e-023
Rn-220	1.4236e-028	5.2674e-018	3.7278e-002	5.3070e-030
Rn-222	3.2078e-023	1.1869e-012	3.2543e-002	1.0439e-024
Ru-106	5.2043e-006	1.9256e+005	5.9459e-005	3.0944e-010
Sb-125	4.2297e-003	1.5650e+008	3.1431e-003	1.3294e-005
Sm-151	0.0000e+000	0.0000e+000	1.1729e-004	0.0000e+000
Sr-90	2.2902e-004	8.4737e+006	1.1607e-003	2.6583e-007
Tc-99	6.8317e-003	2.5277e+008	5.0152e-004	3.4262e-006
Te-125m	1.0365e-003	3.8350e+007	9.4493e-004	9.7940e-007
Th-227	4.7195e-022	1.7462e-011	3.5868e-002	1.6928e-023
Th-228	1.4255e-028	5.2745e-018	3.2139e-002	4.5814e-030
Th-229	2.0737e-019	7.6728e-009	2.9977e-002	6.2163e-021
Th-230	9.1366e-021	3.3805e-010	2.7809e-002	2.5408e-022
Th-231	4.8057e-018	1.7781e-007	1.0580e-003	5.0843e-021
Th-232	2.9637e-028	1.0966e-017	2.3811e-002	7.0569e-030
Th-234	7.2591e-018	2.6859e-007	3.9682e-004	2.8805e-021
Tl-207	4.7522e-022	1.7583e-011	2.9369e-003	1.3957e-024
Tl-208	5.1142e-029	1.8922e-018	2.3467e-002	1.2001e-030
Tl-209	4.4298e-021	1.6390e-010	1.6632e-002	7.3678e-023
U-233	2.4881e-016	9.2060e-006	2.8557e-002	7.1052e-018
U-234	7.5807e-017	2.8049e-006	2.8311e-002	2.1462e-018
U-235	4.8057e-018	1.7781e-007	2.7115e-002	1.3031e-019
U-236	3.2278e-019	1.1943e-008	2.6697e-002	8.6172e-021
U-237	8.6044e-018	3.1836e-007	1.9366e-003	1.6663e-020
U-238	7.2591e-018	2.6859e-007	2.4920e-002	1.8090e-019
Y-90	2.2908e-004	8.4758e+006	5.5411e-003	1.2693e-006

Total

Heat Generation:

9.7117e-004 ✓

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

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DOS File: T25SBW.MS5
Run Date: November 25, 1997
Run Time: 3:54:11 PM
Duration: 00:01:32

File Ref: HKP-26-91
Date: 12/4/97
By: AKB
Checked: _____

for 2016
AKB

Case Title: T25SBW

Description: R/hr @ 1 cm from culvert with SBW Grout from PP Sep. (T25)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions

Height 162.56 cm ✓ 5 ft 4.0 in
Radius 45.72 cm ✓ 1 ft 6.0 in

Dose Points

	X	Y	Z
# 1	56.88 cm ✓	81.28 cm	0 cm
	1 ft 10.4 in	2 ft 8.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	1.07e+06 cm ³	Concrete	1.8
Shield 1	10.16 cm	Concrete	2.35
Transition	1.0 cm	Air	0.0011
Air Gap		Air	0.00122

Source Input

Grouping Method : Standard Indices

Number of Groups : 25

Lower Energy Cutoff : 0.015

Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Ac-225	2.0509e-019	7.5882e-009	1.9212e-019	7.1083e-015
Ac-227	4.8195e-022	1.7832e-011	4.5147e-022	1.6704e-017
Ac-228	1.7920e-028	6.6306e-018	1.6787e-028	6.2112e-024
Am-241	7.3519e-007	2.7202e+004	6.8869e-007	2.5482e-002
At-217	2.0509e-019	7.5882e-009	1.9212e-019	7.1083e-015
Ba-137m	1.1748e-001	4.3467e+009	1.1005e-001	4.0718e+003
Bi-210	5.0457e-024	1.8669e-013	4.7266e-024	1.7488e-019
Bi-211	4.7652e-022	1.7631e-011	4.4638e-022	1.6516e-017
Bi-212	1.4234e-028	5.2665e-018	1.3333e-028	4.9334e-024
Bi-213	2.0508e-019	7.5881e-009	1.9211e-019	7.1082e-015
Bi-214	3.2071e-023	1.1866e-012	3.0043e-023	1.1116e-018
Ce-144	1.8677e-010	6.9106e+000	1.7496e-010	6.4735e-006
Co-60	2.3694e-002	8.7668e+008	2.2195e-002	8.2123e+002
Cs-134	5.9305e-006	2.1943e+005	5.5554e-006	2.0555e-001
Cs-137	1.2419e-001	4.5949e+009	1.1633e-001	4.3042e+003
Eu-154	5.7364e-007	2.1225e+004	5.3735e-007	1.9882e-002
Eu-155	2.4760e-007	9.1612e+003	2.3194e-007	8.5818e-003
Fr-221	2.0509e-019	7.5882e-009	1.9212e-019	7.1083e-015
Fr-223	6.6509e-024	2.4608e-013	6.2302e-024	2.3052e-019
Np-237	4.7649e-012	1.7630e-001	4.4635e-012	1.6515e-007
Pa-231	1.9307e-021	7.1437e-011	1.8086e-021	6.6919e-017
Pa-233	4.7395e-012	1.7536e-001	4.4397e-012	1.6427e-007
Pa-234	1.1615e-020	4.2974e-010	1.0880e-020	4.0256e-016
Pa-234m	7.2591e-018	2.6859e-007	6.8000e-018	2.5160e-013
Pb-209	2.0507e-019	7.5876e-009	1.9210e-019	7.1077e-015

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 Run Date: November 25, 1997
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<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Pb-210	5.0623e-024	1.8731e-013	4.7421e-024	1.7546e-019
Pb-211	4.7652e-022	1.7631e-011	4.4638e-022	1.6516e-017
Pb-212	1.4234e-028	5.2666e-018	1.3334e-028	4.9335e-024
Pb-214	3.2072e-023	1.1866e-012	3.0043e-023	1.1116e-018
Pm-147				
Po-210	4.6149e-024	1.7075e-013	4.3230e-024	1.5995e-019
Po-211	1.3009e-024	4.8133e-014	1.2186e-024	4.5089e-020
Po-212	9.1196e-029	3.3742e-018	8.5428e-029	3.1608e-024
Po-213	2.0065e-019	7.4242e-009	1.8796e-019	6.9546e-015
Po-214	3.2065e-023	1.1864e-012	3.0037e-023	1.1114e-018
Po-215	4.7653e-022	1.7631e-011	4.4639e-022	1.6516e-017
Po-216	1.4236e-028	5.2674e-018	1.3336e-028	4.9343e-024
Po-218	3.2078e-023	1.1869e-012	3.0049e-023	1.1118e-018
Pr-144	1.8678e-010	6.9108e+000	1.7496e-010	6.4737e-006
Pr-144m	2.6709e-012	9.8823e-002	2.5020e-012	9.2572e-008
Pu-238	7.9012e-013	2.9235e-002	7.4015e-013	2.7385e-008
Pu-239	9.8158e-014	3.6319e-003	9.1950e-014	3.4021e-009
Pu-240	2.3438e-014	8.6722e-004	2.1956e-014	8.1237e-010
Pu-241	3.5075e-013	1.2978e-002	3.2857e-013	1.2157e-008
Pu-242	6.7251e-018	2.4883e-007	6.2998e-018	2.3309e-013
Ra-223	4.7653e-022	1.7631e-011	4.4639e-022	1.6516e-017
Ra-224	1.4236e-028	5.2674e-018	1.3336e-028	4.9343e-024
Ra-225	2.0601e-019	7.6223e-009	1.9298e-019	7.1402e-015
Ra-226	3.2138e-023	1.1891e-012	3.0105e-023	1.1139e-018
Ra-228	1.7922e-028	6.6311e-018	1.6788e-028	6.2117e-024
Rh-106	5.2043e-006	1.9256e+005	4.8751e-006	1.8038e-001
Rn-219	4.7653e-022	1.7631e-011	4.4639e-022	1.6516e-017
Rn-220	1.4236e-028	5.2674e-018	1.3336e-028	4.9343e-024
Rn-222	3.2078e-023	1.1869e-012	3.0049e-023	1.1118e-018
Ru-106	5.2043e-006	1.9256e+005	4.8751e-006	1.8038e-001
Sb-125	4.2297e-003	1.5650e+008	3.9622e-003	1.4660e+002
Sm-151				
Sr-90	2.2902e-004	8.4737e+006	2.1453e-004	7.9377e+000
Tc-99	6.8317e-003	2.5277e+008	6.3996e-003	2.3679e+002
Te-125m	1.0365e-003	3.8350e+007	9.7092e-004	3.5924e+001
Th-227	4.7195e-022	1.7462e-011	4.4210e-022	1.6358e-017
Th-228	1.4255e-028	5.2745e-018	1.3354e-028	4.9409e-024
Th-229	2.0737e-019	7.6728e-009	1.9426e-019	7.1875e-015
Th-230	9.1366e-021	3.3805e-010	8.5587e-021	3.1667e-016
Th-231	4.8057e-018	1.7781e-007	4.5017e-018	1.6656e-013
Th-232	2.9637e-028	1.0966e-017	2.7763e-028	1.0272e-023
Th-234	7.2591e-018	2.6859e-007	6.8000e-018	2.5160e-013
Tl-207	4.7522e-022	1.7583e-011	4.4516e-022	1.6471e-017
Tl-208	5.1142e-029	1.8922e-018	4.7907e-029	1.7726e-024
Tl-209	4.4298e-021	1.6390e-010	4.1496e-021	1.5354e-016
U-233	2.4881e-016	9.2060e-006	2.3307e-016	8.6237e-012
U-234	7.5807e-017	2.8049e-006	7.1012e-017	2.6275e-012
U-235	4.8057e-018	1.7781e-007	4.5017e-018	1.6656e-013
U-236	3.2278e-019	1.1943e-008	3.0236e-019	1.1187e-014
U-237	8.6044e-018	3.1836e-007	8.0602e-018	2.9823e-013
U-238	7.2591e-018	2.6859e-007	6.8000e-018	2.5160e-013
Y-90	2.2908e-004	8.4758e+006	2.1459e-004	7.9397e+000

Buildup

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 DOS File: T25SBW.MS5
 Run Date: November 25, 1997
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The material reference is : Source

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

Results

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Fluence Rate</u> <u>MeV/cm²/sec</u> <u>No Buildup</u>	<u>Fluence Rate</u> <u>MeV/cm²/sec</u> <u>With Buildup</u>	<u>Exposure Rate</u> <u>mR/hr</u> <u>No Buildup</u>	<u>Exposure Rate</u> <u>mR/hr</u> <u>With Buildup</u>
0.015	3.478e-10	1.685e-105	1.003e-42	1.445e-106	8.603e-44
0.02	2.868e-13	2.150e-60	1.302e-45	7.447e-62	4.509e-47
0.03	3.699e+08	1.045e-13	2.019e-13	1.035e-15	2.001e-15
0.04	6.943e+07	9.294e-08	2.796e-07	4.110e-10	1.236e-09
0.05	1.637e+03	8.015e-10	3.706e-09	2.135e-12	9.873e-12
0.06	9.933e+03	8.404e-08	5.565e-07	1.669e-10	1.105e-09
0.08	4.311e+03	5.023e-07	5.176e-06	7.949e-10	8.190e-09
0.1	5.275e+05	2.073e-04	2.727e-03	3.171e-07	4.173e-06
0.15	3.928e+05	6.691e-04	1.032e-02	1.102e-06	1.699e-05
0.2	1.188e+07	4.626e-02	6.829e-01	8.165e-05	1.205e-03
0.3	6.528e+05	7.467e-03	8.986e-02	1.416e-05	1.705e-04
0.4	4.900e+07	1.179e+00	1.164e+01	2.297e-03	2.267e-02
0.5	1.625e+07	6.915e-01	5.755e+00	1.357e-03	1.130e-02
0.6	3.968e+09	2.681e+02	1.932e+03	5.232e-01	3.771e+00
0.8	2.156e+05	3.002e-02	1.732e-01	5.710e-05	3.294e-04
1.0	8.767e+08	2.127e+02	1.038e+03	3.921e-01	1.913e+00
1.5	8.767e+08	5.718e+02	2.108e+03	9.620e-01	3.547e+00
2.0	5.349e-02	6.811e-08	2.123e-07	1.053e-10	3.284e-10
3.0	1.888e-18	5.803e-24	1.467e-23	7.873e-27	1.990e-26
TOTALS:	6.239e+09	1.054e+03	5.096e+03	1.881e+00	9.267e+00

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

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DOS File: T25SBW.MS5
Run Date: November 25, 1997
Run Time: 3:50:04 PM
Duration: 00:01:30

File Ref: HKP-26
Date: 12/4/97
By: [Signature]
Checked: [Signature]

for 2016
[Signature]

Case Title: T25SBW

Description: R/hr @ 1 m from culvert with SBW Grout from PP Sep. (T25)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions

Height 162.56 cm 5 ft 4.0 in
Radius 45.72 cm 1 ft 6.0 in

Dose Points

1 X Y Z
155.88 cm 81.28 cm 0 cm
5 ft 1.4 in 2 ft 8.0 in 0.0 in

Shields

Shield Name	Dimension	Material	Densit
Source	1.07e+06 cm ³	Concrete	1.8
Shield 1	10.16 cm	Concrete	2.35
Transition	100.0 cm	Air	0.0011
Air Gap		Air	0.0012

Source Input

Grouping Method : Standard Indices

Number of Groups : 25

Lower Energy Cutoff : 0.015

Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Ac-225	2.0509e-019	7.5882e-009	1.9212e-019	7.1083e-015
Ac-227	4.8195e-022	1.7832e-011	4.5147e-022	1.6704e-017
Ac-228	1.7920e-028	6.6306e-018	1.6787e-028	6.2112e-024
Am-241	7.3519e-007	2.7202e+004	6.8869e-007	2.5482e-002
At-217	2.0509e-019	7.5882e-009	1.9212e-019	7.1083e-015
Ba-137m	1.1748e-001	4.3467e+009	1.1005e-001	4.0718e+003
Bi-210	5.0457e-024	1.8669e-013	4.7266e-024	1.7488e-019
Bi-211	4.7652e-022	1.7631e-011	4.4638e-022	1.6516e-017
Bi-212	1.4234e-028	5.2665e-018	1.3333e-028	4.9334e-024
Bi-213	2.0508e-019	7.5881e-009	1.9211e-019	7.1082e-015
Bi-214	3.2071e-023	1.1866e-012	3.0043e-023	1.1116e-018
Ce-144	1.8677e-010	6.9106e+000	1.7496e-010	6.4735e-006
Co-60	2.3694e-002	8.7668e+008	2.2195e-002	8.2123e+002
Cs-134	5.9305e-006	2.1943e+005	5.5554e-006	2.0555e-001
Cs-137	1.2419e-001	4.5949e+009	1.1633e-001	4.3042e+003
Eu-154	5.7364e-007	2.1225e+004	5.3735e-007	1.9882e-002
Eu-155	2.4760e-007	9.1612e+003	2.3194e-007	8.5818e-003
Fr-221	2.0509e-019	7.5882e-009	1.9212e-019	7.1083e-015
Fr-223	6.6509e-024	2.4608e-013	6.2302e-024	2.3052e-019
Np-237	4.7649e-012	1.7630e-001	4.4635e-012	1.6515e-007
Pa-231	1.9307e-021	7.1437e-011	1.8086e-021	6.6919e-017
Pa-233	4.7395e-012	1.7536e-001	4.4397e-012	1.6427e-007
Pa-234	1.1615e-020	4.2974e-010	1.0880e-020	4.0256e-016
Pa-234m	7.2591e-018	2.6859e-007	6.8000e-018	2.5160e-013
Pb-209	2.0507e-019	7.5876e-009	1.9210e-019	7.1077e-015

Page : 2
 DOS File: T25SBW.MS5
 Run Date: November 25, 1997
 Run Time: 3:50:04 PM
 Duration: 00:01:30

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Pb-210	5.0623e-024	1.8731e-013	4.7421e-024	1.7546e-019
Pb-211	4.7652e-022	1.7631e-011	4.4638e-022	1.6516e-017
Pb-212	1.4234e-028	5.2666e-018	1.3334e-028	4.9335e-024
Pb-214	3.2072e-023	1.1866e-012	3.0043e-023	1.1116e-018
Pm-147				
Po-210	4.6149e-024	1.7075e-013	4.3230e-024	1.5995e-019
Po-211	1.3009e-024	4.8133e-014	1.2186e-024	4.5089e-020
Po-212	9.1196e-029	3.3742e-018	8.5428e-029	3.1608e-024
Po-213	2.0065e-019	7.4242e-009	1.8796e-019	6.9546e-015
Po-214	3.2065e-023	1.1864e-012	3.0037e-023	1.1114e-018
Po-215	4.7653e-022	1.7631e-011	4.4639e-022	1.6516e-017
Po-216	1.4236e-028	5.2674e-018	1.3336e-028	4.9343e-024
Po-218	3.2078e-023	1.1869e-012	3.0049e-023	1.1118e-018
Pr-144	1.8678e-010	6.9108e+000	1.7496e-010	6.4737e-006
Pr-144m	2.6709e-012	9.8823e-002	2.5020e-012	9.2572e-008
Pu-238	7.9012e-013	2.9235e-002	7.4015e-013	2.7385e-008
Pu-239	9.8158e-014	3.6319e-003	9.1950e-014	3.4021e-009
Pu-240	2.3438e-014	8.6722e-004	2.1956e-014	8.1237e-010
Pu-241	3.5075e-013	1.2978e-002	3.2857e-013	1.2157e-008
Pu-242	6.7251e-018	2.4883e-007	6.2998e-018	2.3309e-013
Ra-223	4.7653e-022	1.7631e-011	4.4639e-022	1.6516e-017
Ra-224	1.4236e-028	5.2674e-018	1.3336e-028	4.9343e-024
Ra-225	2.0601e-019	7.6223e-009	1.9298e-019	7.1402e-015
Ra-226	3.2138e-023	1.1891e-012	3.0105e-023	1.1139e-018
Ra-228	1.7922e-028	6.6311e-018	1.6788e-028	6.2117e-024
Rh-106	5.2043e-006	1.9256e+005	4.8751e-006	1.8038e-001
Rn-219	4.7653e-022	1.7631e-011	4.4639e-022	1.6516e-017
Rn-220	1.4236e-028	5.2674e-018	1.3336e-028	4.9343e-024
Rn-222	3.2078e-023	1.1869e-012	3.0049e-023	1.1118e-018
Ru-106	5.2043e-006	1.9256e+005	4.8751e-006	1.8038e-001
Sb-125	4.2297e-003	1.5650e+008	3.9622e-003	1.4660e+002
Sm-151				
Sr-90	2.2902e-004	8.4737e+006	2.1453e-004	7.9377e+000
Tc-99	6.8317e-003	2.5277e+008	6.3996e-003	2.3679e+002
Te-125m	1.0365e-003	3.8350e+007	9.7092e-004	3.5924e+001
Th-227	4.7195e-022	1.7462e-011	4.4210e-022	1.6358e-017
Th-228	1.4255e-028	5.2745e-018	1.3354e-028	4.9409e-024
Th-229	2.0737e-019	7.6728e-009	1.9426e-019	7.1875e-015
Th-230	9.1366e-021	3.3805e-010	8.5587e-021	3.1667e-016
Th-231	4.8057e-018	1.7781e-007	4.5017e-018	1.6656e-013
Th-232	2.9637e-028	1.0966e-017	2.7763e-028	1.0272e-023
Th-234	7.2591e-018	2.6859e-007	6.8000e-018	2.5160e-013
Tl-207	4.7522e-022	1.7583e-011	4.4516e-022	1.6471e-017
Tl-208	5.1142e-029	1.8922e-018	4.7907e-029	1.7726e-024
Tl-209	4.4298e-021	1.6390e-010	4.1496e-021	1.5354e-016
U-233	2.4881e-016	9.2060e-006	2.3307e-016	8.6237e-012
U-234	7.5807e-017	2.8049e-006	7.1012e-017	2.6275e-012
U-235	4.8057e-018	1.7781e-007	4.5017e-018	1.6656e-013
U-236	3.2278e-019	1.1943e-008	3.0236e-019	1.1187e-014
U-237	8.6044e-018	3.1836e-007	8.0602e-018	2.9823e-013
U-238	7.2591e-018	2.6859e-007	6.8000e-018	2.5160e-013
Y-90	2.2908e-004	8.4758e+006	2.1459e-004	7.9397e+000

Buildup

Page : 3
 DOS File: T25SBW.MS5
 Run Date: November 25, 1997
 Run Time: 3:50:04 PM
 Duration: 00:01:30

The material reference is : Transition

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

Energy MeV	Activity photons/sec	Results			
		Fluence Rate	Fluence Rate	Exposure Rate	Exposure Rate
		MeV/cm ² /sec No Buildup	MeV/cm ² /sec With Buildup	mR/hr No Buildup	mR/hr With Buildup
0.015	3.478e-10	3.424e-106	2.660e-43	2.937e-107	2.282e-44
0.02	2.868e-13	5.902e-61	6.225e-46	2.044e-62	2.156e-47
0.03	3.699e+08	3.837e-14	8.038e-13	3.803e-16	7.966e-15
0.04	6.943e+07	3.212e-08	1.635e-06	1.420e-10	7.231e-09
0.05	1.637e+03	2.702e-10	2.256e-08	7.197e-13	6.011e-11
0.06	9.933e+03	2.765e-08	2.763e-06	5.492e-11	5.488e-09
0.08	4.311e+03	1.589e-07	1.536e-05	2.514e-10	2.431e-08
0.1	5.275e+05	6.395e-05	5.186e-03	9.784e-08	7.934e-06
0.15	3.928e+05	1.998e-04	1.005e-02	3.290e-07	1.654e-05
0.2	1.188e+07	1.354e-02	4.633e-01	2.390e-05	8.177e-04
0.3	6.528e+05	2.124e-03	4.231e-02	4.029e-06	8.025e-05
0.4	4.900e+07	3.279e-01	4.531e+00	6.390e-04	8.828e-03
0.5	1.625e+07	1.888e-01	2.003e+00	3.707e-04	3.931e-03
0.6	3.968e+09	7.204e+01	6.218e+02	1.406e-01	1.214e+00
0.8	2.156e+05	7.850e-03	5.038e-02	1.493e-05	9.583e-05
1.0	8.767e+08	5.437e+01	2.831e+02	1.002e-01	5.218e-01
1.5	8.767e+08	1.398e+02	5.234e+02	2.352e-01	8.807e-01
2.0	5.349e-02	1.612e-08	4.981e-08	2.492e-11	7.702e-11
3.0	1.888e-18	1.314e-24	3.222e-24	1.782e-27	4.371e-27
TOTALS:	6.239e+09	2.667e+02	1.435e+03	4.770e-01	2.630e+00

MicroShield v5.01 (5.01-00121)
 Lockheed Martin Idaho Technologies Company
 Case File Heat Generation
 Case File: T31ALUM.MS5
 Case Title: T31alum

<u>Isotope</u>	<u>Activity</u> <u>Curies</u>	<u>Activity</u> <u>Bequerels</u>	<u>Heat Generation</u> <u>Watts/Curie</u>	<u>Heat Generation</u> <u>Watts</u>
Am-241	3.5980e+000	1.3313e+011	3.2813e-002	1.1806e-001
Am-243	1.2293e-004	4.5485e+006	3.1704e-002	3.8974e-006
Ce-144	2.8184e-016	1.0428e-005	6.6284e-004	1.8682e-019
Cm-242	9.8945e-005	3.6610e+006	3.6240e-002	3.5858e-006
Cm-244	1.9489e-004	7.2110e+006	3.4409e-002	6.7061e-006
Eu-154	1.0494e+001	3.8828e+011	9.0517e-003	9.4990e-002
Eu-155	6.2965e-001	2.3297e+010	7.2543e-004	4.5676e-004
Np-237	3.2982e-002	1.2203e+009	2.8779e-002	9.4919e-004
Pa-233	3.2982e-002	1.2203e+009	2.4276e-003	8.0065e-005
Pm-147	8.3953e-002	3.1063e+009	3.6731e-004	3.0837e-005
Pr-144	2.8184e-016	1.0428e-005	7.3455e-003	2.0703e-018
Pu-238	1.2593e+001	4.6594e+011	3.2587e-002	4.1036e-001
Pu-239	1.5891e+000	5.8797e+010	3.0551e-002	4.8548e-002
Pu-240	6.2965e-001	2.3297e+010	3.0614e-002	1.9276e-002
Pu-241	5.6968e+000	2.1078e+011	3.1003e-005	1.7662e-004
Pu-242	4.7973e-005	1.7750e+006	2.9184e-002	1.4001e-006
Rh-106	1.1094e-013	4.1047e-003	9.5998e-003	1.0650e-015
Ru-106	1.1094e-013	4.1047e-003	5.9459e-005	6.5963e-018
Sm-151	4.4975e+002	1.6641e+013	1.1729e-004	5.2750e-002
Tc-99	2.9983e-001	1.1094e+010	5.0152e-004	1.5037e-004
Th-230	4.1977e-005	1.5531e+006	2.7809e-002	1.1673e-006
Th-231	7.1960e-006	2.6625e+005	1.0580e-003	7.6131e-009
U-232	4.4975e-006	1.6641e+005	3.1553e-002	1.4191e-007
U-233	4.4975e-006	1.6641e+005	2.8557e-002	1.2843e-007
U-234	9.8945e-002	3.6610e+009	2.8311e-002	2.8013e-003
U-235	6.5963e-004	2.4406e+007	2.7115e-002	1.7886e-005
U-236	1.5891e-003	5.8797e+007	2.6697e-002	4.2425e-005
U-237	1.3792e-004	5.1032e+006	1.9366e-003	2.6710e-007
U-238	3.8978e-005	1.4422e+006	2.4920e-002	9.7135e-007

Total

Heat Generation:

7.4871e-001 ✓

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
DOS File: T31ALUM.MS5
Run Date: November 20, 1997
Run Time: 4:05:32 AM
Duration: 00:01:27

File Ref: HKP-26-
Date: 12/4/97
By: PHK/
Checked: 2/2/98

Case Title: T31alum

Description: R/hr @ 1 cm from mod. canister surf., Alumina calcine (T-31)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions

Height → 91.0 cm / 2 ft 11.8 in
Radius 32.385 cm / 1 ft 0.7 in

Dose Points

#	X	Y	Z
1	34.02 cm / 1 ft 1.4 in	45.5 cm / 1 ft 5.9 in	0 cm / 0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	3.00e+05 cm ³ /	Concrete	1.5 /
Shield 1	.635 cm /	Iron	7.86
Transition	1.0 cm	Air	0.0011
Air Gap		Air	0.00122

Source Input

Grouping Method : Standard Indices

Number of Groups : 25

Lower Energy Cutoff : 0.015

Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Am-241	3.5980e+000	1.3313e+011	1.2000e+001 /	4.4400e+005
Am-243	1.2293e-004	4.5485e+006	4.1000e-004 /	1.5170e+001
Ce-144	2.8184e-016	1.0428e-005	9.4000e-016 /	3.4780e-011
Cm-242	9.8945e-005	3.6610e+006	3.3000e-004 /	1.2210e+001
Cm-244	1.9489e-004	7.2110e+006	6.5000e-004 /	2.4050e+001
Eu-154	1.0494e+001	3.8828e+011	3.5000e+001 /	1.2950e+006
Eu-155	6.2965e-001	2.3297e+010	2.1000e+000 /	7.7700e+004
Np-237	3.2982e-002	1.2203e+009	1.1000e-001 /	4.0700e+003
Pa-233	3.2982e-002	1.2203e+009	1.1000e-001 /	4.0700e+003
Pm-147	8.3953e-002	3.1063e+009	2.8000e-001 /	1.0360e+004
Pr-144	2.8184e-016	1.0428e-005	9.4000e-016 /	3.4780e-011
Pu-238	1.2593e+001	4.6594e+011	4.2000e+001 /	1.5540e+006
Pu-239	1.5891e+000	5.8797e+010	5.3000e+000 /	1.9610e+005
Pu-240	6.2965e-001	2.3297e+010	2.1000e+000 /	7.7700e+004
Pu-241	5.6968e+000	2.1078e+011	1.9000e+001 /	7.0300e+005
Pu-242	4.7973e-005	1.7750e+006	1.6000e-004 /	5.9200e+000
Rh-106	1.1094e-013	4.1047e-003	3.7000e-013 /	1.3690e-008
Ru-106	1.1094e-013	4.1047e-003	3.7000e-013 /	1.3690e-008
Sm-151	4.4975e+002	1.6641e+013	1.5000e+003 /	5.5500e+007
Tc-99	2.9983e-001	1.1094e+010	1.0000e+000 /	3.7000e+004
Th-230	4.1977e-005	1.5531e+006	1.4000e-004 /	5.1800e+000
Th-231	7.1960e-006	2.6625e+005	2.4000e-005 /	8.8800e-001
U-232	4.4975e-006	1.6641e+005	1.5000e-005 /	5.5500e-001
U-233	4.4975e-006	1.6641e+005	1.5000e-005 /	5.5500e-001
U-234	9.8945e-002	3.6610e+009	3.3000e-001 /	1.2210e+004

Page : 2
 DOS File: T31ALUM.MS5
 Run Date: November 20, 1997
 Run Time: 4:05:32 AM
 Duration: 00:01:27

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
U-235	6.5963e-004	2.4406e+007	2.2000e-003	8.1400e+001
U-236	1.5891e-003	5.8797e+007	5.3000e-003	1.9610e+002
U-237	1.3792e-004	5.1032e+006	4.6000e-004	1.7020e+001
U-238	3.8978e-005	1.4422e+006	1.3000e-004	4.8100e+000

Buildup
 The material reference is : Source

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Results</u>			
		<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
		<u>MeV/cm²/sec</u>	<u>MeV/cm²/sec</u>	<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.015	5.008e+02	4.642e-138	4.751e-30	3.982e-139	4.075e-31
0.02	4.920e+09	4.447e-58	7.345e-23	1.541e-59	2.544e-24
0.03	3.581e+09	1.374e-17	2.787e-17	1.362e-19	2.762e-19
0.04	8.325e+10	1.219e-05	3.930e-05	5.391e-08	1.738e-07
0.05	2.146e+10	3.082e-02	1.446e-01	8.211e-05	3.851e-04
0.06	4.856e+10	5.600e+00	3.383e+01	1.112e-02	6.719e-02
0.08	7.432e+09	4.547e+01	3.297e+02	7.196e-02	5.218e-01
0.1	1.625e+11	5.511e+03	4.035e+04	8.431e+00	6.173e+01
0.15	2.476e+07	4.668e+00	2.977e+01	7.688e-03	4.902e-02
0.2	2.654e+10	1.047e+04	5.898e+04	1.848e+01	1.041e+02
0.3	6.110e+08	5.429e+02	2.544e+03	1.030e+00	4.826e+00
0.4	2.813e+09	4.200e+03	1.718e+04	8.184e+00	3.347e+01
0.5	8.407e+08	1.857e+03	6.826e+03	3.646e+00	1.340e+01
0.6	3.132e+10	9.496e+04	3.191e+05	1.854e+02	6.228e+02
0.8	1.514e+11	7.556e+05	2.218e+06	1.437e+03	4.218e+03
1.0	1.194e+11	8.770e+05	2.329e+06	1.617e+03	4.293e+03
1.5	1.515e+11	2.230e+06	4.995e+06	3.751e+03	8.404e+03
2.0	8.072e-08	1.913e-12	3.872e-12	2.958e-15	5.987e-15
TOTALS:	8.162e+11	3.980e+06	9.987e+06	7.030e+03	1.776e+04

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
DOS File: T31ALUM.MS5
Run Date: November 20, 1997
Run Time: 3:46:36 AM
Duration: 00:01:28

File Ref: HKP-26-
Date: 12/4/97
By: THH/klp
Checked: 285/v

Case Title: T31alum

Description: R/hr @ 1 m from mod. canister surf., Alumina calcine (T-31)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions

Height 91.0 cm / 2 ft 11.8 in
Radius 32.385 cm / 1 ft 0.7 in

Dose Points

1 X Y Z
 133.02 cm / 45.5 cm 0 cm
 4 ft 4.4 in 1 ft 5.9 in 0.0 in

Shields

Shield Name	Dimension	Material	Densit
Source	3.00e+05 cm ³	Concrete	1.5 /
Shield 1	.635 cm	Iron	7.86 /
Transition	100.0 cm	Air	0.0011
Air Gap		Air	0.0011

Source Input

Grouping Method : Standard Indices

Number of Groups : 25

Lower Energy Cutoff : 0.015

Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Am-241	3.5980e+000	1.3313e+011	1.2000e+001 /	4.4400e+005
Am-243	1.2293e-004	4.5485e+006	4.1000e-004 /	1.5170e+001
Ce-144	2.8184e-016	1.0428e-005	9.4000e-016 /	3.4780e-011
Cm-242	9.8945e-005	3.6610e+006	3.3000e-004 /	1.2210e+001
Cm-244	1.9489e-004	7.2110e+006	6.5000e-004 /	2.4050e+001
Eu-154	1.0494e+001	3.8828e+011	3.5000e+001 /	1.2950e+006
Eu-155	6.2965e-001	2.3297e+010	2.1000e+000 /	7.7700e+004
Np-237	3.2982e-002	1.2203e+009	1.1000e-001 /	4.0700e+003
Pa-233	3.2982e-002	1.2203e+009	1.1000e-001 /	4.0700e+003
Pm-147	8.3953e-002	3.1063e+009	2.8000e-001 /	1.0360e+004
Pr-144	2.8184e-016	1.0428e-005	9.4000e-016	3.4780e-011
Pu-238	1.2593e+001	4.6594e+011	4.2000e+001 /	1.5540e+006
Pu-239	1.5891e+000	5.8797e+010	5.3000e+000 /	1.9610e+005
Pu-240	6.2965e-001	2.3297e+010	2.1000e+000 /	7.7700e+004
Pu-241	5.6968e+000	2.1078e+011	1.9000e+001 /	7.0300e+005
Pu-242	4.7973e-005	1.7750e+006	1.6000e-004 /	5.9200e+000
Rh-106	1.1094e-013	4.1047e-003	3.7000e-013	1.3690e-008
Ru-106	1.1094e-013	4.1047e-003	3.7000e-013 /	1.3690e-008
Sm-151	4.4975e+002	1.6641e+013	1.5000e+003 /	5.5500e+007
Tc-99	2.9983e-001	1.1094e+010	1.0000e+000 /	3.7000e+004
Th-230	4.1977e-005	1.5531e+006	1.4000e-004 /	5.1800e+000
Th-231	7.1960e-006	2.6625e+005	2.4000e-005 /	8.8800e-001
U-232	4.4975e-006	1.6641e+005	1.5000e-005 /	5.5500e-001
U-233	4.4975e-006	1.6641e+005	1.5000e-005 /	5.5500e-001
U-234	9.8945e-002	3.6610e+009	3.3000e-001 /	1.2210e+004

Page : 2
 DOS File: T31ALUM.MS5
 Run Date: November 20, 1997
 Run Time: 3:46:36 AM
 Duration: 00:01:28

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
U-235	6.5963e-004	2.4406e+007	2.2000e-003	8.1400e+001
U-236	1.5891e-003	5.8797e+007	5.3000e-003	1.9610e+002
U-237	1.3792e-004	5.1032e+006	4.6000e-004	1.7020e+001
U-238	3.8978e-005	1.4422e+006	1.3000e-004	4.8100e+000

Buildup
 The material reference is : Transition

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Results</u>			
		<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
		<u>MeV/cm²/sec</u> <u>No Buildup</u>	<u>MeV/cm²/sec</u> <u>With Buildup</u>	<u>mR/hr</u> <u>No Buildup</u>	<u>mR/hr</u> <u>With Buildup</u>
0.015	5.008e+02	3.803e-132	5.455e-31	3.262e-133	4.679e-32
0.02	4.920e+09	1.194e-56	1.521e-23	4.136e-58	5.267e-25
0.03	3.581e+09	3.803e-18	1.183e-16	3.769e-20	1.173e-18
0.04	8.325e+10	2.167e-06	1.462e-04	9.582e-09	6.466e-07
0.05	2.146e+10	5.599e-03	4.972e-01	1.492e-05	1.324e-03
0.06	4.856e+10	9.858e-01	7.679e+01	1.958e-03	1.525e-01
0.08	7.432e+09	6.833e+00	2.930e+02	1.081e-02	4.637e-01
0.1	1.625e+11	7.270e+02	1.844e+04	1.112e+00	2.821e+01
0.15	2.476e+07	5.238e-01	6.334e+00	8.626e-04	1.043e-02
0.2	2.654e+10	1.101e+03	9.206e+03	1.943e+00	1.625e+01
0.3	6.110e+08	5.397e+01	3.069e+02	1.024e-01	5.822e-01
0.4	2.813e+09	4.051e+02	1.843e+03	7.893e-01	3.591e+00
0.5	8.407e+08	1.753e+02	6.849e+02	3.442e-01	1.344e+00
0.6	3.132e+10	8.816e+03	3.067e+04	1.721e+01	5.986e+01
0.8	1.514e+11	6.833e+04	2.010e+05	1.300e+02	3.824e+02
1.0	1.194e+11	7.770e+04	2.040e+05	1.432e+02	3.760e+02
1.5	1.515e+11	1.905e+05	4.160e+05	3.206e+02	6.999e+02
2.0	8.072e-08	1.598e-13	3.130e-13	2.471e-16	4.840e-16
TOTALS:	8.162e+11	3.479e+05	8.825e+05	6.153e+02	1.569e+03

MicroShield v5.01 (5.01-00121)
 Lockheed Martin Idaho Technologies Company
 Case File Heat Generation
 Case File: T31ZIR.MS5
 Case Title: T31zir

<u>Isotope</u>	<u>Activity</u> <u>Curies</u>	<u>Activity</u> <u>Bequerels</u>	<u>Heat Generation</u> <u>Watts/Curie</u>	<u>Heat Generation</u> <u>Watts</u>
Am-241	1.6191e+001	5.9907e+011	3.2813e-002	5.3127e-001
Am-243	2.7884e-007	1.0317e+004	3.1704e-002	8.8406e-009
Ce-144	5.9967e-009	2.2188e+002	6.6284e-004	3.9748e-012
Cm-242	3.5980e-006	1.3313e+005	3.6240e-002	1.3039e-007
Cm-244	6.2965e-007	2.3297e+004	3.4409e-002	2.1666e-008
Cs-134	0.0000e+000	0.0000e+000	1.0179e-002	0.0000e+000
Eu-154	3.5980e+001	1.3313e+012	9.0517e-003	3.2568e-001
Eu-155	5.3970e-002	1.9969e+009	7.2543e-004	3.9151e-005
Np-237	3.5980e-003	1.3313e+008	2.8779e-002	1.0355e-004
Pa-233	3.5980e-003	1.3313e+008	2.4276e-003	8.7344e-006
Pm-147	5.6968e+000	2.1078e+011	3.6731e-004	2.0925e-003
Pr-144	5.9967e-009	2.2188e+002	7.3455e-003	4.4048e-011
Pu-238	1.4692e+002	5.4360e+012	3.2587e-002	4.7876e+000
Pu-239	2.3387e+000	8.6532e+010	3.0551e-002	7.1449e-002
Pu-240	2.1288e+000	7.8766e+010	3.0614e-002	6.5172e-002
Pu-241	6.8962e+001	2.5516e+012	3.1003e-005	2.1380e-003
Pu-242	4.7973e-003	1.7750e+008	2.9184e-002	1.4001e-004
Rh-106	3.8978e-008	1.4422e+003	9.5998e-003	3.7418e-010
Ru-106	3.8978e-008	1.4422e+003	5.9459e-005	2.3176e-012
Sm-151	2.0389e+002	7.5438e+012	1.1729e-004	2.3913e-002
Tc-99	8.9950e-001	3.3281e+010	5.0152e-004	4.5112e-004
Th-230	3.5980e-007	1.3313e+004	2.7809e-002	1.0006e-008
Th-231	9.5946e-006	3.5500e+005	1.0580e-003	1.0151e-008
U-232	7.1960e-006	2.6625e+005	3.1553e-002	2.2706e-007
U-233	4.4975e-007	1.6641e+004	2.8557e-002	1.2843e-008
U-234	1.1693e-001	4.3266e+009	2.8311e-002	3.3106e-003
U-235	7.4958e-004	2.7735e+007	2.7115e-002	2.0325e-005
U-236	1.9489e-003	7.2110e+007	2.6697e-002	5.2030e-005
U-237	1.6491e-003	6.1016e+007	1.9366e-003	3.1936e-006
U-238	3.5980e-005	1.3313e+006	2.4920e-002	8.9663e-007

Total

Heat Generation:

5.8134e+000 ✓

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
DOS File: T31ZIR.MS5
Run Date: November 20, 1997
Run Time: 4:18:51 AM
Duration: 00:01:28

File Ref: HKP-26-97
Date: 12/4/97
By: Offshoreman
Checked: JB/Dole

Case Title: T31zir

Description: R/hr @ 1 cm from mod. canister surf. Zirconia calcine (T-31)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions

Height 91.0 cm - 2 ft 11.8 in
Radius 32.385 cm - 1 ft 0.7 in

Dose Points

	<u>X</u>	<u>Y</u>	<u>Z</u>
# 1	34.02 cm -	45.5 cm	0 cm
	1 ft 1.4 in	1 ft 5.9 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	3.00e+05 -cm ³	Concrete	1.5 -
Shield 1	.635 -cm	Iron	7.86
Transition	1.0 -cm	Air	0.0011
Air Gap		Air	0.0011

Source Input

Grouping Method : Standard Indices

Number of Groups : 25

Lower Energy Cutoff : 0.015

Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Am-241	1.6191e+001	5.9907e+011	5.4000e+001 -	1.9980e+006
Am-243	2.7884e-007	1.0317e+004	9.3000e-007 -	3.4410e-002
Ce-144	5.9967e-009	2.2188e+002	2.0000e-008 -	7.4000e-004
Cm-242	3.5980e-006	1.3313e+005	1.2000e-005 -	4.4400e-001
Cm-244	6.2965e-007	2.3297e+004	2.1000e-006 -	7.7700e-002
Cs-134				
Eu-154	3.5980e+001	1.3313e+012	1.2000e+002 -	4.4400e+006
Eu-155	5.3970e-002	1.9969e+009	1.8000e-001 -	6.6600e+003
Np-237	3.5980e-003	1.3313e+008	1.2000e-002 -	4.4400e+002
Pa-233	3.5980e-003	1.3313e+008	1.2000e-002 -	4.4400e+002
Pm-147	5.6968e+000	2.1078e+011	1.9000e+001 -	7.0300e+005
Pr-144	5.9967e-009	2.2188e+002	2.0000e-008 -	7.4000e-004
Pu-238	1.4692e+002	5.4360e+012	4.9000e+002 -	1.8130e+007
Pu-239	2.3387e+000	8.6532e+010	7.8000e+000 -	2.8860e+005
Pu-240	2.1288e+000	7.8766e+010	7.1000e+000 -	2.6270e+005
Pu-241	6.8962e+001	2.5516e+012	2.3000e+002 -	8.5100e+006
Pu-242	4.7973e-003	1.7750e+008	1.6000e-002 -	5.9200e+002
Rh-106	3.8978e-008	1.4422e+003	1.3000e-007 -	4.8100e-003
Ru-106	3.8978e-008	1.4422e+003	1.3000e-007 -	4.8100e-003
Sm-151	2.0389e+002	7.5438e+012	6.8000e+002 -	2.5160e+007
Tc-99	8.9950e-001	3.3281e+010	3.0000e+000 -	1.1100e+005
Th-230	3.5980e-007	1.3313e+004	1.2000e-006 -	4.4400e-002
Th-231	9.5946e-006	3.5500e+005	3.2000e-005 -	1.1840e+000
U-232	7.1960e-006	2.6625e+005	2.4000e-005 -	8.8800e-001
U-233	4.4975e-007	1.6641e+004	1.5000e-006 -	5.5500e-002

Page : 2
 DOS File: T31ZIR.MS5
 Run Date: November 20, 1997
 Run Time: 4:18:51 AM
 Duration: 00:01:28

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
U-234	1.1693e-001	4.3266e+009	3.9000e-001 ✓	1.4430e+004
U-235	7.4958e-004	2.7735e+007	2.5000e-003 ✓	9.2500e+001
U-236	1.9489e-003	7.2110e+007	6.5000e-003 ✓	2.4050e+002
U-237	1.6491e-003	6.1016e+007	5.5000e-003 ✓	2.0350e+002
U-238	3.5980e-005	1.3313e+006	1.2000e-004 ✓	4.4400e+000

Buildup

The material reference is : Source

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Results</u>			
		<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
		<u>MeV/cm²/sec</u>	<u>MeV/cm²/sec</u>	<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.015	6.678e+02	6.190e-138	6.335e-30	5.309e-139	5.434e-31
0.02	2.231e+09	2.016e-58	3.330e-23	6.984e-60	1.153e-24
0.03	1.504e+10	5.772e-17	1.170e-16	5.720e-19	1.160e-18
0.04	2.713e+11	3.972e-05	1.281e-04	1.757e-07	5.664e-07
0.05	6.898e+10	9.907e-02	4.646e-01	2.639e-04	1.238e-03
0.06	2.188e+11	2.523e+01	1.524e+02	5.011e-02	3.027e-01
0.08	6.423e+08	3.930e+00	2.850e+01	6.218e-03	4.509e-02
0.1	5.392e+11	1.829e+04	1.339e+05	2.798e+01	2.049e+02
0.15	7.693e+06	1.450e+00	9.248e+00	2.388e-03	1.523e-02
0.2	9.095e+10	3.587e+04	2.021e+05	6.332e+01	3.568e+02
0.3	6.798e+07	6.041e+01	2.830e+02	1.146e-01	5.369e-01
0.4	9.503e+09	1.419e+04	5.803e+04	2.765e+01	1.131e+02
0.5	2.882e+09	6.368e+03	2.340e+04	1.250e+01	4.594e+01
0.6	1.074e+11	3.256e+05	1.094e+06	6.355e+02	2.135e+03
0.8	5.191e+11	2.591e+06	7.603e+06	4.928e+03	1.446e+04
1.0	4.095e+11	3.007e+06	7.986e+06	5.543e+03	1.472e+04
1.5	5.195e+11	7.644e+06	1.713e+07	1.286e+04	2.881e+04
2.0	1.717e+00	4.070e-05	8.237e-05	6.293e-08	1.274e-07
TOTALS:	2.775e+12	1.364e+07	3.423e+07	2.410e+04	6.085e+04

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
DOS File: T31ZIR.MS5
Run Date: November 20, 1997
Run Time: 4:23:28 AM
Duration: 00:01:26

File Ref: HKP-26-97
Date: 12/4/97
By: [Signature]
Checked: [Signature]

Case Title: T31zir

Description: R/hr @ 1 m from mod. canister surf. Zirconia calcine (T-31)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions
Height 91.0 cm 2 ft 11.8 in
Radius 32.385 cm 1 ft 0.7 in

Dose Points
1 X Y Z
133.02 cm 45.5 cm 0 cm
4 ft 4.4 in 1 ft 5.9 in 0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	3.00e+05 cm ³	Concrete	1.5
Shield 1	.635 cm	Iron	7.86
Transition	100.0 cm	Air	0.0011
Air Gap		Air	0.0011

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Am-241	1.6191e+001	5.9907e+011	5.4000e+001	1.9980e+006
Am-243	2.7884e-007	1.0317e+004	9.3000e-007	3.4410e-002
Ce-144	5.9967e-009	2.2188e+002	2.0000e-008	7.4000e-004
Cm-242	3.5980e-006	1.3313e+005	1.2000e-005	4.4400e-001
Cm-244	6.2965e-007	2.3297e+004	2.1000e-006	7.7700e-002
Cs-134				
Eu-154	3.5980e+001	1.3313e+012	1.2000e+002	4.4400e+006
Eu-155	5.3970e-002	1.9969e+009	1.8000e-001	6.6600e+003
Np-237	3.5980e-003	1.3313e+008	1.2000e-002	4.4400e+002
Pa-233	3.5980e-003	1.3313e+008	1.2000e-002	4.4400e+002
Pm-147	5.6968e+000	2.1078e+011	1.9000e+001	7.0300e+005
Pr-144	5.9967e-009	2.2188e+002	2.0000e-008	7.4000e-004
Pu-238	1.4692e+002	5.4360e+012	4.9000e+002	1.8130e+007
Pu-239	2.3387e+000	8.6532e+010	7.8000e+000	2.8860e+005
Pu-240	2.1288e+000	7.8766e+010	7.1000e+000	2.6270e+005
Pu-241	6.8962e+001	2.5516e+012	2.3000e+002	8.5100e+006
Pu-242	4.7973e-003	1.7750e+008	1.6000e-002	5.9200e+002
Rh-106	3.8978e-008	1.4422e+003	1.3000e-007	4.8100e-003
Ru-106	3.8978e-008	1.4422e+003	1.3000e-007	4.8100e-003
Sm-151	2.0389e+002	7.5438e+012	6.8000e+002	2.5160e+007
Tc-99	8.9950e-001	3.3281e+010	3.0000e+000	1.1100e+005
Th-230	3.5980e-007	1.3313e+004	1.2000e-006	4.4400e-002
Th-231	9.5946e-006	3.5500e+005	3.2000e-005	1.1840e+000
U-232	7.1960e-006	2.6625e+005	2.4000e-005	8.8800e-001
U-233	4.4975e-007	1.6641e+004	1.5000e-006	5.5500e-002

Page : 2
 DOS File: T31ZIR.MS5
 Run Date: November 20, 1997
 Run Time: 4:23:28 AM
 Duration: 00:01:26

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
U-234	1.1693e-001	4.3266e+009	3.9000e-001	1.4430e+004
U-235	7.4958e-004	2.7735e+007	2.5000e-003	9.2500e+001
U-236	1.9489e-003	7.2110e+007	6.5000e-003	2.4050e+002
U-237	1.6491e-003	6.1016e+007	5.5000e-003	2.0350e+002
U-238	3.5980e-005	1.3313e+006	1.2000e-004	4.4400e+000

Buildup

The material reference is : Transition

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Fluence Rate</u> <u>MeV/cm²/sec</u> <u>No Buildup</u>	<u>Results</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
			<u>Fluence Rate</u> <u>MeV/cm²/sec</u> <u>With Buildup</u>	<u>mR/hr</u> <u>No Buildup</u>	<u>mR/hr</u> <u>With Buildup</u>
0.015	6.678e+02	5.071e-132	7.273e-31	4.349e-133	6.238e-32
0.02	2.231e+09	5.413e-57	6.894e-24	1.875e-58	2.388e-25
0.03	1.504e+10	1.597e-17	4.970e-16	1.583e-19	4.925e-18
0.04	2.713e+11	7.061e-06	4.765e-04	3.123e-08	2.107e-06
0.05	6.898e+10	1.800e-02	1.598e+00	4.794e-05	4.257e-03
0.06	2.188e+11	4.441e+00	3.459e+02	8.821e-03	6.871e-01
0.08	6.423e+08	5.905e-01	2.532e+01	9.344e-04	4.008e-02
0.1	5.392e+11	2.413e+03	6.118e+04	3.691e+00	9.361e+01
0.15	7.693e+06	1.628e-01	1.968e+00	2.680e-04	3.240e-03
0.2	9.095e+10	3.773e+03	3.155e+04	6.660e+00	5.568e+01
0.3	6.798e+07	6.004e+00	3.415e+01	1.139e-02	6.477e-02
0.4	9.503e+09	1.368e+03	6.226e+03	2.666e+00	1.213e+01
0.5	2.882e+09	6.012e+02	2.348e+03	1.180e+00	4.609e+00
0.6	1.074e+11	3.023e+04	1.052e+05	5.900e+01	2.052e+02
0.8	5.191e+11	2.343e+05	6.892e+05	4.456e+02	1.311e+03
1.0	4.095e+11	2.664e+05	6.994e+05	4.911e+02	1.289e+03
1.5	5.195e+11	6.533e+05	1.426e+06	1.099e+03	2.400e+03
2.0	1.717e+00	3.400e-06	6.659e-06	5.257e-09	1.030e-08
TOTALS:	2.775e+12	1.192e+06	3.022e+06	2.109e+03	5.372e+03

MicroShield v5.01 (5.01-00121)
 Lockheed Martin Idaho Technologies Company
 Case File Heat Generation
 Case File: T31SBW16.MS5
 Case Title: T31SBW

<u>Isotope</u>	<u>Activity</u> <u>Curies</u>	<u>Activity</u> <u>Bequerels</u>	<u>Heat Generation</u> <u>Watts/Curie</u>	<u>Heat Generation</u> <u>Watts</u>
Ac-225	1.1777e-005	4.3576e+005	3.4574e-002	4.0718e-007
Ac-227	6.9218e-008	2.5611e+003	4.7208e-004	3.2676e-011
Ac-228	2.5144e-014	9.3032e-004	8.0395e-003	2.0214e-016
Am-241	2.6637e+000	9.8559e+010	3.2813e-002	8.7405e-002
At-217	1.1777e-005	4.3576e+005	4.1888e-002	4.9332e-007
Bi-210	5.6058e-010	2.0741e+001	2.3060e-003	1.2927e-012
Bi-211	6.8438e-008	2.5322e+003	3.9163e-002	2.6802e-009
Bi-212	2.0002e-014	7.4008e-004	1.6753e-002	3.3511e-016
Bi-213	1.1777e-005	4.3576e+005	4.1771e-003	4.9195e-008
Bi-214	3.3644e-009	1.2448e+002	1.2767e-002	4.2953e-011
Ce-144	4.9347e-006	1.8259e+005	6.6284e-004	3.2710e-009
Eu-154	1.8583e+000	6.8759e+010	9.0517e-003	1.6821e-002
Eu-155	3.0925e-001	1.1442e+010	7.2543e-004	2.2434e-004
Fr-221	1.1777e-005	4.3576e+005	3.7907e-002	4.4644e-007
Fr-223	9.5520e-010	3.5343e+001	2.5771e-003	2.4617e-012
Np-237	1.0001e-001	3.7005e+009	2.8779e-002	2.8783e-003
Pa-231	2.7728e-007	1.0259e+004	3.2329e-002	8.9642e-009
Pa-233	1.0001e-001	3.7005e+009	2.4276e-003	2.4279e-004
Pa-234	1.6000e-006	5.9200e+004	1.4604e-002	2.3366e-008
Pa-234m	1.0000e-003	3.7000e+007	4.9490e-003	4.9490e-006
Pb-209	1.1777e-005	4.3574e+005	1.1714e-003	1.3795e-008
Pb-210	5.6230e-010	2.0805e+001	2.3060e-004	1.2966e-013
Pb-211	6.8438e-008	2.5322e+003	2.9963e-003	2.0506e-010
Pb-212	2.0003e-014	7.4009e-004	1.9044e-003	3.8092e-017
Pb-214	3.3644e-009	1.2448e+002	3.1921e-003	1.0740e-011
Po-210	5.1557e-010	1.9076e+001	3.1446e-002	1.6212e-011
Po-211	1.8684e-010	6.9129e+000	4.4166e-002	8.2518e-012
Po-212	1.2815e-014	4.7417e-004	5.2078e-002	6.6740e-016
Po-213	1.1523e-005	4.2634e+005	4.9660e-002	5.7222e-007
Po-214	3.3637e-009	1.2446e+002	4.5570e-002	1.5328e-010
Po-215	6.8439e-008	2.5322e+003	4.3787e-002	2.9967e-009
Po-216	2.0006e-014	7.4021e-004	4.0184e-002	8.0390e-016
Po-218	3.3651e-009	1.2451e+002	3.5576e-002	1.1972e-010
Pr-144	4.9349e-006	1.8259e+005	7.3455e-003	3.6249e-008
Pr-144m	7.0568e-008	2.6110e+003	3.3653e-004	2.3748e-011
Pu-238	2.4958e+001	9.2346e+011	3.2587e-002	8.1332e-001
Pu-239	2.9984e+000	1.1094e+011	3.0551e-002	9.1602e-002
Pu-240	6.9860e-001	2.5848e+010	3.0614e-002	2.1387e-002
Pu-241	1.0819e+001	4.0029e+011	3.1003e-005	3.3541e-004
Pu-242	0.0000e+000	0.0000e+000	2.9184e-002	0.0000e+000
Ra-223	6.8439e-008	2.5322e+003	3.4973e-002	2.3935e-009
Ra-224	2.0006e-014	7.4021e-004	3.3714e-002	6.7447e-016
Ra-225	1.1802e-005	4.3667e+005	7.0678e-004	8.3414e-009
Ra-226	3.3707e-009	1.2472e+002	2.8394e-002	9.5708e-011
Ra-228	2.5146e-014	9.3039e-004	6.8576e-005	1.7244e-018
Rh-106	2.1196e-006	7.8425e+004	9.5998e-003	2.0348e-008
Rn-219	6.8439e-008	2.5322e+003	4.0502e-002	2.7719e-009
Rn-220	2.0006e-014	7.4021e-004	3.7278e-002	7.4577e-016
Rn-222	3.3651e-009	1.2451e+002	3.2543e-002	1.0951e-010
Ru-106	2.1196e-006	7.8425e+004	5.9459e-005	1.2603e-010

<u>Isotope</u>	<u>Activity</u> <u>Curies</u>	<u>Activity</u> <u>Becquerels</u>	<u>Heat Generation</u> <u>Watts/Curie</u>	<u>Heat Generation</u> <u>Watts</u>
Tc-99	1.0999e-001	4.0697e+009	5.0152e-004	5.5164e-005
Th-227	6.7781e-008	2.5079e+003	3.5868e-002	2.4312e-009
Th-228	2.0032e-014	7.4119e-004	3.2139e-002	6.4381e-016
Th-229	1.1838e-005	4.3802e+005	2.9977e-002	3.5487e-007
Th-230	8.6251e-007	3.1913e+004	2.7809e-002	2.3986e-008
Th-231	6.9006e-004	2.5532e+007	1.0580e-003	7.3006e-007
Th-232	4.1428e-014	1.5328e-003	2.3811e-002	9.8644e-016
Th-234	1.0000e-003	3.7000e+007	3.9682e-004	3.9682e-007
Tl-207	6.8251e-008	2.5253e+003	2.9369e-003	2.0045e-010
Tl-208	7.1868e-015	2.6591e-004	2.3467e-002	1.6865e-016
Tl-209	2.5439e-007	9.4123e+003	1.6632e-002	4.2310e-009
U-233	6.6077e-003	2.4448e+008	2.8557e-002	1.8869e-004
U-234	5.7503e-003	2.1276e+008	2.8311e-002	1.6280e-004
U-235	6.9006e-004	2.5532e+007	2.7115e-002	1.8711e-005
U-236	4.4393e-005	1.6426e+006	2.6697e-002	1.1852e-006
U-237	2.6540e-004	9.8197e+006	1.9366e-003	5.1397e-007
U-238	1.0000e-003	3.7000e+007	2.4920e-002	2.4920e-005

Total

Heat Generation:

1.0347e+000 ✓

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
DOS File: Case1
Run Date: November 25, 1997
Run Time: 5:55:39 PM
Duration: 00:01:31

File Ref: HKP-26-9
Date: 12/4/97
By: *[Signature]*
Checked: *[Signature]*

for 2016
[Signature]

Case Title: T31SBW
Description: R/hr @ 1 cm from canister surface with SBW (T31)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions

Height 122.0 cm 4 ft 0.0 in
Radius 32.385 cm 1 ft 0.7 in

Dose Points

	X	Y	Z
# 1	34.02 cm	61 cm	0 cm
	1 ft 1.4 in	2 ft 0.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	4.02e+05 cm ³	Concrete	1.5
Shield 1	.635 cm	Iron	7.86
Transition	1.0 cm	Air	0.0011
Air Gap		Air	0.0011

Source Input

Grouping Method : Standard Indices

Number of Groups : 25

Lower Energy Cutoff : 0.015

Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Ac-225	1.1777e-005	4.3576e+005	2.9299e-005	1.0840e+000
Ac-227	6.9218e-008	2.5611e+003	1.7220e-007	6.3712e-003
Ac-228	2.5144e-014	9.3032e-004	6.2551e-014	2.3144e-009
Am-241	2.6637e+000	9.8559e+010	6.6267e+000	2.4519e+005
At-217	1.1777e-005	4.3576e+005	2.9299e-005	1.0840e+000
Bi-210	5.6058e-010	2.0741e+001	1.3946e-009	5.1599e-005
Bi-211	6.8438e-008	2.5322e+003	1.7025e-007	6.2994e-003
Bi-212	2.0002e-014	7.4008e-004	4.9760e-014	1.8411e-009
Bi-213	1.1777e-005	4.3576e+005	2.9298e-005	1.0840e+000
Bi-214	3.3644e-009	1.2448e+002	8.3697e-009	3.0968e-004
Ce-144	4.9347e-006	1.8259e+005	1.2276e-005	4.5422e-001
Eu-154	1.8583e+000	6.8759e+010	4.6231e+000	1.7105e+005
Eu-155	3.0925e-001	1.1442e+010	7.6934e-001	2.8465e+004
Fr-221	1.1777e-005	4.3576e+005	2.9299e-005	1.0840e+000
Fr-223	9.5520e-010	3.5343e+001	2.3763e-009	8.7923e-005
Np-237	1.0001e-001	3.7005e+009	2.4881e-001	9.2059e+003
Pa-231	2.7728e-007	1.0259e+004	6.8980e-007	2.5522e-002
Pa-233	1.0001e-001	3.7005e+009	2.4881e-001	9.2059e+003
Pa-234	1.6000e-006	5.9200e+004	3.9804e-006	1.4727e-001
Pa-234m	1.0000e-003	3.7000e+007	2.4877e-003	9.2046e+001
Pb-209	1.1777e-005	4.3574e+005	2.9298e-005	1.0840e+000
Pb-210	5.6230e-010	2.0805e+001	1.3989e-009	5.1758e-005
Pb-211	6.8438e-008	2.5322e+003	1.7025e-007	6.2994e-003
Pb-212	2.0003e-014	7.4009e-004	4.9761e-014	1.8412e-009
Pb-214	3.3644e-009	1.2448e+002	8.3697e-009	3.0968e-004

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<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Po-210	5.1557e-010	1.9076e+001	1.2826e-009	4.7456e-005
Po-211	1.8684e-010	6.9129e+000	4.6479e-010	1.7197e-005
Po-212	1.2815e-014	4.7417e-004	3.1881e-014	1.1796e-009
Po-213	1.1523e-005	4.2634e+005	2.8666e-005	1.0606e+000
Po-214	3.3637e-009	1.2446e+002	8.3679e-009	3.0961e-004
Po-215	6.8439e-008	2.5322e+003	1.7026e-007	6.2995e-003
Po-216	2.0006e-014	7.4021e-004	4.9769e-014	1.8415e-009
Po-218	3.3651e-009	1.2451e+002	8.3715e-009	3.0974e-004
Pr-144	4.9349e-006	1.8259e+005	1.2277e-005	4.5424e-001
Pr-144m	7.0568e-008	2.6110e+003	1.7555e-007	6.4955e-003
Pu-238	2.4958e+001	9.2346e+011	6.2090e+001	2.2973e+006
Pu-239	2.9984e+000	1.1094e+011	7.4591e+000	2.7599e+005
Pu-240	6.9860e-001	2.5848e+010	1.7379e+000	6.4303e+004
Pu-241	1.0819e+001	4.0029e+011	2.6914e+001	9.9581e+005
Pu-242				
Ra-223	6.8439e-008	2.5322e+003	1.7026e-007	6.2995e-003
Ra-224	2.0006e-014	7.4021e-004	4.9769e-014	1.8415e-009
Ra-225	1.1802e-005	4.3667e+005	2.9360e-005	1.0863e+000
Ra-226	3.3707e-009	1.2472e+002	8.3855e-009	3.1026e-004
Ra-228	2.5146e-014	9.3039e-004	6.2556e-014	2.3146e-009
Rh-106	2.1196e-006	7.8425e+004	5.2730e-006	1.9510e-001
Rn-219	6.8439e-008	2.5322e+003	1.7026e-007	6.2995e-003
Rn-220	2.0006e-014	7.4021e-004	4.9769e-014	1.8415e-009
Rn-222	3.3651e-009	1.2451e+002	8.3715e-009	3.0974e-004
Ru-106	2.1196e-006	7.8425e+004	5.2730e-006	1.9510e-001
Tc-99	1.0999e-001	4.0697e+009	2.7363e-001	1.0124e+004
Th-227	6.7781e-008	2.5079e+003	1.6862e-007	6.2390e-003
Th-228	2.0032e-014	7.4119e-004	4.9835e-014	1.8439e-009
Th-229	1.1838e-005	4.3802e+005	2.9450e-005	1.0897e+000
Th-230	8.6251e-007	3.1913e+004	2.1457e-006	7.9391e-002
Th-231	6.9006e-004	2.5532e+007	1.7167e-003	6.3517e+001
Th-232	4.1428e-014	1.5328e-003	1.0306e-013	3.8133e-009
Th-234	1.0000e-003	3.7000e+007	2.4877e-003	9.2046e+001
Tl-207	6.8251e-008	2.5253e+003	1.6979e-007	6.2822e-003
Tl-208	7.1868e-015	2.6591e-004	1.7879e-014	6.6152e-010
Tl-209	2.5439e-007	9.4123e+003	6.3284e-007	2.3415e-002
U-233	6.6077e-003	2.4448e+008	1.6438e-002	6.0821e+002
U-234	5.7503e-003	2.1276e+008	1.4305e-002	5.2929e+002
U-235	6.9006e-004	2.5532e+007	1.7167e-003	6.3517e+001
U-236	4.4393e-005	1.6426e+006	1.1044e-004	4.0862e+000
U-237	2.6540e-004	9.8197e+006	6.6023e-004	2.4429e+001
U-238	1.0000e-003	3.7000e+007	2.4877e-003	9.2046e+001

Buildup

The material reference is : Source

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

Results

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<u>Energy</u>	<u>Activity</u>	<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
<u>MeV</u>	<u>photons/sec</u>	<u>MeV/cm²/sec</u>	<u>MeV/cm²/sec</u>	<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.015	4.879e+04	8.578e-138	3.795e-28	7.358e-139	3.255e-29
0.02	4.119e+01	5.890e-67	5.042e-31	2.040e-68	1.746e-32
0.03	3.028e+09	6.183e-18	1.254e-17	6.127e-20	1.243e-19
0.04	1.607e+10	1.727e-06	5.590e-06	7.638e-09	2.472e-08
0.05	4.248e+09	4.788e-03	2.247e-02	1.276e-05	5.985e-05
0.06	3.616e+10	3.237e+00	1.945e+01	6.430e-03	3.863e-02
0.08	4.145e+09	1.914e+01	1.379e+02	3.028e-02	2.182e-01
0.1	3.188e+10	8.094e+02	5.908e+03	1.238e+00	9.038e+00
0.15	6.760e+07	9.515e+00	6.061e+01	1.567e-02	9.980e-02
0.2	4.727e+09	1.392e+03	7.839e+03	2.456e+00	1.383e+01
0.3	1.853e+09	1.228e+03	5.758e+03	2.330e+00	1.092e+01
0.4	6.207e+08	6.915e+02	2.831e+03	1.347e+00	5.516e+00
0.5	1.489e+08	2.455e+02	9.035e+02	4.818e-01	1.774e+00
0.6	5.546e+09	1.255e+04	4.226e+04	2.450e+01	8.248e+01
0.8	2.681e+10	9.991e+04	2.942e+05	1.900e+02	5.596e+02
1.0	2.115e+10	1.160e+05	3.096e+05	2.139e+02	5.706e+02
1.5	2.683e+10	2.956e+05	6.668e+05	4.973e+02	1.122e+03
2.0	2.515e+03	4.473e-02	9.132e-02	6.917e-05	1.412e-04
3.0	2.654e-04	8.965e-09	1.613e-08	1.216e-11	2.189e-11
TOTALS:	1.833e+11	5.285e+05	1.336e+06	9.336e+02	2.376e+03

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
DOS File: T31SBW16.MS5
Run Date: November 25, 1997
Run Time: 6:03:02 PM
Duration: 00:01:31

File Ref: HKP-26
Date: 12/4/97
By: [Signature]
Checked: [Signature]

Case Title: T31SBW
Description: R/hr @ 1 m from canister surface with SBW (T31)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions
Height 122.0 cm 4 ft 0.0 in
Radius 32.385 cm 1 ft 0.7 in

Dose Points
1 X Y Z
133.02 cm 61 cm 0 cm
4 ft 4.4 in 2 ft 0.0 in 0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	4.02e+05 cm ³	Concrete	1.5
Shield 1	.635 cm	Iron	7.86
Transition	100.0 cm	Air	0.0011
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Ac-225	1.1777e-005	4.3576e+005	2.9299e-005	1.0840e+000
Ac-227	6.9218e-008	2.5611e+003	1.7220e-007	6.3712e-003
Ac-228	2.5144e-014	9.3032e-004	6.2551e-014	2.3144e-009
Am-241	2.6637e+000	9.8559e+010	6.6267e+000	2.4519e+005
At-217	1.1777e-005	4.3576e+005	2.9299e-005	1.0840e+000
Bi-210	5.6058e-010	2.0741e+001	1.3946e-009	5.1599e-005
Bi-211	6.8438e-008	2.5322e+003	1.7025e-007	6.2994e-003
Bi-212	2.0002e-014	7.4008e-004	4.9760e-014	1.8411e-009
Bi-213	1.1777e-005	4.3576e+005	2.9298e-005	1.0840e+000
Bi-214	3.3644e-009	1.2448e+002	8.3697e-009	3.0968e-004
Ce-144	4.9347e-006	1.8259e+005	1.2276e-005	4.5422e-001
Eu-154	1.8583e+000	6.8759e+010	4.6231e+000	1.7105e+005
Eu-155	3.0925e-001	1.1442e+010	7.6934e-001	2.8465e+004
Fr-221	1.1777e-005	4.3576e+005	2.9299e-005	1.0840e+000
Fr-223	9.5520e-010	3.5343e+001	2.3763e-009	8.7923e-005
Np-237	1.0001e-001	3.7005e+009	2.4881e-001	9.2059e+003
Pa-231	2.7728e-007	1.0259e+004	6.8980e-007	2.5522e-002
Pa-233	1.0001e-001	3.7005e+009	2.4881e-001	9.2059e+003
Pa-234	1.6000e-006	5.9200e+004	3.9804e-006	1.4727e-001
Pa-234m	1.0000e-003	3.7000e+007	2.4877e-003	9.2046e+001
Pb-209	1.1777e-005	4.3574e+005	2.9298e-005	1.0840e+000
Pb-210	5.6230e-010	2.0805e+001	1.3989e-009	5.1758e-005
Pb-211	6.8438e-008	2.5322e+003	1.7025e-007	6.2994e-003
Pb-212	2.0003e-014	7.4009e-004	4.9761e-014	1.8412e-009
Pb-214	3.3644e-009	1.2448e+002	8.3697e-009	3.0968e-004

Page : 2
 DOS File: T31SBW16.MS5
 Run Date: November 25, 1997
 Run Time: 6:03:02 PM
 Duration: 00:01:31

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Po-210	5.1557e-010	1.9076e+001	1.2826e-009	4.7456e-005
Po-211	1.8684e-010	6.9129e+000	4.6479e-010	1.7197e-005
Po-212	1.2815e-014	4.7417e-004	3.1881e-014	1.1796e-009
Po-213	1.1523e-005	4.2634e+005	2.8666e-005	1.0606e+000
Po-214	3.3637e-009	1.2446e+002	8.3679e-009	3.0961e-004
Po-215	6.8439e-008	2.5322e+003	1.7026e-007	6.2995e-003
Po-216	2.0006e-014	7.4021e-004	4.9769e-014	1.8415e-009
Po-218	3.3651e-009	1.2451e+002	8.3715e-009	3.0974e-004
Pr-144	4.9349e-006	1.8259e+005	1.2277e-005	4.5424e-001
Pr-144m	7.0568e-008	2.6110e+003	1.7555e-007	6.4955e-003
Pu-238	2.4958e+001	9.2346e+011	6.2090e+001	2.2973e+006
Pu-239	2.9984e+000	1.1094e+011	7.4591e+000	2.7599e+005
Pu-240	6.9860e-001	2.5848e+010	1.7379e+000	6.4303e+004
Pu-241	1.0819e+001	4.0029e+011	2.6914e+001	9.9581e+005
Pu-242				
Ra-223	6.8439e-008	2.5322e+003	1.7026e-007	6.2995e-003
Ra-224	2.0006e-014	7.4021e-004	4.9769e-014	1.8415e-009
Ra-225	1.1802e-005	4.3667e+005	2.9360e-005	1.0863e+000
Ra-226	3.3707e-009	1.2472e+002	8.3855e-009	3.1026e-004
Ra-228	2.5146e-014	9.3039e-004	6.2556e-014	2.3146e-009
Rh-106	2.1196e-006	7.8425e+004	5.2730e-006	1.9510e-001
Rn-219	6.8439e-008	2.5322e+003	1.7026e-007	6.2995e-003
Rn-220	2.0006e-014	7.4021e-004	4.9769e-014	1.8415e-009
Rn-222	3.3651e-009	1.2451e+002	8.3715e-009	3.0974e-004
Ru-106	2.1196e-006	7.8425e+004	5.2730e-006	1.9510e-001
Tc-99	1.0999e-001	4.0697e+009	2.7363e-001	1.0124e+004
Th-227	6.7781e-008	2.5079e+003	1.6862e-007	6.2390e-003
Th-228	2.0032e-014	7.4119e-004	4.9835e-014	1.8439e-009
Th-229	1.1838e-005	4.3802e+005	2.9450e-005	1.0897e+000
Th-230	8.6251e-007	3.1913e+004	2.1457e-006	7.9391e-002
Th-231	6.9006e-004	2.5532e+007	1.7167e-003	6.3517e+001
Th-232	4.1428e-014	1.5328e-003	1.0306e-013	3.8133e-009
Th-234	1.0000e-003	3.7000e+007	2.4877e-003	9.2046e+001
Tl-207	6.8251e-008	2.5253e+003	1.6979e-007	6.2822e-003
Tl-208	7.1868e-015	2.6591e-004	1.7879e-014	6.6152e-010
Tl-209	2.5439e-007	9.4123e+003	6.3284e-007	2.3415e-002
U-233	6.6077e-003	2.4448e+008	1.6438e-002	6.0821e+002
U-234	5.7503e-003	2.1276e+008	1.4305e-002	5.2929e+002
U-235	6.9006e-004	2.5532e+007	1.7167e-003	6.3517e+001
U-236	4.4393e-005	1.6426e+006	1.1044e-004	4.0862e+000
U-237	2.6540e-004	9.8197e+006	6.6023e-004	2.4429e+001
U-238	1.0000e-003	3.7000e+007	2.4877e-003	9.2046e+001

Buildup

The material reference is : Transition

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

Results

Page : 3
 DOS File: T31SBW16.MS5
 Run Date: November 25, 1997
 Run Time: 6:03:02 PM
 Duration: 00:01:31

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Fluence Rate</u> <u>MeV/cm²/sec</u> <u>No Buildup</u>	<u>Fluence Rate</u> <u>MeV/cm²/sec</u> <u>With Buildup</u>	<u>Exposure Rate</u> <u>mR/hr</u> <u>No Buildup</u>	<u>Exposure Rate</u> <u>mR/hr</u> <u>With Buildup</u>
0.015	4.879e+04	2.763e-130	5.160e-29	2.370e-131	4.426e-30
0.02	4.119e+01	7.456e-65	1.236e-31	2.583e-66	4.283e-33
0.03	3.028e+09	2.409e-18	7.499e-17	2.387e-20	7.432e-19
0.04	1.607e+10	3.257e-07	2.210e-05	1.441e-09	9.775e-08
0.05	4.248e+09	9.116e-04	8.206e-02	2.428e-06	2.186e-04
0.06	3.616e+10	6.292e-01	4.997e+01	1.250e-03	9.926e-02
0.08	4.145e+09	3.413e+00	1.497e+02	5.401e-03	2.369e-01
0.1	3.188e+10	1.302e+02	3.373e+03	1.992e-01	5.160e+00
0.15	6.760e+07	1.327e+00	1.633e+01	2.185e-03	2.689e-02
0.2	4.727e+09	1.830e+02	1.554e+03	3.229e-01	2.743e+00
0.3	1.853e+09	1.533e+02	8.838e+02	2.908e-01	1.677e+00
0.4	6.207e+08	8.394e+01	3.866e+02	1.635e-01	7.533e-01
0.5	1.489e+08	2.921e+01	1.154e+02	5.734e-02	2.265e-01
0.6	5.546e+09	1.470e+03	5.170e+03	2.870e+00	1.009e+01
0.8	2.681e+10	1.142e+04	3.392e+04	2.172e+01	6.453e+01
1.0	2.115e+10	1.301e+04	3.445e+04	2.398e+01	6.351e+01
1.5	2.683e+10	3.199e+04	7.038e+04	5.383e+01	1.184e+02
2.0	2.515e+03	4.731e-03	9.330e-03	7.316e-06	1.443e-05
3.0	2.654e-04	9.218e-10	1.592e-09	1.251e-12	2.160e-12
TOTALS:	1.833e+11	5.848e+04	1.505e+05	1.034e+02	2.675e+02

MicroShield v5.01 (5.01-00121)
 Lockheed Martin Idaho Technologies Company
 Case File Heat Generation
 Case File: T32ALUM.MS5
 Case Title: T32Alum

<u>Isotope</u>	<u>Activity</u> <u>Curies</u>	<u>Activity</u> <u>Bequerels</u>	<u>Heat Generation</u> <u>Watts/Curie</u>	<u>Heat Generation</u> <u>Watts</u>
Am-241	1.1743e-003	4.3448e+007	3.2813e-002	3.8531e-005
Am-243	4.1633e-008	1.5404e+003	3.1704e-002	1.3200e-009
Ba-137m	5.8607e+002	2.1685e+013	3.9212e-003	2.2981e+000
Ce-144	3.9498e-019	1.4614e-008	6.6284e-004	2.6181e-022
Cm-242	3.3093e-008	1.2244e+003	3.6240e-002	1.1993e-009
Cm-244	6.6186e-008	2.4489e+003	3.4409e-002	2.2774e-009
Cs-134	3.2026e-006	1.1849e+005	1.0179e-002	3.2599e-008
Cs-137	6.1916e+002	2.2909e+013	1.0122e-003	6.2674e-001
Eu-154	3.5228e-003	1.3034e+008	9.0517e-003	3.1887e-005
Eu-155	2.1350e-004	7.8996e+006	7.2543e-004	1.5488e-007
Np-237	8.7537e-015	3.2389e-004	2.8779e-002	2.5192e-016
Pa-233	8.7537e-015	3.2389e-004	2.4276e-003	2.1250e-017
Pm-147	2.8823e-005	1.0665e+006	3.6731e-004	1.0587e-008
Pr-144	3.8933e-019	1.4405e-008	7.3455e-003	2.8599e-021
Pu-238	5.3376e-011	1.9749e+000	3.2587e-002	1.7394e-012
Pu-239	6.7254e-012	2.4884e-001	3.0551e-002	2.0546e-013
Pu-240	2.6688e-012	9.8746e-002	3.0614e-002	8.1704e-014
Pu-241	2.3485e-011	8.6896e-001	3.1003e-005	7.2813e-016
Pu-242	2.0283e-016	7.5047e-006	2.9184e-002	5.9194e-018
Rh-106	4.2701e-014	1.5799e-003	9.5998e-003	4.0992e-016
Ru-106	4.2701e-014	1.5799e-003	5.9459e-005	2.5389e-018
Sb-125	9.2874e-005	3.4363e+006	3.1431e-003	2.9191e-007
Sm-151	6.7254e-001	2.4884e+010	1.1729e-004	7.8880e-005
Sr-90	5.6579e+002	2.0934e+013	1.1607e-003	6.5672e-001
Tc-99	2.3485e-001	8.6896e+009	5.0152e-004	1.1778e-004
Th-230	8.5402e-005	3.1599e+006	2.7809e-002	2.3749e-006
Th-231	1.4945e-005	5.5298e+005	1.0580e-003	1.5812e-008
U-232	6.4051e-020	2.3699e-009	3.1553e-002	2.0210e-021
U-233	6.7254e-020	2.4884e-009	2.8557e-002	1.9205e-021
U-234	1.4945e-015	5.5298e-005	2.8311e-002	4.2312e-017
U-235	9.6077e-018	3.5548e-007	2.7115e-002	2.6052e-019
U-236	2.3485e-017	8.6896e-007	2.6697e-002	6.2699e-019
U-237	2.0283e-018	7.5047e-008	1.9366e-003	3.9280e-021
U-238	5.5511e-019	2.0539e-008	2.4920e-002	1.3833e-020
Y-90	5.6579e+002	2.0934e+013	5.5411e-003	3.1351e+000

Total

Heat Generation:

6.7169e+000

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
DOS File: Case1
Run Date: November 20, 1997
Run Time: 4:54:56 AM
Duration: 00:01:31

File Ref: HKP-26
Date: 12/4/96
By: DH/ghd
Checked: 92/3/97

Case Title: T32Alum
Description: R/hr @ 1 cm from culvert with Class C Grout (T32)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions
Height 162.56 cm 5 ft 4.0 in
Radius 45.72 cm 1 ft 6.0 in

Dose Points
1 X Y Z
 56.88 cm 81.28 cm - 0 cm
 1 ft 10.4 in 2 ft 8.0 in 0.0 in

Shields
Shield Name Dimension Material Densit
Source 1.07e+06 cm³ Concrete 1.8
Shield 1 10.16 cm Concrete 2.35
Transition 1.0 cm ✓ Air 0.0011
Air Gap Air 0.0011

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded
Library : Grove

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Am-241	1.1743e-003	4.3448e+007	1.1000e-003 ✓	4.0700e+001
Am-243	4.1633e-008	1.5404e+003	3.9000e-008 ✓	1.4430e-003
Ba-137m	5.8607e+002	2.1685e+013	5.4900e+002 ✓	2.0313e+007
Ce-144	3.9498e-019	1.4614e-008	3.7000e-019 ✓	1.3690e-014
Cm-242	3.3093e-008	1.2244e+003	3.1000e-008 ✓	1.1470e-003
Cm-244	6.6186e-008	2.4489e+003	6.2000e-008 ✓	2.2940e-003
Cs-134	3.2026e-006	1.1849e+005	3.0000e-006 ✓	1.1100e-001
Cs-137	6.1916e+002	2.2909e+013	5.8000e+002 ✓	2.1460e+007
Eu-154	3.5228e-003	1.3034e+008	3.3000e-003 ✓	1.2210e+002
Eu-155	2.1350e-004	7.8996e+006	2.0000e-004 ✓	7.4000e+000
Np-237	8.7537e-015	3.2389e-004	8.2000e-015 ✓	3.0340e-010
Pa-233	8.7537e-015	3.2389e-004	8.2000e-015 ✓	3.0340e-010
Pm-147	2.8823e-005	1.0665e+006	2.7000e-005 ✓	9.9900e-001
Pr-144	3.8933e-019	1.4405e-008	3.6471e-019 ✓	1.3494e-014
Pu-238	5.3376e-011	1.9749e+000	5.0000e-011 ✓	1.8500e-006
Pu-239	6.7254e-012	2.4884e-001	6.3000e-012 ✓	2.3310e-007
Pu-240	2.6688e-012	9.8746e-002	2.5000e-012 ✓	9.2500e-008
Pu-241	2.3485e-011	8.6896e-001	2.2000e-011 ✓	8.1400e-007
Pu-242	2.0283e-016	7.5047e-006	1.9000e-016 ✓	7.0300e-012
Rh-106	4.2701e-014	1.5799e-003	4.0000e-014 ✓	1.4800e-009
Ru-106	4.2701e-014	1.5799e-003	4.0000e-014 ✓	1.4800e-009
Sb-125	9.2874e-005	3.4363e+006	8.7000e-005 ✓	3.2190e+000
Sm-151	6.7254e-001	2.4884e+010	6.3000e-001 ✓	2.3310e+004
Sr-90	5.6579e+002	2.0934e+013	5.3000e+002 ✓	1.9610e+007
Tc-99	2.3485e-001	8.6896e+009	2.2000e-001 ✓	8.1400e+003

Page : 2
 DOS File: Case1
 Run Date: November 20, 1997
 Run Time: 4:54:56 AM
 Duration: 00:01:31

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Th-230	8.5402e-005	3.1599e+006	8.0000e-005	2.9600e+000
Th-231	1.4945e-005	5.5298e+005	1.4000e-005	5.1800e-001
U-232	6.4051e-020	2.3699e-009	6.0000e-020	2.2200e-015
U-233	6.7254e-020	2.4884e-009	6.3000e-020	2.3310e-015
U-234	1.4945e-015	5.5298e-005	1.4000e-015	5.1800e-011
U-235	9.6077e-018	3.5548e-007	9.0000e-018	3.3300e-013
U-236	2.3485e-017	8.6896e-007	2.2000e-017	8.1400e-013
U-237	2.0283e-018	7.5047e-008	1.9000e-018	7.0300e-014
U-238	5.5511e-019	2.0539e-008	5.2000e-019	1.9240e-014
Y-90	5.6579e+002	2.0934e+013	5.3000e+002	1.9610e+007

Buildup
 The material reference is : Source

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Results</u>			
		<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
		<u>MeV/cm²/sec</u> <u>No Buildup</u>	<u>MeV/cm²/sec</u> <u>With Buildup</u>	<u>mR/hr</u> <u>No Buildup</u>	<u>mR/hr</u> <u>With Buildup</u>
0.015	1.040e+03	5.039e-93	3.000e-30	4.322e-94	2.573e-31
0.02	7.358e+06	5.515e-41	3.339e-26	1.910e-42	1.157e-27
0.03	1.277e+12	3.607e-10	6.973e-10	3.575e-12	6.911e-12
0.04	3.014e+11	4.035e-04	1.214e-03	1.784e-06	5.368e-06
0.05	7.204e+06	3.526e-06	1.631e-05	9.394e-09	4.344e-08
0.06	1.579e+07	1.336e-04	8.848e-04	2.654e-07	1.757e-06
0.08	2.554e+06	2.976e-04	3.066e-03	4.709e-07	4.852e-06
0.1	5.440e+07	2.137e-02	2.812e-01	3.270e-05	4.303e-04
0.15	1.165e+04	1.985e-05	3.061e-04	3.269e-08	5.041e-07
0.2	9.162e+06	3.568e-02	5.267e-01	6.297e-05	9.296e-04
0.3	1.437e+04	1.644e-04	1.979e-03	3.119e-07	3.753e-06
0.4	2.006e+06	4.825e-02	4.763e-01	9.402e-05	9.281e-04
0.5	6.397e+05	2.723e-02	2.266e-01	5.345e-05	4.448e-04
0.6	1.951e+13	1.318e+06	9.501e+06	2.573e+03	1.855e+04
0.8	5.094e+07	7.092e+00	4.091e+01	1.349e-02	7.781e-02
1.0	4.010e+07	9.729e+00	4.747e+01	1.793e-02	8.749e-02
1.5	5.086e+07	3.317e+01	1.223e+02	5.581e-02	2.058e-01
2.0	1.115e-10	1.420e-16	4.426e-16	2.195e-19	6.845e-19
TOTALS:	2.109e+13	1.318e+06	9.501e+06	2.573e+03	1.855e+04

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
DOS File: T32ALUM.MS5
Run Date: November 20, 1997
Run Time: 5:02:51 AM
Duration: 00:01:29

File Ref: HKP-216-
Date: 12/4/99
By: [Signature]
Checked: [Signature]

Case Title: T32Alum
Description: R/hr @ 1 m from culvert with Alum. Class C Grout (T32)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions

Height 162.56 cm ✓ 5 ft 4.0 in
Radius 45.72 cm ✓ 1 ft 6.0 in

Dose Points

	<u>X</u>	<u>Y</u>	<u>Z</u>
# 1	155.88 cm	81.28 cm	0 cm
	5 ft 1.4 in	2 ft 8.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Densit
Source	1.07e+06 cm ³	Concrete	1.8
Shield 1	10.16 cm	Concrete	2.35
Transition	100.0 cm	Air	0.0011
Air Gap		Air	0.0012

Source Input

Grouping Method : Standard Indices

Number of Groups : 25

Lower Energy Cutoff : 0.015

Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Am-241	1.1743e-003	4.3448e+007	1.1000e-003 ✓	4.0700e+001
Am-243	4.1633e-008	1.5404e+003	3.9000e-008 ✓	1.4430e-003
Ba-137m	5.8607e+002	2.1685e+013	5.4900e+002 ✓	2.0313e+007
Ce-144	3.9498e-019	1.4614e-008	3.7000e-019 ✓	1.3690e-014
Cm-242	3.3093e-008	1.2244e+003	3.1000e-008 ✓	1.1470e-003
Cm-244	6.6186e-008	2.4489e+003	6.2000e-008 ✓	2.2940e-003
Cs-134	3.2026e-006	1.1849e+005	3.0000e-006 ✓	1.1100e-001
Cs-137	6.1916e+002	2.2909e+013	5.8000e+002 ✓	2.1460e+007
Eu-154	3.5228e-003	1.3034e+008	3.3000e-003 ✓	1.2210e+002
Eu-155	2.1350e-004	7.8996e+006	2.0000e-004 ✓	7.4000e+000
Np-237	8.7537e-015	3.2389e-004	8.2000e-015 ✓	3.0340e-010
Pa-233	8.7537e-015	3.2389e-004	8.2000e-015 ✓	3.0340e-010
Pm-147	2.8823e-005	1.0665e+006	2.7000e-005 ✓	9.9900e-001
Pr-144	3.8933e-019	1.4405e-008	3.6471e-019 ✓	1.3494e-014
Pu-238	5.3376e-011	1.9749e+000	5.0000e-011 ✓	1.8500e-006
Pu-239	6.7254e-012	2.4884e-001	6.3000e-012 ✓	2.3310e-007
Pu-240	2.6688e-012	9.8746e-002	2.5000e-012 ✓	9.2500e-008
Pu-241	2.3485e-011	8.6896e-001	2.2000e-011 ✓	8.1400e-007
Pu-242	2.0283e-016	7.5047e-006	1.9000e-016 ✓	7.0300e-012
Rh-106	4.2701e-014	1.5799e-003	4.0000e-014 ✓	1.4800e-009
Ru-106	4.2701e-014	1.5799e-003	4.0000e-014 ✓	1.4800e-009
Sb-125	9.2874e-005	3.4363e+006	8.7000e-005 ✓	3.2190e+000
Sm-151	6.7254e-001	2.4884e+010	6.3000e-001 ✓	2.3310e+004
Sr-90	5.6579e+002	2.0934e+013	5.3000e+002 ✓	1.9610e+007
Tc-99	2.3485e-001	8.6896e+009	2.2000e-001 ✓	8.1400e+003

Page : 2
 DOS File: T32ALUM.MS5
 Run Date: November 20, 1997
 Run Time: 5:02:51 AM
 Duration: 00:01:29

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Th-230	8.5402e-005	3.1599e+006	8.0000e-005	2.9600e+000
Th-231	1.4945e-005	5.5298e+005	1.4000e-005	5.1800e-001
U-232	6.4051e-020	2.3699e-009	6.0000e-020	2.2200e-015
U-233	6.7254e-020	2.4884e-009	6.3000e-020	2.3310e-015
U-234	1.4945e-015	5.5298e-005	1.4000e-015	5.1800e-011
U-235	9.6077e-018	3.5548e-007	9.0000e-018	3.3300e-013
U-236	2.3485e-017	8.6896e-007	2.2000e-017	8.1400e-013
U-237	2.0283e-018	7.5047e-008	1.9000e-018	7.0300e-014
U-238	5.5511e-019	2.0539e-008	5.2000e-019	1.9240e-014
Y-90	5.6579e+002	2.0934e+013	5.3000e+002	1.9610e+007

Buildup

The material reference is : Shield 1

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

Results

<u>Energy</u>	<u>Activity</u>	<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
<u>MeV</u>	<u>photons/sec</u>	<u>MeV/cm²/sec</u>	<u>MeV/cm²/sec</u>	<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.015	1.040e+03	1.024e-93	4.742e-31	8.783e-95	4.067e-32
0.02	7.358e+06	1.514e-41	5.278e-27	5.244e-43	1.828e-28
0.03	1.277e+12	1.325e-10	2.561e-10	1.313e-12	2.538e-12
0.04	3.014e+11	1.394e-04	4.190e-04	6.167e-07	1.853e-06
0.05	7.204e+06	1.189e-06	5.483e-06	3.167e-09	1.461e-08
0.06	1.579e+07	4.396e-05	2.889e-04	8.731e-08	5.739e-07
0.08	2.554e+06	9.410e-05	9.507e-04	1.489e-07	1.504e-06
0.1	5.440e+07	6.594e-03	8.409e-02	1.009e-05	1.287e-04
0.15	1.165e+04	5.927e-06	8.690e-05	9.760e-09	1.431e-07
0.2	9.162e+06	1.044e-02	1.450e-01	1.843e-05	2.558e-04
0.3	1.437e+04	4.676e-05	5.237e-04	8.871e-08	9.934e-07
0.4	2.006e+06	1.342e-02	1.228e-01	2.616e-05	2.393e-04
0.5	6.397e+05	7.437e-03	5.725e-02	1.460e-05	1.124e-04
0.6	1.951e+13	3.542e+05	2.360e+06	6.914e+02	4.607e+03
0.8	5.094e+07	1.855e+00	9.890e+00	3.527e-03	1.881e-02
1.0	4.010e+07	2.487e+00	1.123e+01	4.584e-03	2.070e-02
1.5	5.086e+07	8.109e+00	2.778e+01	1.364e-02	4.673e-02
2.0	1.115e-10	3.360e-17	9.763e-17	5.195e-20	1.510e-19
TOTALS:	2.109e+13	3.542e+05	2.360e+06	6.914e+02	4.607e+03

MicroShield v5.01 (5.01-00121)
 Lockheed Martin Idaho Technologies Company
 Case File Heat Generation
 Case File: T32ZIR.MS5
 Case Title: T32Zir

<u>Isotope</u>	<u>Activity</u> <u>Curies</u>	<u>Activity</u> <u>Bequerels</u>	<u>Heat Generation</u> <u>Watts/Curie</u>	<u>Heat Generation</u> <u>Watts</u>
Am-241	8.9672e-003	3.3179e+008	3.2813e-002	2.9424e-004
Am-243	1.4945e-010	5.5298e+000	3.1704e-002	4.7383e-012
Ba-137m	3.9391e+002	1.4575e+013	3.9212e-003	1.5446e+000
Ce-144	1.3878e-011	5.1348e-001	6.6284e-004	9.1988e-015
Cm-242	1.9215e-009	7.1097e+001	3.6240e-002	6.9637e-011
Cm-244	3.4161e-010	1.2639e+001	3.4409e-002	1.1754e-011
Cs-134	1.1743e-003	4.3448e+007	1.0179e-002	1.1953e-005
Cs-135	0.0000e+000	0.0000e+000	3.3375e-004	0.0000e+000
Cs-137	4.1633e+002	1.5404e+013	1.0122e-003	4.2143e-001
Eu-154	2.0283e-002	7.5047e+008	9.0517e-003	1.8359e-004
Eu-155	2.9891e-005	1.1060e+006	7.2543e-004	2.1683e-008
Np-237	1.6013e-015	5.9247e-005	2.8779e-002	4.6084e-017
Pa-233	1.6013e-015	5.9247e-005	2.4276e-003	3.8872e-018
Pm-147	3.0958e-003	1.1454e+008	3.6731e-004	1.1371e-006
Pr-144	1.3878e-011	5.1348e-001	7.3455e-003	1.0194e-013
Pu-238	1.0035e-009	3.7128e+001	3.2587e-002	3.2700e-011
Pu-239	1.6013e-011	5.9247e-001	3.0551e-002	4.8920e-013
Pu-240	1.4945e-011	5.5298e-001	3.0614e-002	4.5754e-013
Pu-241	4.6971e-010	1.7379e+001	3.1003e-005	1.4563e-014
Pu-242	3.3093e-014	1.2244e-003	2.9184e-002	9.6580e-016
Rh-106	2.3485e-008	8.6896e+002	9.5998e-003	2.2545e-010
Ru-106	2.3485e-008	8.6896e+002	5.9459e-005	1.3964e-012
Sb-125	7.5794e-003	2.8044e+008	3.1431e-003	2.3823e-005
Sm-151	5.0173e-001	1.8564e+010	1.1729e-004	5.8847e-005
Sr-90	5.4444e+002	2.0144e+013	1.1607e-003	6.3194e-001
Tc-99	9.7144e-002	3.5943e+009	5.0152e-004	4.8720e-005
Th-230	1.1743e-006	4.3448e+004	2.7809e-002	3.2656e-008
Th-231	3.2026e-005	1.1849e+006	1.0580e-003	3.3882e-008
U-232	1.7080e-019	6.3197e-009	3.1553e-002	5.3894e-021
U-233	1.0675e-020	3.9498e-010	2.8557e-002	3.0485e-022
U-234	2.7756e-015	1.0270e-004	2.8311e-002	7.8580e-017
U-235	1.7080e-017	6.3197e-007	2.7115e-002	4.6314e-019
U-236	4.5903e-017	1.6984e-006	2.6697e-002	1.2255e-018
U-237	3.9498e-017	1.4614e-006	1.9366e-003	7.6492e-020
U-238	8.5402e-019	3.1599e-008	2.4920e-002	2.1282e-020
Y-90	5.4444e+002	2.0144e+013	5.5411e-003	3.0168e+000

Total

Heat Generation:

5.6154e+000 ✓

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
DOS File: T32ZIR.MS5
Run Date: November 20, 1997
Run Time: 5:18:47 AM
Duration: 00:01:28

File Ref: HKP-26-97
Date: 12/4/97
By: gld
Checked: gld

Case Title: T32Zir

Description: R/hr @ 1 cm from culvert with Zir. Class C Grout (T32)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions

Height 162.56 cm / 5 ft 4.0 in
Radius 45.72 cm / 1 ft 6.0 in

Dose Points

1 X Y Z
 56.88 cm / 81.28 cm 0 cm
 1 ft 10.4 in / 2 ft 8.0 in 0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	1.07e+06 cm ³	Concrete	1.8
Shield 1	10.16 cm	Concrete	2.35
Transition	1.0 cm	Air	0.0011
Air Gap		Air	0.00122

Source Input

Grouping Method : Standard Indices

Number of Groups : 25

Lower Energy Cutoff : 0.015

Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Am-241	8.9672e-003	3.3179e+008	8.4000e-003	3.1080e+002
Am-243	1.4945e-010	5.5298e+000	1.4000e-010	5.1800e-006
Ba-137m	3.9391e+002	1.4575e+013	3.6900e+002	1.3653e+007
Ce-144	1.3878e-011	5.1348e-001	1.3000e-011	4.8100e-007
Cm-242	1.9215e-009	7.1097e+001	1.8000e-009	6.6600e-005
Cm-244	3.4161e-010	1.2639e+001	3.2000e-010	1.1840e-005
Cs-134	1.1743e-003	4.3448e+007	1.1000e-003	4.0700e+001
Cs-135				
Cs-137	4.1633e+002	1.5404e+013	3.9000e+002	1.4430e+007
Eu-154	2.0283e-002	7.5047e+008	1.9000e-002	7.0300e+002
Eu-155	2.9891e-005	1.1060e+006	2.8000e-005	1.0360e+000
Np-237	1.6013e-015	5.9247e-005	1.5000e-015	5.5500e-011
Pa-233	1.6013e-015	5.9247e-005	1.5000e-015	5.5500e-011
Pm-147	3.0958e-003	1.1454e+008	2.9000e-003	1.0730e+002
Pr-144	1.3878e-011	5.1348e-001	1.3000e-011	4.8100e-007
Pu-238	1.0035e-009	3.7128e+001	9.4000e-010	3.4780e-005
Pu-239	1.6013e-011	5.9247e-001	1.5000e-011	5.5500e-007
Pu-240	1.4945e-011	5.5298e-001	1.4000e-011	5.1800e-007
Pu-241	4.6971e-010	1.7379e+001	4.4000e-010	1.6280e-005
Pu-242	3.3093e-014	1.2244e-003	3.1000e-014	1.1470e-009
Rh-106	2.3485e-008	8.6896e+002	2.2000e-008	8.1400e-004
Ru-106	2.3485e-008	8.6896e+002	2.2000e-008	8.1400e-004
Sb-125	7.5794e-003	2.8044e+008	7.1000e-003	2.6270e+002
Sm-151	5.0173e-001	1.8564e+010	4.7000e-001	1.7390e+004
Sr-90	5.4444e+002	2.0144e+013	5.1000e+002	1.8870e+007

Page : 2
 DOS File: T32ZIR.MS5
 Run Date: November 20, 1997
 Run Time: 5:18:47 AM
 Duration: 00:01:28

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Tc-99	9.7144e-002	3.5943e+009	9.1000e-002 ✓	3.3670e+003
Th-230	1.1743e-006	4.3448e+004	1.1000e-006 ✓	4.0700e-002
Th-231	3.2026e-005	1.1849e+006	3.0000e-005 ✓	1.1100e+000
U-232	1.7080e-019	6.3197e-009	1.6000e-019 ✓	5.9200e-015
U-233	1.0675e-020	3.9498e-010	1.0000e-020 ✓	3.7000e-016
U-234	2.7756e-015	1.0270e-004	2.6000e-015 ✓	9.6200e-011
U-235	1.7080e-017	6.3197e-007	1.6000e-017 ✓	5.9200e-013
U-236	4.5903e-017	1.6984e-006	4.3000e-017 ✓	1.5910e-012
U-237	3.9498e-017	1.4614e-006	3.7000e-017 ✓	1.3690e-012
U-238	8.5402e-019	3.1599e-008	8.0000e-019 ✓	2.9600e-014
Y-90	5.4444e+002	2.0144e+013	5.1000e+002 ✓	1.8870e+007

Buildup
 The material reference is : Source

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Results</u>		<u>Exposure Rate</u>	
		<u>Fluence Rate</u> <u>MeV/cm²/sec</u> <u>No Buildup</u>	<u>Fluence Rate</u> <u>MeV/cm²/sec</u> <u>With Buildup</u>	<u>Exposure Rate</u> <u>mR/hr</u> <u>No Buildup</u>	<u>Exposure Rate</u> <u>mR/hr</u> <u>With Buildup</u>
0.015	2.229e+03	1.080e-92	6.429e-30	9.261e-94	5.514e-31
0.02	5.489e+06	4.114e-41	2.491e-26	1.425e-42	8.629e-28
0.03	8.586e+11	2.425e-10	4.688e-10	2.403e-12	4.646e-12
0.04	2.028e+11	2.714e-04	8.164e-04	1.200e-06	3.610e-06
0.05	3.886e+07	1.902e-05	8.796e-05	5.067e-08	2.343e-07
0.06	1.197e+08	1.013e-03	6.707e-03	2.012e-06	1.332e-05
0.08	4.696e+05	5.472e-05	5.638e-04	8.660e-08	8.923e-07
0.1	3.047e+08	1.197e-01	1.575e+00	1.831e-04	2.410e-03
0.15	7.057e+05	1.202e-03	1.854e-02	1.980e-06	3.053e-05
0.2	7.254e+07	2.825e-01	4.170e+00	4.985e-04	7.359e-03
0.3	1.185e+06	1.355e-02	1.631e-01	2.571e-05	3.094e-04
0.4	9.316e+07	2.241e+00	2.212e+01	4.367e-03	4.310e-02
0.5	3.129e+07	1.332e+00	1.109e+01	2.615e-03	2.176e-02
0.6	1.311e+13	8.860e+05	6.386e+06	1.729e+03	1.247e+04
0.8	3.336e+08	4.644e+01	2.679e+02	8.833e-02	5.095e-01
1.0	2.321e+08	5.631e+01	2.747e+02	1.038e-01	5.064e-01
1.5	2.942e+08	1.918e+02	7.073e+02	3.228e-01	1.190e+00
2.0	3.975e-03	5.060e-09	1.578e-08	7.825e-12	2.440e-11
TOTALS:	1.418e+13	8.863e+05	6.387e+06	1.730e+03	1.247e+04

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
DOS File: T32ALUM.MS5
Run Date: November 20, 1997
Run Time: 5:15:11 AM
Duration: 00:01:27

File Ref: HKP-2697
Date: 12/4/97
By: [Signature]
Checked: [Signature]

Case Title: T32Zir
Description: R/hr @ 1 m from culvert with Zir. Class C Grout (T32)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions
Height 162.56 cm / 5 ft 4.0 in
Radius 45.72 cm / 1 ft 6.0 in

Dose Points
1 X Y Z
 155.88 cm / 81.28 cm / 0 cm
 5 ft 1.4 in 2 ft 8.0 in 0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	1.07e+06 cm ³	Concrete	1.8
Shield 1	10.16 cm	Concrete	2.35
Transition	100.0 cm	Air	0.0011
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Am-241	8.9672e-003	3.3179e+008	8.4000e-003	3.1080e+002
Am-243	1.4945e-010	5.5298e+000	1.4000e-010	5.1800e-006
Ba-137m	3.9391e+002	1.4575e+013	3.6900e+002	1.3653e+007
Ce-144	1.3878e-011	5.1348e-001	1.3000e-011	4.8100e-007
Cm-242	1.9215e-009	7.1097e+001	1.8000e-009	6.6600e-005
Cm-244	3.4161e-010	1.2639e+001	3.2000e-010	1.1840e-005
Cs-134	1.1743e-003	4.3448e+007	1.1000e-003	4.0700e+001
Cs-135				
Cs-137	4.1633e+002	1.5404e+013	3.9000e+002	1.4430e+007
Eu-154	2.0283e-002	7.5047e+008	1.9000e-002	7.0300e+002
Eu-155	2.9891e-005	1.1060e+006	2.8000e-005	1.0360e+000
Np-237	1.6013e-015	5.9247e-005	1.5000e-015	5.5500e-011
Pa-233	1.6013e-015	5.9247e-005	1.5000e-015	5.5500e-011
Pm-147	3.0958e-003	1.1454e+008	2.9000e-003	1.0730e+002
Pr-144	1.3878e-011	5.1348e-001	1.3000e-011	4.8100e-007
Pu-238	1.0035e-009	3.7128e+001	9.4000e-010	3.4780e-005
Pu-239	1.6013e-011	5.9247e-001	1.5000e-011	5.5500e-007
Pu-240	1.4945e-011	5.5298e-001	1.4000e-011	5.1800e-007
Pu-241	4.6971e-010	1.7379e+001	4.4000e-010	1.6280e-005
Pu-242	3.3093e-014	1.2244e-003	3.1000e-014	1.1470e-009
Rh-106	2.3485e-008	8.6896e+002	2.2000e-008	8.1400e-004
Ru-106	2.3485e-008	8.6896e+002	2.2000e-008	8.1400e-004
Sb-125	7.5794e-003	2.8044e+008	7.1000e-003	2.6270e+002
Sm-151	5.0173e-001	1.8564e+010	4.7000e-001	1.7390e+004
Sr-90	5.4444e+002	2.0144e+013	5.1000e+002	1.8870e+007

Page : 2
 DOS File: T32ALUM.MS5
 Run Date: November 20, 1997
 Run Time: 5:15:11 AM
 Duration: 00:01:27

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Tc-99	9.7144e-002	3.5943e+009	9.1000e-002	3.3670e+003
Th-230	1.1743e-006	4.3448e+004	1.1000e-006	4.0700e-002
Th-231	3.2026e-005	1.1849e+006	3.0000e-005	1.1100e+000
U-232	1.7080e-019	6.3197e-009	1.6000e-019	5.9200e-015
U-233	1.0675e-020	3.9498e-010	1.0000e-020	3.7000e-016
U-234	2.7756e-015	1.0270e-004	2.6000e-015	9.6200e-011
U-235	1.7080e-017	6.3197e-007	1.6000e-017	5.9200e-013
U-236	4.5903e-017	1.6984e-006	4.3000e-017	1.5910e-012
U-237	3.9498e-017	1.4614e-006	3.7000e-017	1.3690e-012
U-238	8.5402e-019	3.1599e-008	8.0000e-019	2.9600e-014
Y-90	5.4444e+002	2.0144e+013	5.1000e+002	1.8870e+007

Buildup

The material reference is : Transition

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Results</u>			
		<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
		<u>MeV/cm²/sec</u>	<u>MeV/cm²/sec</u>	<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.015	2.229e+03	2.194e-93	1.705e-30	1.882e-94	1.462e-31
0.02	5.489e+06	1.129e-41	1.191e-26	3.912e-43	4.127e-28
0.03	8.586e+11	8.908e-11	1.866e-09	8.828e-13	1.849e-11
0.04	2.028e+11	9.378e-05	4.774e-03	4.148e-07	2.112e-05
0.05	3.886e+07	6.412e-06	5.355e-04	1.708e-08	1.427e-06
0.06	1.197e+08	3.332e-04	3.330e-02	6.619e-07	6.614e-05
0.08	4.696e+05	1.731e-05	1.673e-03	2.739e-08	2.648e-06
0.1	3.047e+08	3.693e-02	2.995e+00	5.650e-05	4.582e-03
0.15	7.057e+05	3.589e-04	1.805e-02	5.910e-07	2.972e-05
0.2	7.254e+07	8.267e-02	2.829e+00	1.459e-04	4.993e-03
0.3	1.185e+06	3.855e-03	7.680e-02	7.313e-06	1.457e-04
0.4	9.316e+07	6.235e-01	8.614e+00	1.215e-03	1.678e-02
0.5	3.129e+07	3.638e-01	3.858e+00	7.140e-04	7.572e-03
0.6	1.311e+13	2.381e+05	2.055e+06	4.647e+02	4.011e+03
0.8	3.336e+08	1.214e+01	7.794e+01	2.310e-02	1.482e-01
1.0	2.321e+08	1.439e+01	7.494e+01	2.653e-02	1.381e-01
1.5	2.942e+08	4.690e+01	1.756e+02	7.890e-02	2.955e-01
2.0	3.975e-03	1.198e-09	3.701e-09	1.852e-12	5.723e-12
TOTALS:	1.418e+13	2.382e+05	2.056e+06	4.649e+02	4.012e+03

MicroShield v5.01 (5.01-00121)
 Lockheed Martin Idaho Technologies Company
 Case File Heat Generation
 Case File: T32SBW.MS5
 Case Title: T32SBW

<u>Isotope</u>	<u>Activity Curies</u>	<u>Activity Bequerels</u>	<u>Heat Generation Watts/Curie</u>	<u>Heat Generation Watts</u>
Ac-225	2.2163e-019	8.2002e-009	3.4574e-002	7.6624e-021
Ac-227	5.6765e-022	2.1003e-011	4.7208e-004	2.6797e-025
Ac-228	2.1092e-028	7.8041e-018	8.0395e-003	1.6957e-030
Am-241	8.3874e-007	3.1033e+004	3.2813e-002	2.7521e-008
Am-243	2.1312e-045	7.8856e-035	3.1704e-002	6.7569e-047
At-217	2.2163e-019	8.2001e-009	4.1888e-002	9.2834e-021
Ba-137m	1.3053e-001	4.8297e+009	3.9212e-003	5.1185e-004
Bi-210	6.2659e-024	2.3184e-013	2.3060e-003	1.4449e-026
Bi-211	5.6125e-022	2.0766e-011	3.9163e-002	2.1980e-023
Bi-212	1.6745e-028	6.1957e-018	1.6753e-002	2.8054e-030
Bi-213	2.2162e-019	8.2000e-009	4.1771e-003	9.2574e-022
Bi-214	4.0211e-023	1.4878e-012	1.2767e-002	5.1337e-025
Ce-144	2.1072e-010	7.7965e+000	6.6284e-004	1.3967e-013
Cm-242	2.7027e-056	1.0000e-045	3.6240e-002	9.7948e-058
Cm-244	6.1906e-044	2.2905e-033	3.4409e-002	2.1301e-045
Cs-134	6.8291e-006	2.5268e+005	1.0179e-002	6.9514e-008
Cs-137	1.3798e-001	5.1054e+009	1.0122e-003	1.3967e-004
Eu-154	6.6924e-007	2.4762e+004	9.0517e-003	6.0578e-009
Eu-155	2.8512e-007	1.0549e+004	7.2543e-004	2.0683e-010
Fr-221	2.2163e-019	8.2001e-009	3.7907e-002	8.4012e-021
Fr-223	7.8335e-024	2.8984e-013	2.5771e-003	2.0188e-026
Np-237	5.2411e-012	1.9392e-001	2.8779e-002	1.5084e-013
Np-239	2.1312e-045	7.8856e-035	2.4625e-003	5.2482e-048
Pa-231	2.2741e-021	8.4141e-011	3.2329e-002	7.3518e-023
Pa-233	5.2122e-012	1.9285e-001	2.4276e-003	1.2653e-014
Pa-234	1.3664e-020	5.0558e-010	1.4604e-002	1.9955e-022
Pa-234m	8.5402e-018	3.1599e-007	4.9490e-003	4.2265e-020
Pb-209	2.2161e-019	8.1995e-009	1.1714e-003	2.5959e-022
Pb-210	6.2867e-024	2.3261e-013	2.3060e-004	1.4497e-027
Pb-211	5.6125e-022	2.0766e-011	2.9963e-003	1.6817e-024
Pb-212	1.6745e-028	6.1958e-018	1.9044e-003	3.1890e-031
Pb-214	4.0211e-023	1.4878e-012	3.1921e-003	1.2836e-025
Pm-147	1.1984e-045	4.4342e-035	3.6731e-004	4.4020e-049
Po-210	5.7254e-024	2.1184e-013	3.1446e-002	1.8004e-025
Po-211	1.5322e-024	5.6692e-014	4.4166e-002	6.7672e-026
Po-212	1.0729e-028	3.9696e-018	5.2078e-002	5.5872e-030
Po-213	2.1684e-019	8.0229e-009	4.9660e-002	1.0768e-020
Po-214	4.0202e-023	1.4875e-012	4.5570e-002	1.8320e-024
Po-215	5.6126e-022	2.0766e-011	4.3787e-002	2.4576e-023
Po-216	1.6748e-028	6.1968e-018	4.0184e-002	6.7300e-030
Po-218	4.0219e-023	1.4881e-012	3.5576e-002	1.4309e-024
Pr-144	2.1072e-010	7.7968e+000	7.3455e-003	1.5479e-012
Pr-144m	3.0133e-012	1.1149e-001	3.3653e-004	1.0141e-015
Pu-238	1.1025e-012	4.0792e-002	3.2587e-002	3.5927e-014
Pu-239	1.3870e-013	5.1320e-003	3.0551e-002	4.2374e-015
Pu-240	3.4092e-014	1.2614e-003	3.0614e-002	1.0437e-015
Pu-241	5.1329e-013	1.8992e-002	3.1003e-005	1.5914e-017
Pu-242	9.5006e-018	3.5152e-007	2.9184e-002	2.7727e-019
Ra-223	5.6126e-022	2.0766e-011	3.4973e-002	1.9629e-023
Ra-224	1.6748e-028	6.1968e-018	3.3714e-002	5.6464e-030

<u>Isotope</u>	<u>Activity</u> <u>Curies</u>	<u>Activity</u> <u>Bequerels</u>	<u>Heat Generation</u> <u>Watts/Curie</u>	<u>Heat Generation</u> <u>Watts</u>
Ra-225	2.2262e-019	8.2369e-009	7.0678e-004	1.5734e-022
Ra-226	4.0295e-023	1.4909e-012	2.8394e-002	1.1441e-024
Ra-228	2.1094e-028	7.8047e-018	6.8576e-005	1.4465e-032
Rh-106	5.8831e-006	2.1767e+005	9.5998e-003	5.6476e-008
Rn-219	5.6126e-022	2.0766e-011	4.0502e-002	2.2732e-023
Rn-220	1.6748e-028	6.1968e-018	3.7278e-002	6.2433e-030
Rn-222	4.0219e-023	1.4881e-012	3.2543e-002	1.3089e-024
Ru-106	5.8831e-006	2.1767e+005	5.9459e-005	3.4980e-010
Sb-125	4.7814e-003	1.7691e+008	3.1431e-003	1.5028e-005
Sm-147	4.4618e-054	1.6509e-043	1.3324e-002	5.9448e-056
Sr-90	3.3679e+001	1.2461e+012	1.1607e-003	3.9092e-002
Te-125m	1.1717e-003	4.3352e+007	9.4493e-004	1.1071e-006
Th-227	5.5587e-022	2.0567e-011	3.5868e-002	1.9938e-023
Th-228	1.6770e-028	6.2051e-018	3.2139e-002	5.3898e-030
Th-229	2.2409e-019	8.2915e-009	2.9977e-002	6.7176e-021
Th-230	1.1641e-020	4.3070e-010	2.7809e-002	3.2372e-022
Th-231	5.6605e-018	2.0944e-007	1.0580e-003	5.9886e-021
Th-232	3.4922e-028	1.2921e-017	2.3811e-002	8.3152e-030
Th-234	8.5402e-018	3.1599e-007	3.9682e-004	3.3889e-021
Tl-207	5.5972e-022	2.0709e-011	2.9369e-003	1.6438e-024
Tl-208	6.0165e-029	2.2261e-018	2.3467e-002	1.4119e-030
Tl-209	4.7870e-021	1.7712e-010	1.6632e-002	7.9619e-023
U-233	2.6883e-016	9.9468e-006	2.8557e-002	7.6769e-018
U-234	9.9298e-017	3.6740e-006	2.8311e-002	2.8113e-018
U-235	5.6605e-018	2.0944e-007	2.7115e-002	1.5349e-019
U-236	3.8215e-019	1.4140e-008	2.6697e-002	1.0202e-020
U-237	1.2592e-017	4.6590e-007	1.9366e-003	2.4385e-020
U-238	8.5402e-018	3.1599e-007	2.4920e-002	2.1282e-019
Y-90	3.3688e+001	1.2464e+012	5.5411e-003	1.8667e-001

Total

Heat Generation:

2.2643e-001 ✓

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

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DOS File: T32ALUM.MS5
Run Date: November 24, 1997
Run Time: 5:04:05 PM
Duration: 00:01:35

File Ref: HKP-26-97
Date: 12/4/97
By: AKK/epam
Checked: AKK

for 2016
AKK

Case Title: T32SBW

Description: R/hr @ 1 cm from culvert with Class C Grout/SBW (T32)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions

Height 162.56 cm / 5 ft 4.0 in
Radius 45.72 cm / 1 ft 6.0 in

Dose Points

	X	Y	Z
# 1	56.88 cm / 1 ft 10.4 in	81.28 cm / 2 ft 8.0 in	0 cm / 0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	1.07e+06 cm ³	Concrete	1.8
Shield 1	10.16 cm	Concrete	2.35
Transition	1.0 cm	Air	0.0011
Air Gap		Air	0.00122

Source Input

Grouping Method : Standard Indices

Number of Groups : 25

Lower Energy Cutoff : 0.015

Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Ac-225	2.2163e-019	8.2002e-009	2.0761e-019	7.6815e-015
Ac-227	5.6765e-022	2.1003e-011	5.3174e-022	1.9675e-017
Ac-228	2.1092e-028	7.8041e-018	1.9758e-028	7.3105e-024
Am-241	8.3874e-007	3.1033e+004	7.8569e-007	2.9071e-002
Am-243	2.1312e-045	7.8856e-035	1.9964e-045	7.3868e-041
At-217	2.2163e-019	8.2001e-009	2.0761e-019	7.6815e-015
Ba-137m	1.3053e-001	4.8297e+009	1.2228e-001	4.5242e+003
Bi-210	6.2659e-024	2.3184e-013	5.8695e-024	2.1717e-019
Bi-211	5.6125e-022	2.0766e-011	5.2575e-022	1.9453e-017
Bi-212	1.6745e-028	6.1957e-018	1.5686e-028	5.8038e-024
Bi-213	2.2162e-019	8.2000e-009	2.0760e-019	7.6814e-015
Bi-214	4.0211e-023	1.4878e-012	3.7667e-023	1.3937e-018
Ce-144	2.1072e-010	7.7965e+000	1.9739e-010	7.3034e-006
Cm-242	2.7027e-056	1.0000e-045	2.5318e-056	9.3676e-052
Cm-244	6.1906e-044	2.2905e-033	5.7991e-044	2.1457e-039
Cs-134	6.8291e-006	2.5268e+005	6.3971e-006	2.3669e-001
Cs-137	1.3798e-001	5.1054e+009	1.2926e-001	4.7825e+003
Eu-154	6.6924e-007	2.4762e+004	6.2691e-007	2.3196e-002
Eu-155	2.8512e-007	1.0549e+004	2.6708e-007	9.8820e-003
Fr-221	2.2163e-019	8.2001e-009	2.0761e-019	7.6815e-015
Fr-223	7.8335e-024	2.8984e-013	7.3380e-024	2.7151e-019
Np-237	5.2411e-012	1.9392e-001	4.9096e-012	1.8166e-007
Np-239	2.1312e-045	7.8856e-035	1.9964e-045	7.3868e-041
Pa-231	2.2741e-021	8.4141e-011	2.1302e-021	7.8819e-017
Pa-233	5.2122e-012	1.9285e-001	4.8825e-012	1.8065e-007

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 Duration: 00:01:35

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Pa-234	1.3664e-020	5.0558e-010	1.2800e-020	4.7360e-016
Pa-234m	8.5402e-018	3.1599e-007	8.0000e-018	2.9600e-013
Pb-209	2.2161e-019	8.1995e-009	2.0759e-019	7.6809e-015
Pb-210	6.2867e-024	2.3261e-013	5.8891e-024	2.1790e-019
Pb-211	5.6125e-022	2.0766e-011	5.2575e-022	1.9453e-017
Pb-212	1.6745e-028	6.1958e-018	1.5686e-028	5.8039e-024
Pb-214	4.0211e-023	1.4878e-012	3.7668e-023	1.3937e-018
Pm-147	1.1984e-045	4.4342e-035	1.1226e-045	4.1537e-041
Po-210	5.7254e-024	2.1184e-013	5.3633e-024	1.9844e-019
Po-211	1.5322e-024	5.6692e-014	1.4353e-024	5.3106e-020
Po-212	1.0729e-028	3.9696e-018	1.0050e-028	3.7185e-024
Po-213	2.1684e-019	8.0229e-009	2.0312e-019	7.5155e-015
Po-214	4.0202e-023	1.4875e-012	3.7659e-023	1.3934e-018
Po-215	5.6126e-022	2.0766e-011	5.2576e-022	1.9453e-017
Po-216	1.6748e-028	6.1968e-018	1.5689e-028	5.8049e-024
Po-218	4.0219e-023	1.4881e-012	3.7676e-023	1.3940e-018
Pr-144	2.1072e-010	7.7968e+000	1.9740e-010	7.3037e-006
Pr-144m	3.0133e-012	1.1149e-001	2.8227e-012	1.0444e-007
Pu-238	1.1025e-012	4.0792e-002	1.0328e-012	3.8212e-008
Pu-239	1.3870e-013	5.1320e-003	1.2993e-013	4.8074e-009
Pu-240	3.4092e-014	1.2614e-003	3.1936e-014	1.1816e-009
Pu-241	5.1329e-013	1.8992e-002	4.8083e-013	1.7791e-008
Pu-242	9.5006e-018	3.5152e-007	8.8997e-018	3.2929e-013
Ra-223	5.6126e-022	2.0766e-011	5.2576e-022	1.9453e-017
Ra-224	1.6748e-028	6.1968e-018	1.5689e-028	5.8049e-024
Ra-225	2.2262e-019	8.2369e-009	2.0854e-019	7.7159e-015
Ra-226	4.0295e-023	1.4909e-012	3.7747e-023	1.3966e-018
Ra-228	2.1094e-028	7.8047e-018	1.9760e-028	7.3111e-024
Rh-106	5.8831e-006	2.1767e+005	5.5110e-006	2.0391e-001
Rn-219	5.6126e-022	2.0766e-011	5.2576e-022	1.9453e-017
Rn-220	1.6748e-028	6.1968e-018	1.5689e-028	5.8049e-024
Rn-222	4.0219e-023	1.4881e-012	3.7676e-023	1.3940e-018
Ru-106	5.8831e-006	2.1767e+005	5.5110e-006	2.0391e-001
Sb-125	4.7814e-003	1.7691e+008	4.4790e-003	1.6572e+002
Sm-147	4.4618e-054	1.6509e-043	4.1796e-054	1.5464e-049
Sr-90	3.3679e+001	1.2461e+012	3.1549e+001	1.1673e+006
Te-125m	1.1717e-003	4.3352e+007	1.0976e-003	4.0610e+001
Th-227	5.5587e-022	2.0567e-011	5.2071e-022	1.9266e-017
Th-228	1.6770e-028	6.2051e-018	1.5710e-028	5.8126e-024
Th-229	2.2409e-019	8.2915e-009	2.0992e-019	7.7671e-015
Th-230	1.1641e-020	4.3070e-010	1.0904e-020	4.0346e-016
Th-231	5.6605e-018	2.0944e-007	5.3024e-018	1.9619e-013
Th-232	3.4922e-028	1.2921e-017	3.2713e-028	1.2104e-023
Th-234	8.5402e-018	3.1599e-007	8.0000e-018	2.9600e-013
Tl-207	5.5972e-022	2.0709e-011	5.2431e-022	1.9400e-017
Tl-208	6.0165e-029	2.2261e-018	5.6360e-029	2.0853e-024
Tl-209	4.7870e-021	1.7712e-010	4.4843e-021	1.6592e-016
U-233	2.6883e-016	9.9468e-006	2.5183e-016	9.3177e-012
U-234	9.9298e-017	3.6740e-006	9.3017e-017	3.4416e-012
U-235	5.6605e-018	2.0944e-007	5.3024e-018	1.9619e-013
U-236	3.8215e-019	1.4140e-008	3.5798e-019	1.3245e-014
U-237	1.2592e-017	4.6590e-007	1.1795e-017	4.3643e-013
U-238	8.5402e-018	3.1599e-007	8.0000e-018	2.9600e-013
Y-90	3.3688e+001	1.2464e+012	3.1557e+001	1.1676e+006

: e : 3
 File: T32ALUM.MS5
 Run Date: November 24, 1997
 Run Time: 5:04:05 PM
 Duration: 00:01:35

Buildup
 The material reference is : Source

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

<u>Energy</u> MeV	<u>Activity</u> photons/sec	<u>Results</u>			
		<u>Fluence Rate</u> MeV/cm ² /sec	<u>Fluence Rate</u> MeV/cm ² /sec	<u>Exposure Rate</u> mR/hr	<u>Exposure Rate</u> mR/hr
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.015	4.083e-10	1.978e-105	1.178e-42	1.697e-106	1.010e-43
0.02	3.378e-13	2.532e-60	1.533e-45	8.771e-62	5.311e-47
0.03	4.132e+08	1.167e-13	2.256e-13	1.156e-15	2.236e-15
0.04	7.732e+07	1.035e-07	3.113e-07	4.577e-10	1.377e-09
0.05	1.902e+03	9.310e-10	4.305e-09	2.480e-12	1.147e-11
0.06	1.133e+04	9.588e-08	6.349e-07	1.904e-10	1.261e-09
0.08	3.276e+03	3.817e-07	3.933e-06	6.041e-10	6.224e-09
0.1	5.967e+05	2.344e-04	3.085e-03	3.586e-07	4.720e-06
0.15	4.440e+05	7.564e-04	1.167e-02	1.246e-06	1.921e-05
0.2	1.343e+07	5.229e-02	7.720e-01	9.230e-05	1.362e-03
0.3	7.379e+05	8.440e-03	1.016e-01	1.601e-05	1.927e-04
0.4	5.539e+07	1.332e+00	1.315e+01	2.596e-03	2.563e-02
0.5	1.836e+07	7.817e-01	6.505e+00	1.534e-03	1.277e-02
0.6	4.410e+09	2.979e+02	2.147e+03	5.815e-01	4.191e+00
0.8	2.484e+05	3.458e-02	1.995e-01	6.578e-05	3.794e-04
1.0	1.932e+04	4.687e-03	2.287e-02	8.640e-06	4.215e-05
1.5	1.895e+04	1.236e-02	4.556e-02	2.079e-05	7.665e-05
2.0	6.035e-02	7.684e-08	2.396e-07	1.188e-10	3.705e-10
3.0	2.222e-18	6.827e-24	1.725e-23	9.262e-27	2.341e-26
TOTALS:	4.989e+09	3.001e+02	2.168e+03	5.858e-01	4.232e+00

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

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DOS File: T32ALUM.MS5
Run Date: November 24, 1997
Run Time: 5:10:40 PM
Duration: 00:01:32

File Ref: HKP-26
Date: 12/4/96
By: [Signature]
Checked: [Signature]

for 2016
[Signature]

Case Title: T32SBW

Description: R/hr @ 1 m from culvert with Class C Grout/SBW (T32)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions

Height 162.56 cm / 5 ft 4.0 in
Radius 45.72 cm / 1 ft 6.0 in

Dose Points

1 X 155.88 cm / 5 ft 1.4 in Y 81.28 cm / 2 ft 8.0 in Z 0 cr / 0.0 in

Shields

Shield Name	Dimension	Material	Densit
Source	1.07e+06 cm ³	Concrete	1.8
Shield 1	10.16 cm	Concrete	2.35
Transition	100.0 cm	Air	0.0011
Air Gap		Air	0.0012

Source Input

Grouping Method : Standard Indices

Number of Groups : 25

Lower Energy Cutoff : 0.015

Photons < 0.015 : Excluded

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Ac-225	2.2163e-019	8.2002e-009	2.0761e-019	7.6815e-015
Ac-227	5.6765e-022	2.1003e-011	5.3174e-022	1.9675e-017
Ac-228	2.1092e-028	7.8041e-018	1.9758e-028	7.3105e-024
Am-241	8.3874e-007	3.1033e+004	7.8569e-007	2.9071e-002
Am-243	2.1312e-045	7.8856e-035	1.9964e-045	7.3868e-041
At-217	2.2163e-019	8.2001e-009	2.0761e-019	7.6815e-015
Ba-137m	1.3053e-001	4.8297e+009	1.2228e-001	4.5242e+003
Bi-210	6.2659e-024	2.3184e-013	5.8695e-024	2.1717e-019
Bi-211	5.6125e-022	2.0766e-011	5.2575e-022	1.9453e-017
Bi-212	1.6745e-028	6.1957e-018	1.5686e-028	5.8038e-024
Bi-213	2.2162e-019	8.2000e-009	2.0760e-019	7.6814e-015
Bi-214	4.0211e-023	1.4878e-012	3.7667e-023	1.3937e-018
Ce-144	2.1072e-010	7.7965e+000	1.9739e-010	7.3034e-006
Cm-242	2.7027e-056	1.0000e-045	2.5318e-056	9.3676e-052
Cm-244	6.1906e-044	2.2905e-033	5.7991e-044	2.1457e-039
Cs-134	6.8291e-006	2.5268e+005	6.3971e-006	2.3669e-001
Cs-137	1.3798e-001	5.1054e+009	1.2926e-001	4.7825e+003
Eu-154	6.6924e-007	2.4762e+004	6.2691e-007	2.3196e-002
Eu-155	2.8512e-007	1.0549e+004	2.6708e-007	9.8820e-003
Fr-221	2.2163e-019	8.2001e-009	2.0761e-019	7.6815e-015
Fr-223	7.8335e-024	2.8984e-013	7.3380e-024	2.7151e-019
Np-237	5.2411e-012	1.9392e-001	4.9096e-012	1.8166e-007
Np-239	2.1312e-045	7.8856e-035	1.9964e-045	7.3868e-041
Pa-231	2.2741e-021	8.4141e-011	2.1302e-021	7.8819e-017
Pa-233	5.2122e-012	1.9285e-001	4.8825e-012	1.8065e-007

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<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Pa-234	1.3664e-020	5.0558e-010	1.2800e-020	4.7360e-016
Pa-234m	8.5402e-018	3.1599e-007	8.0000e-018	2.9600e-013
Pb-209	2.2161e-019	8.1995e-009	2.0759e-019	7.6809e-015
Pb-210	6.2867e-024	2.3261e-013	5.8891e-024	2.1790e-019
Pb-211	5.6125e-022	2.0766e-011	5.2575e-022	1.9453e-017
Pb-212	1.6745e-028	6.1958e-018	1.5686e-028	5.8039e-024
Pb-214	4.0211e-023	1.4878e-012	3.7668e-023	1.3937e-018
Pm-147	1.1984e-045	4.4342e-035	1.1226e-045	4.1537e-041
Po-210	5.7254e-024	2.1184e-013	5.3633e-024	1.9844e-019
Po-211	1.5322e-024	5.6692e-014	1.4353e-024	5.3106e-020
Po-212	1.0729e-028	3.9696e-018	1.0050e-028	3.7185e-024
Po-213	2.1684e-019	8.0229e-009	2.0312e-019	7.5155e-015
Po-214	4.0202e-023	1.4875e-012	3.7659e-023	1.3934e-018
Po-215	5.6126e-022	2.0766e-011	5.2576e-022	1.9453e-017
Po-216	1.6748e-028	6.1968e-018	1.5689e-028	5.8049e-024
Po-218	4.0219e-023	1.4881e-012	3.7676e-023	1.3940e-018
Pr-144	2.1072e-010	7.7968e+000	1.9740e-010	7.3037e-006
Pr-144m	3.0133e-012	1.1149e-001	2.8227e-012	1.0444e-007
Pu-238	1.1025e-012	4.0792e-002	1.0328e-012	3.8212e-008
Pu-239	1.3870e-013	5.1320e-003	1.2993e-013	4.8074e-009
Pu-240	3.4092e-014	1.2614e-003	3.1936e-014	1.1816e-009
Pu-241	5.1329e-013	1.8992e-002	4.8083e-013	1.7791e-008
Pu-242	9.5006e-018	3.5152e-007	8.8997e-018	3.2929e-013
Ra-223	5.6126e-022	2.0766e-011	5.2576e-022	1.9453e-017
Ra-224	1.6748e-028	6.1968e-018	1.5689e-028	5.8049e-024
Ra-225	2.2262e-019	8.2369e-009	2.0854e-019	7.7159e-015
Ra-226	4.0295e-023	1.4909e-012	3.7747e-023	1.3966e-018
Ra-228	2.1094e-028	7.8047e-018	1.9760e-028	7.3111e-024
Rh-106	5.8831e-006	2.1767e+005	5.5110e-006	2.0391e-001
Rn-219	5.6126e-022	2.0766e-011	5.2576e-022	1.9453e-017
Rn-220	1.6748e-028	6.1968e-018	1.5689e-028	5.8049e-024
Rn-222	4.0219e-023	1.4881e-012	3.7676e-023	1.3940e-018
Ru-106	5.8831e-006	2.1767e+005	5.5110e-006	2.0391e-001
Sb-125	4.7814e-003	1.7691e+008	4.4790e-003	1.6572e+002
Sm-147	4.4618e-054	1.6509e-043	4.1796e-054	1.5464e-049
Sr-90	3.3679e+001	1.2461e+012	3.1549e+001	1.1673e+006
Te-125m	1.1717e-003	4.3352e+007	1.0976e-003	4.0610e+001
Th-227	5.5587e-022	2.0567e-011	5.2071e-022	1.9266e-017
Th-228	1.6770e-028	6.2051e-018	1.5710e-028	5.8126e-024
Th-229	2.2409e-019	8.2915e-009	2.0992e-019	7.7671e-015
Th-230	1.1641e-020	4.3070e-010	1.0904e-020	4.0346e-016
Th-231	5.6605e-018	2.0944e-007	5.3024e-018	1.9619e-013
Th-232	3.4922e-028	1.2921e-017	3.2713e-028	1.2104e-023
Th-234	8.5402e-018	3.1599e-007	8.0000e-018	2.9600e-013
Tl-207	5.5972e-022	2.0709e-011	5.2431e-022	1.9400e-017
Tl-208	6.0165e-029	2.2261e-018	5.6360e-029	2.0853e-024
Tl-209	4.7870e-021	1.7712e-010	4.4843e-021	1.6592e-016
U-233	2.6883e-016	9.9468e-006	2.5183e-016	9.3177e-012
U-234	9.9298e-017	3.6740e-006	9.3017e-017	3.4416e-012
U-235	5.6605e-018	2.0944e-007	5.3024e-018	1.9619e-013
U-236	3.8215e-019	1.4140e-008	3.5798e-019	1.3245e-014
U-237	1.2592e-017	4.6590e-007	1.1795e-017	4.3643e-013
U-238	8.5402e-018	3.1599e-007	8.0000e-018	2.9600e-013
Y-90	3.3688e+001	1.2464e+012	3.1557e+001	1.1676e+006

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Buildup
 The material reference is : Transition

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

Results

<u>Energy</u>	<u>Activity</u>	<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
<u>MeV</u>	<u>photons/sec</u>	<u>MeV/cm²/sec</u>	<u>MeV/cm²/sec</u>	<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.015	4.083e-10	4.020e-106	3.123e-43	3.448e-107	2.679e-44
0.02	3.378e-13	6.951e-61	7.332e-46	2.408e-62	2.540e-47
0.03	4.132e+08	4.287e-14	8.979e-13	4.248e-16	8.899e-15
0.04	7.732e+07	3.576e-08	1.821e-06	1.582e-10	8.053e-09
0.05	1.902e+03	3.139e-10	2.621e-08	8.361e-13	6.983e-11
0.06	1.133e+04	3.155e-08	3.152e-06	6.266e-11	6.261e-09
0.08	3.276e+03	1.207e-07	1.167e-05	1.910e-10	1.847e-08
0.1	5.967e+05	7.234e-05	5.866e-03	1.107e-07	8.974e-06
0.15	4.440e+05	2.258e-04	1.136e-02	3.719e-07	1.870e-05
0.2	1.343e+07	1.530e-02	5.237e-01	2.701e-05	9.243e-04
0.3	7.379e+05	2.401e-03	4.782e-02	4.554e-06	9.072e-05
0.4	5.539e+07	3.707e-01	5.122e+00	7.223e-04	9.979e-03
0.5	1.836e+07	2.135e-01	2.264e+00	4.190e-04	4.443e-03
0.6	4.410e+09	8.006e+01	6.910e+02	1.563e-01	1.349e+00
0.8	2.484e+05	9.043e-03	5.804e-02	1.720e-05	1.104e-04
1.0	1.932e+04	1.198e-03	6.238e-03	2.208e-06	1.150e-05
1.5	1.895e+04	3.021e-03	1.131e-02	5.082e-06	1.903e-05
2.0	6.035e-02	1.818e-08	5.619e-08	2.812e-11	8.689e-11
3.0	2.222e-18	1.545e-24	3.790e-24	2.097e-27	5.142e-27
TOTALS:	4.989e+09	8.067e+01	6.991e+02	1.575e-01	1.364e+00

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

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File Ref: HMP-26-9
Date: 12/4/97
By: HHK
Checked: HHK

for 2016
HHK

Case Title: T32SBW

Description: R/hr @ 1 m from culvert with Class C Grout/SBW (T32)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions

Height 162.56 cm 5 ft 4.0 in
Radius 45.72 cm 1 ft 6.0 in

Dose Points

	<u>X</u>	<u>Y</u>	<u>Z</u>
# 1	155.88 cm	81.28 cm	0 cm
	5 ft 1.4 in	2 ft 8.0 in	0.0 in

Shields

<u>Shield Name</u>	<u>Dimension</u>	<u>Material</u>	<u>Density</u>
Source	1.07e+06 cm ³	Concrete	1.8
Shield 1	10.16 cm	Concrete	2.35
Transition	100.0 cm	Air	0.0011
Air Gap		Air	0.00122

Source Input

Grouping Method : Standard Indices

Number of Groups : 25

Lower Energy Cutoff : 0.015

Photons < 0.015 : Excluded

Library : Grove

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Ac-225	2.2163e-019	8.2002e-009	2.0761e-019	7.6815e-015
Ac-227	5.6765e-022	2.1003e-011	5.3174e-022	1.9675e-017
Ac-228	2.1092e-028	7.8041e-018	1.9758e-028	7.3105e-024
Am-241	8.3874e-007	3.1033e+004	7.8569e-007	2.9071e-002
Am-243	2.1312e-045	7.8856e-035	1.9964e-045	7.3868e-041
At-217	2.2163e-019	8.2001e-009	2.0761e-019	7.6815e-015
Ba-137m	1.3053e-001	4.8297e+009	1.2228e-001	4.5242e+003
Bi-210	6.2659e-024	2.3184e-013	5.8695e-024	2.1717e-019
Bi-211	5.6125e-022	2.0766e-011	5.2575e-022	1.9453e-017
Bi-212	1.6745e-028	6.1957e-018	1.5686e-028	5.8038e-024
Bi-213	2.2162e-019	8.2000e-009	2.0760e-019	7.6814e-015
Bi-214	4.0211e-023	1.4878e-012	3.7667e-023	1.3937e-018
Ce-144	2.1072e-010	7.7965e+000	1.9739e-010	7.3034e-006
Cm-242	2.7027e-056	1.0000e-045	2.5318e-056	9.3676e-052
Cm-244	6.1906e-044	2.2905e-033	5.7991e-044	2.1457e-039
Cs-134	6.8291e-006	2.5268e+005	6.3971e-006	2.3669e-001
Cs-137	1.3798e-001	5.1054e+009	1.2926e-001	4.7825e+003
Eu-154	6.6924e-007	2.4762e+004	6.2691e-007	2.3196e-002
Eu-155	2.8512e-007	1.0549e+004	2.6708e-007	9.8820e-003
Fr-221	2.2163e-019	8.2001e-009	2.0761e-019	7.6815e-015
Fr-223	7.8335e-024	2.8984e-013	7.3380e-024	2.7151e-019
Np-237	5.2411e-012	1.9392e-001	4.9096e-012	1.8166e-007
Np-239	2.1312e-045	7.8856e-035	1.9964e-045	7.3868e-041
Pa-231	2.2741e-021	8.4141e-011	2.1302e-021	7.8819e-017
Pa-233	5.2122e-012	1.9285e-001	4.8825e-012	1.8065e-007

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<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Pa-234	1.3664e-020	5.0558e-010	1.2800e-020	4.7360e-016
Pa-234m	8.5402e-018	3.1599e-007	8.0000e-018	2.9600e-013
Pb-209	2.2161e-019	8.1995e-009	2.0759e-019	7.6809e-015
Pb-210	6.2867e-024	2.3261e-013	5.8891e-024	2.1790e-019
Pb-211	5.6125e-022	2.0766e-011	5.2575e-022	1.9453e-017
Pb-212	1.6745e-028	6.1958e-018	1.5686e-028	5.8039e-024
Pb-214	4.0211e-023	1.4878e-012	3.7668e-023	1.3937e-018
Pm-147	1.1984e-045	4.4342e-035	1.1226e-045	4.1537e-041
Po-210	5.7254e-024	2.1184e-013	5.3633e-024	1.9844e-019
Po-211	1.5322e-024	5.6692e-014	1.4353e-024	5.3106e-020
Po-212	1.0729e-028	3.9696e-018	1.0050e-028	3.7185e-024
Po-213	2.1684e-019	8.0229e-009	2.0312e-019	7.5155e-015
Po-214	4.0202e-023	1.4875e-012	3.7659e-023	1.3934e-018
Po-215	5.6126e-022	2.0766e-011	5.2576e-022	1.9453e-017
Po-216	1.6748e-028	6.1968e-018	1.5689e-028	5.8049e-024
Po-218	4.0219e-023	1.4881e-012	3.7676e-023	1.3940e-018
Pr-144	2.1072e-010	7.7968e+000	1.9740e-010	7.3037e-006
Pr-144m	3.0133e-012	1.1149e-001	2.8227e-012	1.0444e-007
Pu-238	1.1025e-012	4.0792e-002	1.0328e-012	3.8212e-008
Pu-239	1.3870e-013	5.1320e-003	1.2993e-013	4.8074e-009
Pu-240	3.4092e-014	1.2614e-003	3.1936e-014	1.1816e-009
Pu-241	5.1329e-013	1.8992e-002	4.8083e-013	1.7791e-008
Pu-242	9.5006e-018	3.5152e-007	8.8997e-018	3.2929e-013
Ra-223	5.6126e-022	2.0766e-011	5.2576e-022	1.9453e-017
Ra-224	1.6748e-028	6.1968e-018	1.5689e-028	5.8049e-024
Ra-225	2.2262e-019	8.2369e-009	2.0854e-019	7.7159e-015
Ra-226	4.0295e-023	1.4909e-012	3.7747e-023	1.3966e-018
Ra-228	2.1094e-028	7.8047e-018	1.9760e-028	7.3111e-024
Rh-106	5.8831e-006	2.1767e+005	5.5110e-006	2.0391e-001
Rn-219	5.6126e-022	2.0766e-011	5.2576e-022	1.9453e-017
Rn-220	1.6748e-028	6.1968e-018	1.5689e-028	5.8049e-024
Rn-222	4.0219e-023	1.4881e-012	3.7676e-023	1.3940e-018
Ru-106	5.8831e-006	2.1767e+005	5.5110e-006	2.0391e-001
Sb-125	4.7814e-003	1.7691e+008	4.4790e-003	1.6572e+002
Sm-147	4.4618e-054	1.6509e-043	4.1796e-054	1.5464e-049
Sr-90	3.3679e+001	1.2461e+012	3.1549e+001	1.1673e+006
Te-125m	1.1717e-003	4.3352e+007	1.0976e-003	4.0610e+001
Th-227	5.5587e-022	2.0567e-011	5.2071e-022	1.9266e-017
Th-228	1.6770e-028	6.2051e-018	1.5710e-028	5.8126e-024
Th-229	2.2409e-019	8.2915e-009	2.0992e-019	7.7671e-015
Th-230	1.1641e-020	4.3070e-010	1.0904e-020	4.0346e-016
Th-231	5.6605e-018	2.0944e-007	5.3024e-018	1.9619e-013
Th-232	3.4922e-028	1.2921e-017	3.2713e-028	1.2104e-023
Th-234	8.5402e-018	3.1599e-007	8.0000e-018	2.9600e-013
Tl-207	5.5972e-022	2.0709e-011	5.2431e-022	1.9400e-017
Tl-208	6.0165e-029	2.2261e-018	5.6360e-029	2.0853e-024
Tl-209	4.7870e-021	1.7712e-010	4.4843e-021	1.6592e-016
U-233	2.6883e-016	9.9468e-006	2.5183e-016	9.3177e-012
U-234	9.9298e-017	3.6740e-006	9.3017e-017	3.4416e-012
U-235	5.6605e-018	2.0944e-007	5.3024e-018	1.9619e-013
U-236	3.8215e-019	1.4140e-008	3.5798e-019	1.3245e-014
U-237	1.2592e-017	4.6590e-007	1.1795e-017	4.3643e-013
U-238	8.5402e-018	3.1599e-007	8.0000e-018	2.9600e-013
Y-90	3.3688e+001	1.2464e+012	3.1557e+001	1.1676e+006

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 Run Time: 5:13:07 PM
 Duration: 00:01:34

Buildup
 The material reference is : Shield 1

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

Results					
<u>Energy</u>	<u>Activity</u>	<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
<u>MeV</u>	<u>photons/sec</u>	<u>MeV/cm²/sec</u>	<u>MeV/cm²/sec</u>	<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.015	4.083e-10	4.020e-106	1.862e-43	3.448e-107	1.597e-44
0.02	3.378e-13	6.951e-61	2.423e-46	2.408e-62	8.395e-48
0.03	4.132e+08	4.287e-14	8.285e-14	4.248e-16	8.211e-16
0.04	7.732e+07	3.576e-08	1.075e-07	1.582e-10	4.754e-10
0.05	1.902e+03	3.139e-10	1.448e-09	8.361e-13	3.857e-12
0.06	1.133e+04	3.155e-08	2.074e-07	6.266e-11	4.119e-10
0.08	3.276e+03	1.207e-07	1.220e-06	1.910e-10	1.930e-09
0.1	5.967e+05	7.234e-05	9.224e-04	1.107e-07	1.411e-06
0.15	4.440e+05	2.258e-04	3.311e-03	3.719e-07	5.453e-06
0.2	1.343e+07	1.530e-02	2.125e-01	2.701e-05	3.750e-04
0.3	7.379e+05	2.401e-03	2.688e-02	4.554e-06	5.100e-05
0.4	5.539e+07	3.707e-01	3.392e+00	7.223e-04	6.608e-03
0.5	1.836e+07	2.135e-01	1.643e+00	4.190e-04	3.226e-03
0.6	4.410e+09	8.006e+01	5.334e+02	1.563e-01	1.041e+00
0.8	2.484e+05	9.043e-03	4.823e-02	1.720e-05	9.173e-05
1.0	1.932e+04	1.198e-03	5.411e-03	2.208e-06	9.974e-06
1.5	1.895e+04	3.021e-03	1.035e-02	5.082e-06	1.741e-05
2.0	6.035e-02	1.818e-08	5.284e-08	2.812e-11	8.171e-11
3.0	2.222e-18	1.545e-24	3.664e-24	2.097e-27	4.972e-27
TOTALS:	4.989e+09	8.067e+01	5.388e+02	1.575e-01	1.052e+00

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company
Case File Heat Generation
Case File: T32BGL.MS5
Case Title: T-32bGLASS

<u>Isotope</u>	<u>Activity</u> <u>Curies</u>	<u>Activity</u> <u>Bequerels</u>	<u>Heat Generation</u> <u>Watts/Curie</u>	<u>Heat Generation</u> <u>Watts</u>
Ba-137m	1.0727e+006	3.9691e+016	3.9212e-003	4.2064e+003
Cs-137	1.1375e+006	4.2088e+016	1.0122e-003	1.1514e+003
Sr-90	1.0439e+006	3.8625e+016	1.1607e-003	1.2117e+003
Y-90	1.0439e+006	3.8625e+016	5.5411e-003	5.7845e+003
		Total	Heat Generation:	1.2354e+004

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
 S File: T32BGL.MS5
 on Date: December 4, 1997
 on Time: 9:18:54 AM
 uration: 00:00:29

File Ref: HKP-26-9
 Date: 12/4/97
 By: W. H. Hines
 Checked: W. H. Hines

Case Title: T-32bGLASS
Description: R/hr @ 1 cm from canister surf., Class A Glass (T-32b)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions
 Height 262.8 cm . 8 ft 7.5 in.
 Radius 29.53 cm . 11.6 in.

Dose Points

	<u>X</u>	<u>Y</u>	<u>Z</u>
# 1	31.48 cm ✓	131.4 cm	0 cm
	1 ft 0.4 in	4 ft 3.7 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	7.20e+05 cm ³	Concrete	2.56 ✓
Shield 1	.95 cm	Iron	7.86.
Transition	1.0 cm	Air	0.0011
Air Gap		Air	0.0011

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Ba-137m	1.0727e+006	3.9691e+016	1.4900e+006 ✓	5.5130e+010
Cs-137	1.1375e+006	4.2088e+016	1.5800e+006 ✓	5.8460e+010
Sr-90	1.0439e+006	3.8625e+016	1.4500e+006 ✓	5.3650e+010
Y-90	1.0439e+006	3.8625e+016	1.4500e+006 ✓	5.3650e+010

Buildup
 The material reference is : Source

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm ² /sec No Buildup	Results		Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
			Fluence Rate MeV/cm ² /sec With Buildup			
0.0318	8.217e+14	4.477e-19	1.648e-17		3.729e-21	1.373e-19
0.0322	1.516e+15	5.705e-18	4.267e-17		4.591e-20	3.434e-19
0.0364	5.517e+14	3.814e-11	1.183e-10		2.167e-13	6.721e-13
0.6616	3.571e+16	2.325e+10	8.459e+10		4.507e+07	1.640e+08
TOTALS:	3.860e+16	2.325e+10	8.459e+10		4.507e+07	1.640e+08

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
 DOS File: T32BGL.MS5
 Run Date: December 4, 1997
 Run Time: 9:26:03 AM
 Duration: 00:00:29

File Ref: HKP-26-97
 Date: 12/4/97
 By: [Signature]
 Checked: [Signature]

Case Title: T-32bGLASS
Description: R/hr @ 1 m from canister surf., Class A Glass (T-32b)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions

Height	262.8 cm	8 ft 7.5 in
Radius	29.53 cm	11.6 in

Dose Points

	<u>X</u>	<u>Y</u>	<u>Z</u>
# 1	130.48 cm	131.4 cm	0 cm
	4 ft 3.4 in	4 ft 3.7 in	0.0 in

Shields

<u>Shield Name</u>	<u>Dimension</u>	<u>Material</u>	<u>Density</u>
Source	7.20e+05 cm ³	Concrete	2.56
Shield 1	.95 cm	Iron	7.86
Transition	100.0 cm	Air	0.0011
Air Gap		Air	0.00122

Source Input

Grouping Method : Actual Photon Energies

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Ba-137m	1.0727e+006	3.9691e+016	1.4900e+006	5.5130e+010
Cs-137	1.1375e+006	4.2088e+016	1.5800e+006	5.8460e+010
Sr-90	1.0439e+006	3.8625e+016	1.4500e+006	5.3650e+010
Y-90	1.0439e+006	3.8625e+016	1.4500e+006	5.3650e+010

Buildup

The material reference is : Transition

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

Results

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Fluence Rate</u> <u>MeV/cm²/sec</u> <u>No Buildup</u>	<u>Fluence Rate</u> <u>MeV/cm²/sec</u> <u>With Buildup</u>	<u>Exposure Rate</u> <u>mR/hr</u> <u>No Buildup</u>	<u>Exposure Rate</u> <u>mR/hr</u> <u>With Buildup</u>
0.0318	8.217e+14	5.819e-18	4.090e-16	4.847e-20	3.407e-18
0.0322	1.516e+15	6.101e-17	3.887e-15	4.910e-19	3.129e-17
0.0364	5.517e+14	8.102e-11	7.022e-09	4.603e-13	3.990e-11
0.6616	3.571e+16	4.085e+09	1.654e+10	7.918e+06	3.207e+07
TOTALS:	3.860e+16	4.085e+09	1.654e+10	7.918e+06	3.207e+07

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company
Case File Heat Generation
Case File: T32BZIR.MS5
Case Title: T-32bZGLASS

<u>Isotope</u>	<u>Activity</u> <u>Curies</u>	<u>Activity</u> <u>Bequerels</u>	<u>Heat Generation</u> <u>Watts/Curie</u>	<u>Heat Generation</u> <u>Watts</u>
Ba-137m	3.2038e+004	1.1854e+015	3.9212e-003	1.2563e+002
Cs-137	3.4126e+004	1.2626e+015	1.0122e-003	3.4543e+001
Sr-90	4.7373e+004	1.7528e+015	1.1607e-003	5.4987e+001
Y-90	4.7373e+004	1.7528e+015	5.5411e-003	2.6250e+002
		Total	Heat Generation:	4.7765e+002

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
 File: T32BZIR.MS5
 Date: December 5, 1997
 Time: 2:10:27 PM
 Duration: 00:00:28

File Ref: HKP-26-97
 Date: 12/5/97
 By: AKH/...
 Checked: _____

Case Title: T-32bZGLASS

Description: R/hr @ 1 cm from canister surf., Class A Zir. Glass (T-32b)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions
 Height 262.8 cm 8 ft 7.5 in
 Radius 29.53 cm 11.6 in

Dose Points

	<u>X</u>	<u>Y</u>	<u>Z</u>
# 1	31.48 cm	131.4 cm	0 cm
	1 ft 0.4 in	4 ft 3.7 in	0.0 in

Shields

<u>Shield Name</u>	<u>Dimension</u>	<u>Material</u>	<u>Density</u>
Source	7.20e+05 cm ³	Concrete	2.56
Shield 1	.95 cm	Iron	7.86
Transition	1.0 cm	Air	0.0011
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 4
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded

Library : Grove

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Ba-137m	3.2038e+004	1.1854e+015	4.4500e+004	1.6465e+009
Cs-137	3.4126e+004	1.2626e+015	4.7400e+004	1.7538e+009
Sr-90	4.7373e+004	1.7528e+015	6.5800e+004	2.4346e+009
Y-90	4.7373e+004	1.7528e+015	6.5800e+004	2.4346e+009

Buildup
The material reference is : Source

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Results</u>			
		<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
		<u>MeV/cm²/sec</u>	<u>MeV/cm²/sec</u>	<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.0318	2.454e+13	1.337e-20	4.923e-19	1.114e-22	4.100e-21
0.0322	4.528e+13	1.704e-19	1.274e-18	1.371e-21	1.025e-20
0.0364	1.648e+13	1.139e-12	3.533e-12	6.471e-15	2.007e-14
0.6616	1.067e+15	6.944e+08	2.526e+09	1.346e+06	4.897e+06
TOTALS:	1.153e+15	6.944e+08	2.526e+09	1.346e+06	4.897e+06

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
 File: T32BZIR.MS5
 Date: December 5, 1997
 Time: 2:13:09 PM
 Date: 00:00:28

File Ref: HKP-26-4
 Date: 12/5/97
 By: OH/...
 Checked: _____

Case Title: T-32bZGLASS

Description: R/hr @ 1 m from canister surf., Class A Zir. Glass (T-32b)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions

Height	262.8 cm	8 ft 7.5 in
Radius	29.53 cm	11.6 in

Dose Points

	<u>X</u>	<u>Y</u>	<u>Z</u>
# 1	130.48 cm	131.4 cm	0 cm
	4 ft 3.4 in	4 ft 3.7 in	0.0 in

Shields

<u>Shield Name</u>	<u>Dimension</u>	<u>Material</u>	<u>Density</u>
Source	7.20e+05 cm ³	Concrete	2.56
Shield 1	.95 cm	Iron	7.86
Transition	100.0 cm	Air	0.0011
Air Gap		Air	0.00122

Source Input

Grouping Method : Standard Indices

Number of Groups : 4

Lower Energy Cutoff : 0.015

Photons < 0.015 : Excluded

Library : Grove

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Ba-137m	3.2038e+004	1.1854e+015	4.4500e+004	1.6465e+009
Cs-137	3.4126e+004	1.2626e+015	4.7400e+004	1.7538e+009
Sr-90	4.7373e+004	1.7528e+015	6.5800e+004	2.4346e+009
Y-90	4.7373e+004	1.7528e+015	6.5800e+004	2.4346e+009

Buildup

The material reference is : Transition

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

Results

<u>Energy</u>	<u>Activity</u>	<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
<u>MeV</u>	<u>photons/sec</u>	<u>MeV/cm²/sec</u>	<u>MeV/cm²/sec</u>	<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.0318	2.454e+13	1.738e-19	1.222e-17	1.448e-21	1.018e-19
0.0322	4.528e+13	1.822e-18	1.161e-16	1.466e-20	9.344e-19
0.0364	1.648e+13	2.420e-12	2.097e-10	1.375e-14	1.192e-12
0.6616	1.067e+15	1.220e+08	4.940e+08	2.365e+05	9.578e+05
TOTALS:	1.153e+15	1.220e+08	4.940e+08	2.365e+05	9.578e+05

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company
Case File Heat Generation
Case File: T32BSBW1.MS5
Case Title: T-32bsbwGLASS

<u>Isotope</u>	<u>Activity</u> <u>Curies</u>	<u>Activity</u> <u>Bequerels</u>	<u>Heat Generation</u> <u>Watts/Curie</u>	<u>Heat Generation</u> <u>Watts</u>
Ba-137m	8.7129e+003	3.2238e+014	3.9212e-003	3.4165e+001
Cs-137	9.2103e+003	3.4078e+014	1.0122e-003	9.3231e+000
Sr-90	8.4934e+003	3.1426e+014	1.1607e-003	9.8585e+000
Y-90	8.4956e+003	3.1434e+014	5.5411e-003	4.7075e+001
		Total	Heat Generation:	1.0042e+002

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
 File: T32BSBW.MS5
 Date: December 5, 1997
 Run Time: 2:34:32 PM
 Duration: 00:00:28

File Ref: HKP-26-4
 Date: 12/5/97
 By: W. H. H. H.
 Checked: _____

Case Title: T-32bsbwGLASS

Description: R/hr @ 1 cm from canister surf., Class A SBW Glass (T-32b)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions
 Height 262.8 cm 8 ft 7.5 in
 Radius 29.53 cm 11.6 in

Dose Points

	<u>X</u>	<u>Y</u>	<u>Z</u>
# 1	31.48 cm	131.4 cm	0 cm
	1 ft 0.4 in	4 ft 3.7 in	0.0 in

Shields

<u>Shield Name</u>	<u>Dimension</u>	<u>Material</u>	<u>Density</u>
Source	7.20e+05 cm ³	Concrete	2.34
Shield 1	.95 cm	Iron	7.86
Transition	1.0 cm	Air	0.0011
Air Gap		Air	0.00122

Source Input

Grouping Method : Actual Photon Energies

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Ba-137m	8.7129e+003	3.2238e+014	1.2102e+004	4.4778e+008
Cs-137	9.2103e+003	3.4078e+014	1.2793e+004	4.7334e+008
Sr-90	8.4934e+003	3.1426e+014	1.1797e+004	4.3650e+008
Y-90	8.4956e+003	3.1434e+014	1.1800e+004	4.3661e+008

Buildup

The material reference is : Source

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

Results

<u>Energy</u>	<u>Activity</u>	<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
<u>MeV</u>	<u>photons/sec</u>	<u>MeV/cm²/sec</u>	<u>MeV/cm²/sec</u>	<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.0318	6.674e+12	4.958e-21	1.367e-19	4.130e-23	1.139e-21
0.0322	1.231e+13	6.259e-20	3.837e-19	5.037e-22	3.088e-21
0.0364	4.481e+12	3.865e-13	1.198e-12	2.196e-15	6.806e-15
0.6616	2.901e+14	2.062e+08	7.496e+08	3.998e+05	1.453e+06
TOTALS:	3.135e+14	2.062e+08	7.496e+08	3.998e+05	1.453e+06

MicroShield v5.01 (5.01-00121)
Lockheed Martin Idaho Technologies Company

Page : 1
 File: T32BSBW.MS5
 Date: December 5, 1997
 Time: 2:32:13 PM
 Duration: 00:00:28

File Ref: HHP-26-97
 Date: 12/5/97
 By: ATK/Johnson
 Checked: _____

Case Title: T-32bsbwGLASS

Description: R/hr @ 1 m from canister surf., Class A SBW Glass (T-32b)
Geometry: 7 - Cylinder Volume - Side Shields

Source Dimensions

Height	262.8 cm	8 ft 7.5 in
Radius	29.53 cm	11.6 in

Dose Points

	<u>X</u>	<u>Y</u>	<u>Z</u>
# 1	130.48 cm	131.4 cm	0 cm
	4 ft 3.4 in	4 ft 3.7 in	0.0 in

Shields

<u>Shield Name</u>	<u>Dimension</u>	<u>Material</u>	<u>Density</u>
Source	7.20e+05 cm ³	Concrete	2.34
Shield 1	.95 cm	Iron	7.86
Transition	100.0 cm	Air	0.0011
Air Gap		Air	0.00122

Source Input

Grouping Method : Actual Photon Energies

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Ba-137m	8.7129e+003	3.2238e+014	1.2102e+004	4.4778e+008
Cs-137	9.2103e+003	3.4078e+014	1.2793e+004	4.7334e+008
Sr-90	8.4934e+003	3.1426e+014	1.1797e+004	4.3650e+008
Y-90	8.4956e+003	3.1434e+014	1.1800e+004	4.3661e+008

Buildup

The material reference is : Transition

Integration Parameters

Radial	23
Circumferential	23
Y Direction (axial)	23

<u>Energy</u>	<u>Activity</u>	<u>Fluence Rate</u>	Results		<u>Exposure Rate</u>	<u>Exposure Rate</u>
<u>MeV</u>	<u>photons/sec</u>	<u>MeV/cm²/sec</u>	<u>Fluence Rate</u>		<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>MeV/cm²/sec</u>		<u>No Buildup</u>	<u>With Buildup</u>
			<u>With Buildup</u>			
0.0318	6.674e+12	5.171e-20	3.588e-18		4.307e-22	2.988e-20
0.0322	1.231e+13	5.421e-19	3.445e-17		4.363e-21	2.772e-19
0.0364	4.481e+12	7.200e-13	6.240e-11		4.091e-15	3.545e-13
0.6616	2.901e+14	3.625e+07	1.465e+08		7.027e+04	2.839e+05
TOTALS:	3.135e+14	3.625e+07	1.465e+08		7.027e+04	2.839e+05

INEEL/EXT-97-01147

Revision 1

February 1998

**Standard Criteria of Candidate
Repositories and Environmental
Regulations for the Treatment and
Disposal of ICPP Radioactive Mixed
Wastes**

J. Banaee

INEEL/EXT-97-01147

Revision 1

Standard Criteria of Candidate Repositories and Environmental Regulations for the Treatment and Disposal of ICPP Radioactive Mixed Wastes

J. Banaee

February 1998

**Idaho National Engineering and Environmental Laboratory
Lockheed Martin Idaho Technologies Company
Idaho Falls, Idaho 83415**

**Prepared for the
U.S. Department of Energy
Assistant Secretary of Environmental Management
Under DOE Idaho Operations Office
Contract DE-AC07-94ID13223**

ABSTRACT

A feasibility study is being conducted to evaluate various treatment alternative proposed for the radioactive mixed wastes currently stored at the Idaho Chemical processing Plant (ICPP). The wastes have been generated from spent nuclear fuel (SNF) reprocessing and decontamination activities. They include high-level waste (HLW), sodium-bearing waste (SBW), and other radioactive wastes. The proposed treatment alternatives are expected to convert the wastes to stable waste forms that will be suitable for permanent disposal. The objectives of this study are (a) to identify and to present an analysis of the existing regulatory requirements for the disposal of various waste forms resulting from the proposed treatment options, and (b) to present a survey of the waste acceptance criteria of the candidate repositories for each waste type. The waste forms must be disposed in accordance with the requirements established by the Environmental Protection Agency (EPA), the Department of Energy (DOE), the DOE Idaho Operations Office (DOE-ID), the Nuclear Regulatory Commission (NRC), and other applicable state and local standards. In addition, for the purpose of transportation between sites, the Department of Transportation (DOT) and NRC regulations apply.

Several options are being considered including four non-separations and two separations processes. In addition, a no-action alternative has been proposed, defined as the continuation of the current practice of calcination and storage in stainless steel bins at ICPP. The non-separation options would entail converting the wastes to one of several high-level waste (HLW) forms. These are glass, glass-ceramic, and a hydroceramic or cementitious waste form. The separation options are expected to generate up to three different waste streams; designated as high activity waste (HAW), low activity waste (LAW), and transuranic (TRU) waste. It is planned for the HAW to be vitrified, and for the LAW to be grouted. The TRU waste portion will be dried in preparation for disposal.

Several potential facilities have been considered for the disposal of these waste products. The HLW and HAW will be sent to a HLW geologic repository. Presently, the Yucca Mountain in Nevada is designated as the candidate site for a HLW geologic repository. An alternative location proposed for the disposal of the hydroceramic HLW is the Greater Confinement Disposal (GCD) facility at the Nevada Test site. The grouted LAW will be transported to a LLW disposal facility, and the TRU waste will be disposed of at the Waste Isolation Pilot Plant (WIPP).

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ACRONYMS

AEA	Atomic Energy Act
ALARA	as low as reasonably achievable
ANL-W	Argonne National Laboratory-West
BDAT	best demonstrated overall technology
BMP	best management practice
CFR	Code of Federal Regulations
CH	contact handled
CMBST	combustion
CRWMS	Civilian Radioactive Waste Management System
DET	Determination of Equivalent Treatment
DOE	U.S. Department of Energy
DOE-HQ	DOE Head Quarters
DOE-ID	DOE Idaho Operations Office
DOE-NV	DOE Nevada Operations Office
DOT	U.S. Department of Transportation
EM	DOE Environmental Management
EPA	Environmental Protection Agency
FGE	Fissile Gram Equivalent
FR	Federal Register
GCD	Greater Confinement Disposal
HAW	high-activity waste
HIPing	hot isostatic pressing
HLW	high-level waste
HWIR	Hazardous Waste Identification Rule

ICPP	Idaho Chemical Processing Plant
INEEL	Idaho National Engineering and Environmental Laboratory
LAW	low-activity waste
LDR	Land Disposal Restriction
LLW	low-level waste
LMITCO	Lockheed Martin Idaho Technologies Company
LWA	Land Withdrawal Act
NEPA	National Environmental Policy Act
NTS	Nevada Test Site
NRC	Nuclear Regulatory Commission
NRF	Naval Reactor Facility
NWPA	National Waste Policy Act
NWPAA	National Waste Policy Amendments Act
OCRWM	Office of Civilian Radioactive Waste Management
PA	Performance Assessment
PGDHS	Policy of Geometric Design of Highways and Streets
PR	Production Record
QA	Quality Assurance
QAPP	Quality Assurance Program Plan
RADCON	Radiological Control
RCRA	Resource Conservation and Recovery Act
RH	remote handled
RPO	Repository Project Office
RWMC	Radioactive Waste Management Complex
SAR	Safety Analysis Report

SARP	Safety Analysis Report for Packaging
SBW	sodium bearing waste
SNL	Sandia National Laboratory
SS	stainless steel
SSR	storage and shipping containers
TBD	to be determined
TCLP	Toxicity Characteristic Leaching Procedure
TDOP	ten drum overpacks
TRU	transuranic
TSD	waste treatment, storage, and disposal
UTS	Universal Treatment Standard
VOC	volatile organic compound
WAPS	Waste Acceptance Product Specification
WASRD	Waste Acceptance System Requirements Document
WCP	Waste Form Compliance Plan
WIPP	Waste Isolation Pilot Plant
WMO	Waste Management Office
WQR	Waste Form Qualification Report

Standard Criteria of Candidate Repositories and Environmental Regulations for the Treatment and Disposal of ICPP Radioactive Mixed wastes

1. INTRODUCTION

The Idaho Chemical Processing Plant (ICPP) at the Idaho National Engineering and Environmental Laboratory (INEEL) has been used for reprocessing spent nuclear fuel (SNF) since 1953. In April 1992, the Department of Energy (DOE) discontinued SNF reprocessing and shifted its focus toward management and disposition of the radioactive wastes generated from the reprocessing and related decontamination activities. The wastes generated include liquid high-level waste (HLW)^a and sodium-bearing waste (SBW). These wastes have been stored in the Tank Farm at ICPP. Most of the liquid HLW has been calcined and stored in stainless steel (SS) bins at ICPP. The Settlement Agreement between the State of Idaho and DOE, the Environmental Protection Agency (EPA) regulations, and non-compliant liquid wastes storage conditions require that the HLW and SBW be processed into acceptable waste products for permanent disposal.

The Settlement Agreement contains several commitments for the treatment and disposal of the HLW and SBW, and their transfer out of Idaho. The Agreement requires that all remaining liquid HLW be calcined by June 30, 1998, and that calcination of all SBW be completed by December 31, 2012. Based on the Agreement, the treatment of all calcine wastes shall be completed by December 31, 2035, and all HLW must be treated to be moved out of Idaho for disposal by the year 2035.

DOE is conducting a feasibility study to evaluate several alternatives proposed for treating the ICPP wastes. Three types of waste are to be treated. These are the HLW, the SBW, and other miscellaneous liquid radioactive wastes with low activities or low-level of radiation. The wastes with low-level of radiation are generated as a result of on-going decontamination activities at ICPP. The proposed treatment options are to convert the wastes to waste products that can be permanently disposed. This study identifies and provides an analysis of the existing regulatory requirements for the treatment and disposal of various waste forms resulting from the proposed options. It also presents a survey of the waste acceptance criteria of the potential candidate repositories for the disposal of each waste product.

There are two main categories of treatment options: non-separation and separation. The non-separation options include: (a) vitrified waste option (VWO), (b) Hot Isostatic Press (HIP) waste option (HWO), (c) direct cementitious waste option (DCWO), and (d) cementitious waste option (CWO). The separation processes are: (a) high-activity waste (HAW)/low activity waste (LAW) separation option, and (b) Transuranic (TRU) /LAW separation option. An additional option proposed is a "no-action" alternative that is to continue calcination and storage in SS bins.

^a HLW is defined by origin, not radionuclide concentration limit. Based on the NRC definition (10 CFR 60.2), HLW is highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing, and any solid material derived from such liquid waste that contains fission products in sufficient concentrations. Along the same line, DOE Order 5820.2A refers to HLW as waste in concentrations requiring permanent isolation. Although HLW relies on source term for its definition, and radionuclide concentration is implied within context, these limits are not specified or defined.

The radioactive wastes stored at ICPP are considered mixed-wastes. These are wastes that contain both Resource Conservation and Recovery Act (RCRA) hazardous contaminants and radionuclides. Therefore, the wastes are subject to the requirements of both RCRA for the hazardous waste contaminants and of the Atomic Energy Act (AEA) standards for management of radioactive material. The AEA standards are administered by DOE. RCRA has established standards under the Land Disposal Restrictions (LDRs) for treatment of hazardous waste prior to land disposal.

The RCRA constituents include characteristic heavy metals, and listed organic and inorganic chemicals, as defined in 40 Code of Federal Regulations (CFR) 261, Subparts C and D. Based on the regulations in 40 CFR 262.3(a)(2)(iv), "mixture rule,"^b and in 40 CFR 262.3(c)(2)(i), "derived from rule,"^b the ICPP wastes and the products resulting from treatment of these wastes are considered listed hazardous wastes. The only way to remove the listed waste from compliance with the RCRA regulations is to have them delisted.

For the purpose of analyses of the regulatory disposal requirements, the waste products resulting from the proposed options are categorized into mixed high-level waste (mixed HLW), mixed transuranic waste (mixed TRU), and mixed low-level waste (mixed LLW). The determination of the classification of the waste products is based on two considerations: waste origin; and the projected composition and estimated concentrations of the radionuclides and of the RCRA hazardous contaminants. These wastes must be disposed in accordance with the requirements established by the EPA, U.S. Department of Energy (DOE), Nuclear Regulatory Commission (NRC), and other applicable state and local standards. In addition, the transportation of the wastes between the sites must comply with the requirements of the U.S. Department of Transportation (DOT) and NRC.

^b Based on 40 CFR 262.3(a)(2)(iv), "mixture rule," and 40 CFR 262.3(c)(2)(i), "derived from rule," any mixture of listed hazardous waste and solid waste is also a listed hazardous waste and any solid waste generated from the storage, treatment, or disposal of a listed hazardous waste is itself a listed hazardous waste.

2. EPA GENERAL DISPOSAL REQUIREMENTS

2.1 RCRA LDR Requirements

RCRA^c has defined treatment standards under LDR in 40 CFR 268 for hazardous waste when the waste is land disposed. The treatment standards for hazardous waste, as designated by their hazardous waste codes^d or hazardous waste numbers (HWNs), are identified in the table of "Treatment Standards for Hazardous Wastes" in 40 CFR 268.40, and in the table of "Universal Treatment Standards" (UTS) in 40 CFR 268.48. The standards are expressed either as specified-technologies or as waste concentrations, and they are based on the performance of the best demonstrated available technology (BDAT) for a waste code. Each waste code can be land disposed only if it meets one of the following three requirements:

- (1) All hazardous constituents in the waste or in the treatment residue must be at or below the values found in the table for that waste, or
- (2) The hazardous constituents in the extract of the waste or in the extract of the treatment residue must be at or below the values found in the table, or
- (3) The waste must be treated using the technology specified in the table, shown in a 5-letter treatment code (e.g., CMBST means combustion). For wastes covered by a technology standard, the wastes may be land disposed after being treated using that specified technology or an equivalent treatment technology approved by the EPA Administrator under the procedures set forth in 40 CFR 268.42(b), determination of equivalent treatment (DET).

The LDR applicability and treatment standards are determined based on hazardous chemical composition and their concentrations in the waste at the point of generation. Consistent with the cradle-to-grave mandate of the LDRs, a hazardous waste generator needs to assess what disposal prohibitions apply at different points in the waste management process (from generation to final disposal)¹. The Tank farm has been used for storage of liquid radioactive mixed wastes that have been generated from the SNF reprocessing and decontamination processes. Thus, the wastes in the Tank Farm represent the point of generation. These wastes are evaluated here to assess what land disposal prohibitions apply.

The LDR analysis of the waste relies on the data from the Tank Farm and other sources.^{2,3} Uncertainties exist about some of the reported data and the projected composition and estimated quantities of chemicals in the wastes. This is due to the nature of the record keeping on historical information and to the uncertainties in the waste processing alternatives being considered.

The wastes in the Tank Farm reportedly contain a variety of RCRA hazardous waste constituents. For a waste which contains various hazardous chemicals, designated by HWNs, the LDRs require that

^c The State of Idaho adopted the Federal EPA RCRA regulations pursuant to the Idaho Hazardous Waste Management Act of 1983, and it has the authority to implement them in Idaho. The regulations are incorporated by reference into the Idaho "Rules and Standards for Hazardous Wastes."

^d Hazardous waste codes and hazardous waste numbers are interchangeable terms. According to the State of Idaho Department of Health and Welfare, both terms are acceptable to the State for designating hazardous waste chemicals.

the waste be treated for each HWNs according to its appropriate treatment standards. Table 1³ presents a full list of RCRA hazardous chemicals reported in the Tank Farm. The reported contaminants and their concentrations are based on analytical data, process knowledge, and historical records. Process knowledge is based on records that these chemicals were used at ICPP. The majority of these contaminants identified, mainly organics, are from the past practice of transferring off-specifications or unused commercial chemical products from laboratory activities and decontamination process solutions. These chemicals were primarily used in the laboratories and dispersed from 1963 to 1988 and were not discarded in large quantities.

2.2 Delisting

EPA has designated listed hazardous wastes with three-digit number following F, P, U, or K letters, as shown in Table 1. However, under the EPA "mixture rule" and "derived-from rule", there are other ways that a waste can be a listed and that is if it is mixed with listed hazardous waste(s). Thus, the entire wastes in the Tank Farm and the treatment products are considered listed wastes. The treated waste products will remain listed until they are delisted by EPA. The potential target repositories considered in this study, with the exception of the Waste Isolation pilot Plant (WIPP), are not authorized to accept any hazardous waste for disposal. Therefore, the wastes must be delisted before disposal. The delisting must be approved by both the waste shipping (Idaho) and waste receiving states (Nevada), and by all other states through which the waste is transported. The waste can be delisted prior to or after treatment. 40 CFR 262.20 and 260.22 contain procedures and definitions whereby anyone can petition EPA to "delist" or "exclude" a listed waste. The EPA has published a technical guidance manual⁴ which contains delisting criteria and processes for preparing a delisting petition. The submittal of a delisting petition does not automatically relieve the petitioner from any of the hazardous waste management requirements, and the petitioned waste is still subject to the regulations in 40 CFR 61 and 40 CFR 268. EPA grants upfront exclusions for wastes and/or wastes from treatment that have not been generated, but will be generated in the future based on available information such as bench- or pilot-scale data. The EPA decision of upfront exclusions petition is based on an evaluation of the characteristics of the untreated waste, process description, and data from bench scale or pilot scale treatment system. If upfront exclusion is granted by EPA for wastes under consideration in this study, the treated waste streams will no longer be considered listed hazardous wastes.

Currently, EPA is reexamining its RCRA regulations for "low-risk" listed hazardous wastes under the proposed Hazardous Waste Identification Rule (HWIR).⁵ Under this proposal, a listed hazardous waste that meets the exit level for low-risk waste would no longer be subject to the hazardous waste management system under Subtitle C of RCRA^c as "listed" hazardous waste. The current EPA list of chemicals and their exit levels is at a preliminary stage and incomplete at this time. The rule will be finalized on April 30, 2001. The possibility of using the HWIR for delisting listed wastes under consideration in this study will need to be investigated once the rule is finalized.

^c Facilities that manage RCRA hazardous waste are referred to as "RCRC Subtitle C" facilities.

Table 1. Tank Farm waste codes (based on Ref. 3).

Hazardous Waste Codes	Chemical Name	LDR Non-Wastewater Standard	Process Knowledge	Concentration (low/high)
DOO2	corrosive	Deact and meet UTS	Yes	pH < 0.5
D002	fluoride	N/A	Yes	329-400 mg/L
Underlying D002	nickel	5.0 mg/L TCLP	Yes	10.9-51.4 mg/L
D004	arsenic	5.0 mg/L TCLP	Yes	< 3.21 mg/L
D005	barium	7.6 mg/L TCLP	Yes	6.8-7.5 mg/L
D006	cadmium	0.19 mg/L TCLP	Yes	83-97 mg/L
D007	chromium	0.86 mg/L TCLP	Yes	135-201 mg/L
D008	lead	0.37 mg/L TCLP	Yes	4.13-441 mg/L
D009	mercury	0.20 mg/L TCLP	Yes	190-205 mg/L
D010	selenium	0.16 mg/L TCLP	Yes	0.82-2.42 mg/L
D011	silver	0.30 mg/L TCLP	Yes	0.48-<2.94 mg/L
F005	benzene	10 mg/kg	Yes	0.0094-0.0758 mg/kg
U019	benzene	10 mg/kg	Yes	0.0094-0.0758 mg/kg
D019	carbontetrachloride	6.0 mg/g	—	2.73 mg/L*
D021	chlorobenzene	6.0 mg/kg	—	—
D022	chloroform	6.0 mg/kg	—	0.307 mg/L
D026	cresol-mixed sorbers	5.6 mg/kg	—	—
D028	1,2-dichloroethane	6.0 mg/kg	—	—
D032	hexahlorobenzene	10 mg/kg	—	—
D034	hexachloroethane	30 mg/kg	—	—
D035	methy ethy ketone	36 mg/kg	—	0.1704 mg/L
D036	nitobenzene	28 mg/kg	—	—
D038	pyridine	16 mg/kg	—	14.47 mg/L
D039	tetrachloroethylene	6.0 mg/kg	Yes	—
D040	trichloroethylene	6.0 mg/kg	Yes	—
F002	carbon tetrachloride	6.0 mg/kg	—	40.9 mg/L*
F002	tetrachloroethylene	6.0 mg/kg	Yes	—
F002	1,1,1-trichloroethane	6.0 mg/kg	—	1857.36 mg/L
F002	1,1,2-trichloroethane	6.0 mg/kg	—	1857.36 mg/L

Table1 (continued).

Hazardous Waste Codes	Chemical Name	LDR Non-Wastewater Standard	Process Knowledge	Concentration (low/high)
F002	trichloroethylene	6.0 mg/kg	Yes	—
F005	benzene	10 mg/kg	Yes	—
F005	carbon disulfide	4.8 mg/L TCLP		0.397 mg/L
F005	isobutyl alcohol	170 mg/kg	Yes	—
F005	methyl ethyl ketone	36 mg/kg		0.1704 mg/L
F005	methylene chloride	30 mg/kg		0.0443 mg/L
F005	pyridene	16 mg/kg		14.47 mg/L
F005	toluene	10 mg/kg		3.07 mg/L
F005	2-nitropropane	CMBST	Yes	—
P098	potassium cyanide	590 mg/kg	—	0.005 mg/L
P104	silver cyanide	590 mg/kg	—	0.1295 mg/L
P105	sodium azide	CHOXD, CHRED, or CMBST	—	0.102 mg/L
P106	sodium cyanide	590 mg/kg	Yes	—
P119	ammonium vanadate	STABL	—	0.0164 mg/L
P120	vanadium pentoxide	STABL	—	0.8179 mg/L
U002	acetone	160 mg/kg	—	—
U003	acetonitrile	CMBST	—	0.0447 mg/L
U012	aniline	14 mg/kg	—	0.808 mg/L
U044	chloroform	6.0 mg/kg	—	0.307 mg/L
U080	methylene chloride	30 mg/kg	—	F-list only
U108	1,4-dioxane	CMBST	—	3.75 mg/L
U122	formaldehyde	CMBST	—	0.0043 mg/L
U123	formic acid	CMBST	—	0.242 mg/L
U133	hydrazine	CHOXD, CHRED, or CMBST	—	0.0683 mg/L
U138	idomethane	65 mg/kg	Yes	—
U140	isobutyl alcohol	170 mg/kg	Yes	—
U159	methyl ethyl ketone	36 mg/kg	—	F-list only
U171	2-nitropropane	CMBST	Yes	—

Table1 (continued).

Hazardous Waste Codes	Chemical Name	LDR Non-Wastewater Standard	Process Knowledge	Concentration (low/high)
U188	phenol	6.2 mg/kg	—	0.1701 mg/L
U196	pyridine	16 mg/kg	—	14.47 mg/L
U210	tetrachloroethylene	6.0 mg/kg	Yes	—
U211	carbon tetrachloride	6.0 mg/kg	—	2.73 mg/L
U219	thiourea	CMBST	—	2.11 mg/L
U220	toluene	10 mg/kg	—	F-list only
U225	bromoform	15 mg/kg	Yes	—
U226	1,1,1-trichloroethane	6.0 mg/kg	—	F-list only
U227	1,1,2-trichloroethane	6.0 mg/kg	—	F-list only
U228	trichloroethylene	6.0 mg/kg	Yes	—
SVOC ^{**} , ⁺	2-nitrophenol	13 mg/kg	—	89 ppb
SVOC ⁺	1,2,4-trichlorobenzene	19 mg/kg	—	10 ppb
U165 (SVOC)	naphthalene	5.6 mg/kg	—	10 ppb
SVOC ⁺	acenaphthene	3.4 mg/kg	—	39 ppb
P048 (SVOC)	2,4-dinitrophenol	160 mg/kg	—	81 ppb
U105 (SVOC)	2,4-dinitrotoluene	140 mg/kg	—	95 ppb
U088 (SVOC)	diethylphthalate	28 mg/kg	—	128 ppb
F027 ? (SVOC)	pentachlorophenol	10 mg/kg	—	10 ppb
SVOC ⁺	di-n-butylphthalate	28 mg/kg	—	10 ppb
SVOC ⁺	butylbenzylphthalate	28 mg/kg	—	10 ppb
U107 (SVOC)	di-n-octylphthalate	28 mg/kg	—	10 ppb
U022 (SVOC)	benzo(a)pyrene	3.4 mg/kg	—	10 ppb

* Two different concentrations are reported in Concentration column for CCl₄ under waste codes D019 and F002.

** Semivolatile organic compounds.

⁺ Waste codes are not known.

3. MIXED HIGH-LEVEL WASTE

The waste processing options that are expected to generate mixed HLW are VWO, HWO, DCWO, CWO, and HAW/LAW separations option. These options produce distinct waste forms including glass,

glass-ceramic, and hydroceramic (pozzolan cement) waste. These wastes are analyzed here to determine their disposal requirements.

3.1 Vitrified Waste Form from VWO

This option includes calcining the ICPP liquid wastes and mixing all the calcine with glass forming material to produce a vitrified or glass waste form. The resultant waste product is a HLW. The vitrified HLW is planned to be disposed of at a HLW geologic repository.

3.1.1 RCRA Disposal Requirements

The reported hazardous constituents in the wastes include characteristic heavy metals (D004-D011), corrosive (D002), and listed chemicals.^{2,3} The listed hazardous chemicals are mainly organic compounds. Vitrification is the LDR specified treatment method for HLW with D002 and D004-D011 HWNs. Vitrification using borosilicate glass technology is considered by the EPA a BDAT for treatment of mixed HLW containing waste codes D002 and D004-D011.¹ This decision is based on the EPA review and analysis of the specific data submitted by DOE on using vitrification to treat mixed HLW, and on the subsequent EPA vitrification site visit.¹ The EPA stated in a Federal Register⁶ that the glass-ceramic process is also an acceptable technology (i.e., BDAT).

Some of the listed hazardous constituents require treatment other than vitrification. In this option, it is planned to calcine all the ICPP wastes prior to vitrification. Due to the operating temperature of the calciner (400 to 600°C), it is very unlikely that these chemicals could survive and be present in existing or future calcines. Little or no analyses have been performed on the existing calcine for the RCRA contaminants.² The RCRA chemicals reported for the calcine are based on the calciner feed composition, and they include a few heavy metals.² The organic chemicals requiring technology-based treatment include eleven listed wastes. Nine of them must be treated with combustion, chemical oxidation, or chemical reduction; and the remaining two require stabilization^f. The nine listed waste codes (eight chemicals—one with two listed waste codes) include 2-nitropropane (F005 and U171, combustion), sodium azide (P105, chemical oxidation, chemical reduction, or combustion), acetonitrile (U003, combustion), 1,4 dioxane (U108, combustion), formaldehyde (U122, combustion), formic acid (U123, combustion), hydrazine (U133, chemical oxidation, chemical reduction, or combustion), and thiourea (U219, combustion). The other two listed waste codes that require stabilization are ammonium vanadate (P119), and vanadium pentoxide (P120). For the waste codes that are subject to the LDR technology-based treatments, the wastes may also be land disposed if treated by an equivalent treatment technology approved by EPA. Under 40 CFR 268.42(b), a petition can be submitted to EPA for using vitrification as an equivalent technology to combustion, chemical oxidation, or stabilization. It is

^f *stabilization*. As defined by EPA LDR, using reagents or combinations of reagents such as Portland cement, lime/pozzolans (e.g., fly ash and cement kiln dust) or other reagents to enhance set/cure time and/or compressive strength, or to overall reduce the leachability of the metals or inorganics are acceptable stabilization methods.

believed that vitrification at very high temperature (at least 2000°F or 1093°C) demonstrates the same level of performance as combustion, chemical oxidation, or stabilization.

As for inorganic chemicals requiring specified technology treatment, none are expected to be present in the calcine wastes. Sodium Azide decomposes upon heating, and Hydrazine could also be expected to decompose in the calciner and in the acidic Tank Farm tanks solution.² The only contaminants reported in Table 1 that could possibly be present in the calcine wastes are Vanadium Pentoxide, Ammonium Vanadate, and Potassium Cyanide.² However, none have been discharged in the Tank Farm since 1988.² Therefore, it is unlikely that they will be present in any future generated calcine. For Vanadium Pentoxide, Ammonium Vanadate, and Potassium Cyanide, it is assumed that the first two compounds are present in concentrations of 1 mg/l (1 mg/kg) and the latter is present in concentration of 0.01 mg/l (0.01 mg/kg). The Potassium Cyanide concentration is far below the LDR treatment standard. Ammonium Vanadate (P119) and Vanadium Pentoxide (P120) must be treated with LDR specified stabilization technology. It is unknown whether other chemical species are generated as a result of incomplete combustion during the calcination. A full characterization study of the calcine wastes is necessary to determine the hazardous waste contents.

The remaining chemicals require concentration-based treatments if their concentrations are above the LDR limits. For concentration-based standards, either a Totals Analysis Tests or the Toxicity Characteristic Leaching Procedure (TCLP) for waste extract must be performed to determine compliance. All the underlying hazardous constituents⁸ for characteristic wastes (e.g., corrosive) subject to the UTS must meet the limits found in 40 CFR 268.48.

Due to the high temperature vitrification process, mercury will be mostly volatilized and collected as elemental mercury in the off-gas scrub solution to be amalgamated, and ultimately, sent to a LLW disposal facility if classified as LLW. It is expected that all the other options considered in this study will be equipped with systems for capturing and treating the off-gas mercury.

3.1.2 HLW Repository Waste Acceptance Criteria

3.1.2.1 Background. The Nuclear Waste Policy Act (NWPA) of 1982 established a Federal policy requiring that DOE manage and dispose of spent nuclear fuel and HLW of domestic origin in geologic repositories. The Act established the Office of Civilian Radioactive Waste Management (OCRWM) to carry out DOE responsibilities, subject to repository licensing by the NRC and the standards set by the EPA. However, the 1987 amendments to the Act, "Nuclear Waste Policy Amendments Act (NWPAA)" required that DOE characterize only Yucca Mountain and terminate activities at other sites. Thus, Yucca Mountain was designated for characterization as the candidate site for a HLW geologic repository. However, future waste projections suggest that, at some time in the future, the first repository will need to be expanded or a second repository constructed.

⁸ 40 CFR 268.2 (i) - Underlying hazardous constituent means any constituent listed in UTS Table 40 CFR 268.48, except for fluoride, vanadium, and zinc, which can be reasonably expected to be present at the point of hazardous waste generation in concentrations above the constituent-specific UTS.

Criteria for acceptance and disposal of waste at the Yucca Mountain repository have not been finalized. The following information is intended to provide preliminary guidance to proceed with waste acceptance issues. The information is based on DOE criteria,⁷⁻⁹ EPA regulatory requirements for disposal of HLW in geologic repositories,¹⁰⁻¹⁵ DOE Environmental Management (EM) Waste Acceptance Product Specifications (EM-WAPS) for transportation and disposal of HLW,¹⁶ Waste Acceptance System Requirements Document (WASRD),¹⁷ DOT, and technical opinions reported in the literature.¹⁸

DOE Order 5820.2A⁷ (in the process of being replaced with DOE Order 435.1^h)⁸ requires that the waste acceptance specifications and criteria based on EPA requirements shall be developed and approved for high-level waste forms prior to startup of the facilities that generate the disposal waste form. The EPA and DOT standards are outlined in 10 CFR 60.113,¹⁰ 10 CFR 60.131(b)(7),¹¹ 10 CFR 60.135,¹² 10 CFR 71,¹³ 49 CFR,¹⁴ and 40 CFR 191.¹⁵ These requirements include environmental radiation protection and other standards applicable to repository performance/operation for HLW management and disposal.

Draft DOE Order 435.1 states that all waste management activities shall be performed in accordance with the requirements in DOE Manual 435.1 (draft).⁹ DOE Manual 435.1 requires that the container management, packaging, and transportation for the immobilized HLW to meet the requirements of the DOE EM WAPS.¹⁶

DOE EM developed the EM-WAPS for the high level waste form generators to serve as the basis for their waste acceptance programs. The specifications are based on the DOE criteria and EPA regulations. In the DOE EM study, the generators included: the South Defense Waste Processing Facility (DWPF) at the Savannah River Site; the West Valley Demonstration Project at West Valley, New York; and the Hanford Waste Vitrification Plant in Washington. The EM WAPS provide background information detailing the deliverables required by the waste acceptance process, and are the technical specifications the waste form generators are required to meet in order to ensure acceptance of their vitrified HLW into the Civilian Radioactive Waste Management System (CRWMS)ⁱ. The OCRWM was to provide the specifications, however, OCRWM is currently redefining its technical and functional baseline. The OCRWM has opted to pass the responsibility for providing product specifications to the waste form generators to EM. However, EM is committed to ensure that the EM-WAPS are in concert with the OCRWM technical baseline.

The EM WAPS¹⁶ and WASRD¹⁷ are used here as technical baseline documents for INEEL HLW acceptance to the repository. The waste acceptance process requires demonstration of compliance with the EM-WAPS via four different documents, each prepared by the generators, reviewed and accepted by EM, and provided to OCRWM. These four documents are the "Waste Form Compliance Plan (WCP)," "Waste Form Qualification Report (WQR)," "Production Records (PR)," and "Storage and Shipping Records (SSR)." The contents of these documents and other potential criteria for the waste acceptance to the repository are discussed below.

^h DOE Order 435.1—This order will replace DOE Order 5820.2A. DOE Order 435.1 has been issued by DOE in draft form. Presently, under current LMITCO contract compliance with DOE Order 5820.2A is mandatory and will remain in effect until replaced with DOE Order 435.1.

ⁱ Civilian Radioactive Waste Management System (CRWMS) - is the composite of the sites, and all facilities, systems, equipment, materials, information, activities, and the personnel required to perform those activities, necessary to manage canistered waste form disposal.

3.1.2.2 Waste Acceptance Documentation. The following waste acceptance documentation shall be developed by the waste generator, maintained as lifetime Quality Assurance (QA) records, and provided to OCRWM:

- A WCP shall describe the generator's plan for demonstrating compliance with the requirements of the EM-WAPS, including tests, analyses and process controls to be performed by the generator, and records that will be provided as evidence.
- A WQR shall compile the results from waste form testing and analysis to demonstrate the ability of the generator to comply with the requirements of the EM-APS.
- PR are the documentation provided by the generator that describes the canistered waste form.
- SSR shall describe the physical attributes of each canistered waste form and identify any abnormal events, such as thermal excursions, which have occurred during storage.

3.1.2.3 Waste Specifications

3.1.2.3.1 EPA RCRA Compliance and DOE Recommendation The waste form to be accepted into the repository will have to be immobilized HLW in vitrified borosilicate glass. In addition, it must meet all other RCRA LDR requirements for disposal as discussed above. Presently, the potential repository at Yucca Mountain is not a RCRA regulated hazardous waste, Subtitle C disposal facility, and consequently does not accept any hazardous waste.¹⁷ As a result, the waste must be delisted prior to disposal at the repository.

DOE's comprehensive environmental assessment of several immobilization technologies for HLW led to the recommendation of borosilicate glass as the preferred waste form.¹⁹ The characteristics of the borosilicate glass waste form in the DOE study are shown in Table 2.¹⁷ DOE's assessment and recommendation were the basis for EPA considering borosilicate glass as a BDAT technology for treatment of HLW.¹ However, DOE's studies of glass-ceramic process and comparison of glass-ceramic process and waste form with borosilicate glass waste have shown that glass-ceramic waste form meets the definition of EPA vitrification and performance of borosilicate waste.⁶ EPA has concurred with the DOE conclusion and has determined that the glass-ceramic process is an acceptable technology to meet the definition of a BDAT.⁶

The EPA standards in 40 CFR 191¹⁵ relating to disposal of HLW contain projected performance requirements for repository in terms of total curies released to the accessible environment over a 10,000-year period. According to the DOE study, the risk assessments for borosilicate glass in a typical repository show virtually no activity is released in a 10,000-year period.¹⁹

Table 2. Characteristics of borosilicate glass waste form

Characteristics	Borosilicate glass
Density, kg/m ³	2750
Waste loading, wt%	28
Toleration of waste variability	Acceptable
Long-term leachability,* g/m ² -day	10 ⁻³ to 10 ⁻⁴
Radiation stability	Very good
Processability**	Relatively simple

* Based on Plutonium leach rates in long-term tests at room temperature.
** Relative ease of producing the waste form.

3.1.2.4 Waste Form Criteria. All radioactive waste must packaged be in a solid form. Free liquids^j are prohibited, either internal or external to the waste package, for any packages shipped to the repository. The prohibition against the presence of liquids is based on limiting the release of contaminated liquids if a container fails during handling or emplacement operations. This restriction also guards against any adverse affects these liquids might have on the structures integrity that contribute to internal corrosion of the waste package. Where material(s) may be added to the canister at the generator site as a liquid, such as in the production of borosilicate glass, test and sample results must be able to demonstrate or otherwise provide assurance that a residual liquid content of less than [TBD]% exists within the canister at time of closure.

3.1.2.5 Chemical Composition During Production. In the PR, the generator must report the oxide composition of the waste form. The PR shall include all elements, excluding oxygen, present in concentrations greater than 0.5 wt% of the glass for each waste type. The generator must describe the method to be used for compliance in the WCP. An estimate of the error of the reported composition and the basis for the estimate shall be reported in the WQR.

The chemical composition and crystalline phases in the amount of each crystalline phase expected to be present in waste must be projected in the WQR. The method to obtain the required data must be recorded in the WCP, and provided in the WQR.

3.1.2.6 Chemical Compatibility. Chemical additives used during the preparation or processing of the canistered waste shall not, as demonstrated through qualified process data, increase the chemical reactivity of any species present in the waste.

3.1.2.7 Radionuclide Inventory Specification. The waste generator must report the inventory of radionuclides (in curies) that have half-lives longer than 10 years and that are, or will be present in

^j A free liquid is a liquid that could be drained from the canister either initially or after the canistered waste form has been subjected to temperatures up to 500°C.

concentrations greater than 0.05% of the total radioactive inventory for each waste type, indexed to the years 2015 and 3115.

The estimates of the total quantities of individual radionuclides to be shipped to the repository must be reported in the WQR. The generator must also report the upper limit of these radionuclides for any canistered waste form, and an average calculated radionuclide inventory per canister for waste type. The method to be used to obtain the required data must be described by the generator in the WCP, and the data must be documented in the WQR. Radionuclide inventory estimates not available for reporting in the initial WQR has to be included in an addendum to the WQR.

In the PR, the generator must provide estimates of the inventories of individual reportable radionuclides for each canister and waste. The generator shall also report the estimated error of these estimates in the WQR.

3.1.2.8 Leach Rates. Leach rates for the HLW form must be based on comparing the total normalized release rates of matrix elements from production samples to the total normalized release of matrix elements from the benchmark glass established in the Environmental Assessment for the vitrified HLW form. The rate is currently established at $1.0 \text{ gm/m}^2\text{-day}$.¹⁸

The measured or calculated mean results for cationic leachate from the phase(s) containing the radionuclides requiring isolation shall be included in the PR. The records shall contain results derived from actual sample analyses, as well as process control information used for verification. When using process control information to project leach rates, the producer shall demonstrate (in the WQR) that the method used will provide information equivalent to the testing of samples of actual production glass.

3.1.2.9 Specification for Phase Stability. The generator must provide the following phase stability data for projected wastes, describe the method used to obtain it in the WCP, and provide data in the WQR:

- The glass transition temperature^k
- A time-temperature-transformation diagram that identifies the duration of exposure at any temperature that causes significant changes in either the phase structure or the phase compositions.

At the time of shipment, the generator must certify that, after the initial cool-down, the waste form temperature will not exceed 400°C. The generator shall describe the compliance method in the WCP.

3.1.2.10 Canister Dimension Specifications. The waste form canister, the canister label, and any secondary canister must be fabricated from austenitic stainless steel. The canister outermost closure must be leaktight to 1×10^{-4} atm-cc/sec helium. The method used to demonstrate compliance shall be described by the generator in the WCP.

^k The glass transition temperature is the temperature at which glass transforms from a rigid solid to a viscous liquid. This temperature corresponds to glass viscosity of $\sim 10^{13}$ poise, and is $< 500^\circ\text{C}$, for most, if not all borosilicate waste glasses.

The overall length of the unfilled canister, after accounting for the closure method, shall be 3.000 m (+0.005 m, -0.020 m), including the neck and lifting flange (see Figure 1). The outer diameter of the unfilled canister shall be 61.0 cm (+1.5 cm, -1.0 cm). The measured length and diameter of the unfilled canister shall be reported in the PR.

Another type of container system proposed for HLW shipment includes an over-length (4.5 meters) canister of the standard diameter.¹⁸ All deviations from the standard size canister must be approved by the repository prior to filling the canister by the shipper. Non-standard waste-package shipment require producer supplied inserts to ensure necessary restraint of the waste package inside the container during transport.

3.1.2.11 Canister Double Containment Specifications. Currently, NRC requires that canisters be doubly contained (10 CFR 71.63) that are used to carry vitrified HLW to the potential Yucca Mountain repository that have plutonium in excess of 20 curies.¹³ Recently, in Federal Register, Vol. 62, May 8, 1997, the NRC proposed an amendment its regulations to remove the double containment requirements for canisters of vitrified HLW containing Plutonium. The NRC stated that the double-containment provision compensates for the fact that the plutonium may not be in a "nonrespirable" form. The NRC believes that essentially nonrespirable solid forms of plutonium should be exempted from the double containment requirement. The DOE believes that HLW immobilized in borosilicate glass, and then put into a stainless steel canister for storage and ultimate disposal appears appropriate to exempt from the double containment requirements.

Figure 1. Standard HLW canister (from Ref. 18).

This amendment is being proposed in response to a DOE petition to allow HLW to be transported and disposed in a more cost-effective and efficient manner without adversely affecting public health and safety.

The containers used to transport canisters of vitrified HLW will be Type B packages certified by the NRC. These packages are required to meet accident resistant standards. The HLW will also be subject to the special transport controls for a "Highway Route Controlled Quantity" pursuant to the DOT regulations. In addition, the amended NWSA of 1982, requires DOE to provide technical assistance and funds to train emergency responders along the planned route.

DOE asserts that shipment of vitrified HLW without double containment will not adversely affect safety. This is because canistered, vitrified HLW provides a comparable level of protection to the packaging of reactor fuel elements that do not require double containment. DOE also noted that the plutonium concentrations within vitrified HLW will be considerably lower than those in spent nuclear fuel, and that vitrified HLW is in an essentially nonrespirable form.

Comments on the petition were received from the EPA, Nye County, Nevada (the site for the proposed spent fuel and HLW repository at Yucca Mountain); and the INEEL Oversight Program of the State of Idaho. The EPA reviewed the petition in accordance with its responsibilities under Section 309 of the Clean Air Act and had no specific comments. The Nye County agreed with the rationale and arguments advanced by the DOE, and had no objection to their petition. The State of Idaho commented that the petition was premature because it did not specify the parameters or performance standards that HLW must meet. The proposed amendment has not been finalized yet.

3.1.2.12 Canistered Waste Form Specifications.

3.1.2.12.1 Specifications for Free Liquid and Gas¹ The generator must ensure that the canistered waste form does not contain detectable amounts of free liquids, and document the method of compliance in the WCP and the detection limits in the WQR.

The generator shall also ensure that the canistered waste form does not contain detectable amounts of free gas¹ other than air, the residuals of air (components of air present in other than normal proportions), noble, and radiogenic gases.^m The internal gas pressure immediately after closure shall not exceed 150 kPa (22 psia) at 25°C. The generator shall describe the method of compliance in the WCP and provide documentation of the ability to comply with this specification and the detection limits in the WQR. The generator shall also document in the WQR, the quantities and compositions of any gases that might accumulate inside the canister from radiogenic decay, in the event the canistered waste form temperature exceeds 400°C. If a canistered waste form exceeds 400°C, it is nonconforming and shall be resolved in accordance with this subsection. Data/information reporting in the WQR, during the qualification process, shall be limited to temperatures up to 500°C.

¹ *free gas*. Free gas is any gas, including radiogenic gases and cover gases like helium, argon, or air, that could contribute to the canister pressurization. This includes gases generated by chemical reaction and radiolytic decomposition.

^m *radiogenic gas*. Radiogenic gas is any gas produced by radioactive transformation; that is, the transmutation of an element into a gaseous element by a change in the atomic nucleus through radioactive decay.

3.1.2.12.2 Specification for Explosiveness, Pyrophoricity, and Combustibility The generator has to ensure that the canistered waste form does not contain detectable amounts of explosive, pyrophoric,ⁿ or combustible materials. The generator must document in the WQR that the canistered waste forms remain nonexplosive, nonpyrophoric, and noncombustible in the event that the temperature exceeds 400°C. If a canistered waste form exceeds 400°C, it is nonconforming and shall be resolved in accordance with section 3.1.2.13. Data reported in the WQR, during the qualification process, must be limited to temperatures up to 500°C.

3.1.2.12.3 Organic Materials Specification The generator must ensure that the canistered waste form does not contain detectable amounts of organic materials. The generator has to describe the method for complying with this specification in the WCP and provide documentation of the ability to comply, and of the detection limits in the WQR.

3.1.2.12.4 Chemical Compatibility Specification The generator must ensure that the contents of the canistered waste form do not cause internal corrosion of the canister. This could adversely affect normal handling during storage or during an abnormal occurrence, such as a canister drop accident. The generator shall describe the method of demonstrating compliance in the WCP. Interactions between the canister and its contents, including any reaction products generated within the canistered waste form, in the event that the temperature exceeds 400°C, shall be discussed in the WQR. If a canistered waste form exceeds 400°C, it is nonconforming and shall be resolved in accordance with Section 3.1.2.13. Reporting data/information in the WQR during the qualification process shall be limited to temperatures up to 500°C.

3.1.2.12.5 Fill Height Specification The generator shall fill the canister to a height equivalent to at least 80% of the volume of the empty canister. The generator shall report this height in the PR and describe the method of compliance in the WCP. Documentation supporting the selected method of compliance shall be provided in the WQR.

3.1.2.12.6 Heat Generation Specification The heat generation rate for each canistered waste form shall not exceed 1500 watts per canister at the year of shipment. The generator shall report the estimated heat generation rate for each canistered waste form in the SSR, and describe the method for compliance in the WCP.

3.1.2.12.7 Heat Generation Projections The generator shall document, in the WQR, the expected thermal output of the canistered waste forms and the range of expected variation for each waste type, indexed to the year 2015. The method to be used for demonstrating compliance shall be described by the generator in the WCP. Projections for compositions not available for reporting in the initial WQR shall be included in an addendum to the WQR.

3.1.2.12.8 Specification for Maximum Dose Rates The canistered waste form shall not exceed a maximum surface (on contact) gamma dose rate of 10^5 rem/hr and a maximum neutron dose

ⁿ *pyrophoric material.* Pyrophoric material is considered any liquid that will ignite spontaneously in air below 54.4°C. Any solid material, other than one classed as an explosive, which under normal conditions is liable to cause fires through friction, retain heat from manufacturing or processing, or which can be ignited readily and when ignited burns so vigorously and persistently as to create a serious transportation, handling, or disposal hazard. Included are spontaneously combustible and water-reactive materials, and especially the materials specified in 49 CFR 173, Subpart E.

rate of 10 rem/hr at the time of shipment. The generator shall provide in the SSR either the calculated or measured values for both gamma and neutron dose rates at the time of shipment for each canistered waste form and describe the method of compliance in the WCP.

3.1.2.12.9 Projections of Dose Rates The generator has to report in the WQR the expected values and the range of expected variation for both gamma and neutron dose rates indexed to the year 2015. The generator shall describe the method for demonstrating compliance in the WCP.

3.1.2.12.10 Subcriticality Specification The generator must prepare a waste form to ensure that, under normal and accident conditions, a nuclear criticality accident is not possible unless at least two unlikely, independent, and concurrent or sequential changes have occurred in the conditions essential to nuclear criticality safety. The calculated effective neutron multiplication factor, k_{eff} , must be shown to be less than 0.90 after allowing for bias in the method of calculation and the uncertainty in the experiments used to validate the method of calculation. The generator shall describe the method of demonstrating compliance in the WCP and provide supporting documentation in the WQR. The WQR shall also include sufficient information on the nuclear characteristics, such as fissile density, of the canistered waste form to enable subcriticality to be confirmed under transportation, storage and disposal conditions.

3.1.2.12.11 Weight Specifications The weight of the canistered waste form shall not exceed the maximum size and weight which can be received, handled, and emplaced in the repository. These parameters shall be controlled as indicated below and shall be documented at the time of shipment. The generator shall describe the method of compliance in the WCP and the basis for compliance in the WQR.

The weight of the canistered waste form shall not exceed 2,500 kg (standard canister). The measured weight and estimated error shall be reported in the Storage and Shipping Records. The dimensions of the canistered waste form shall be such that, at the time of shipment, the canistered waste form will stand upright without support on a flat horizontal surface.

3.1.2.12.12 Drop Test Specification The canistered waste form shall be capable of withstanding a 7 meter drop onto a flat, essentially unyielding surface without breaching (leak rate $<1 \times 10^4$ atm-cc/sec helium). The generator shall describe the method of compliance in the WCP and provide test results and any supporting analyses in the WQR. The test results shall include information on measured canister leak rates and canister deformation after the drop.

3.1.2.12.13 Mechanical Properties The repository will be at atmospheric pressure due to the porous nature of the rock, to the extent that barometric pressure fluctuations are expected to affect the flow and transport. Waste package design will protect against collapse for full immersion pressures up to [TBD] MPa.

3.1.2.13 Quality Assurance Specification. The generator shall establish, maintain, and execute a QA program that applies to the testing and analysis activities that demonstrate compliance with these EM-WAPS during waste form qualification, production, handling, storage, and preparation for shipment. The generator shall submit an action plan, signed by authorized personnel through EM to DOE-OCRWM for correction or disposition of nonconforming waste forms for verification and documented approval from the OCRWM. The action plan must identify and describe the nonconformance and any action to change and correct the existing nonconformance.

3.1.2.14 Other Requirements. Documentation addressing specifications in this section will not appear in either the WCP or the WQR. The required format for complying with these specifications must be developed between DOE-EM and DOE-OCRWM and direction provided to the generators. These requirements are included here for completeness.

3.1.2.14.1 Specification for Test Plans and Procedures The OCRWM Waste Acceptance (WA)/generator shall demonstrate conformance of the system elements requirements as required in the verification matrix in the WASRD.¹⁵ The WA is the OCRWM waste acceptance system or organization that manages the waste acceptance of canistered waste forms from the generator into the CRWMS.

3.1.2.14.2 Specification for Delivery of Non-Standard Canistered Waste Non-standard canistered waste is nonconforming canistered waste forms that has been reviewed by DOE-OCRWM and deemed acceptable. Non-standard canistered waste may be in a condition which requires special handling. The generator shall obtain delivery and procedure confirmation from DOE prior to delivery of other than standard canistered waste.

3.1.2.14.3 Specification for Dose Observation at Time of Shipment The generator shall allow a designated OCRWM representative access to the generator's site to observe preparatory activities prior to canistered waste form shipment and to assist in OCRWM verification of the HLW description prior to loading the transportation cask.

3.1.2.14.4 Specification for DOE Notification of Improperly Described Waste The generator shall not transfer title of improperly described canistered waste form unless DOE-OCRWM agrees in writing to accept title. If the canistered waste form is determined by WA to have been improperly described by OCRWM prior to acceptance, OCRWM reserves the right to refuse acceptance.

3.1.2.14.5 Specification for Resolution of Improperly Described Accepted Waste If WA notifies the generator that, subsequent to its acceptance, WA found a canistered waste form that has been improperly described, the generator has to provide WA a proper description within 30 days of such notification.

3.1.2.14.6 Specification for Transfer of Title to the DOE The generator shall make available a loading facility at his site, designated for transfer of the canistered waste forms to DOE-OCRWM.

3.1.2.14.7 Specification for HLW Annual Report EM shall provide to OCRWM annual reports of waste generation and projections of quantities of canistered waste forms requiring disposal.

3.1.2.14.8 Specification for Final Description of Waste EM shall describe in writing the material in each shipping lot 60 days prior to the scheduled transport of that lot.

3.1.2.14.9 Specification for Fee Payment EM shall execute a suitable interagency agreement with OCRWM reflecting the terms and conditions specified in 10 CFR 961.11¹⁸ with regard to the payment of disposal fees.

3.1.2.14.10 Shipping-Cask Condition Specification The generator shall provide written documentation and certification, in accordance with the applicable requirements in 10 CFR 961.11 and in

10 CFR 71.87, of the cask conditions and contents prior to transfer of the canistered waste forms. Pursuant to these requirements, the package must be designed, constructed, and prepared for transport so that in still air at 38°C (100°F) and in the shade, no accessible surface of a package would have temperature exceeding 50°C (122°F) in a non-exclusive use shipment, or 85°C (185°F) in an exclusive shipment.^o

3.1.2.14.11 Cask Subsystem Packaging Specification The generator shall provide written documentation and certification that the transportation cask subsystem has been packaged to meet DOE, DOT, and NRC requirements and to transfer care, custody, and control of the shipment. These requirements have not been finalized yet.

3.1.2.14.12 Specification for Radiotoxicity at Time of Shipment The generator shall provide, in the Storage and Shipping Records, the name of each radionuclide listed in 49 CFR 173.435 in order of decreasing radiotoxicity, whose activity comprises 1% or greater of the total activity, at the time of shipment.

3.1.2.14.13 HLW Receipt The generator shall provide and pay the costs of interim storage at the repository, until HLW is accepted by the OCRWM.

3.1.2.15 Transportation. Issues related to the transportation of HLW under the NWPA will be established to assist the DOE in developing a policy related to transportation, and implementing a transportation program. The program is to provide criteria for safe, uninterrupted, and uneventful shipment of HLW to the repository. Transportation options are as follows:

- National Transportation:
 - Highway shipments—HLW would be shipped by truck
 - Rail shipment—HLW would be shipped by rail
- Regional Transportation:
 - Use legal-weight trucks
 - Use heavy-haul trucks—transfer facility at existing rail line

Both the generator and the repository are expected to be equipped with railroad capabilities. Any highway transport will be limited to a special tractor/trailer transporter for local transport (likely) only to nearest available railroad. Transportation of the waste will be coordinated by the Repository Project Office (RPO) in compliance with all applicable DOE, DOT, and NRC regulations. DOE/RPO assures regulatory compliance of the waste and provides formal waste acceptance notification.

^o *exclusive use.* Exclusive use means the sole use by a single consignor of a conveyance for which all initial, intermediate, and final loading and unloading are carried out in accordance with the direction of the consignor or consignee. The consignor and the carrier must ensure that any loading or unloading is performed by personnel having radiological training and resources appropriate for safe-handling of the consignment. The consignor must issue specific instructions, in writing, for maintenance of exclusive use shipment controls, and include them with the shipping paper information provided to the carrier by the consignor.

3.2 Hydroceramic or Grout Waste Form from DCWO

This option involves calcining the ICPP liquid radioactive wastes and mixing all the calcine wastes with clay, blast furnace slag, and other additives to produce a hydroceramic or grout form of feldspathoid/Zeolite. The resultant waste product is planned to be sent to a HLW repository for permanent disposal.

Based on the reported data², the waste is subject to the same requirements for disposal as in the vitrification option discussed above. Grouting is not an LDR specified technology, therefore, a DET petition must be submitted to EPA for permission to use the alternative grouting method.

3.3 Glass-Ceramic Waste Form from HWO

The glass-ceramic waste form results from a process which uses high temperature and pressure to convert all the calcine wastes (existing and future) previously mixed with titanium powder, amorphous silica, and other glass forming additives to a glass-ceramic material. The HIP method (with minor variations from the proposed option described in this report) was investigated for immobilizing HLW calcine at the INEEL in early 1990's. The DOE submitted an application to EPA for an extension of LDR effective date for certain types of mixed wastes including HLW and other waste streams in 1992.⁶ The EPA proposed a decision on the DOE's request which was published in 57 Federal Register⁶ (FR) in 1992. As part of the EPA requirements for granting such an extension, the DOE had to provide sufficient data and to demonstrate treatment capability for the mixed HLW. The DOE presented the EPA with laboratory and pilot scale data on the glass-ceramic treatment process. DOE stated that the glass-ceramic process is the preferred method for INEEL HLW immobilization.⁶ The DOE also indicated that the glass-ceramic process meets the definition of HLW vitrification (HLVIT) used by the EPA in 40 CFR 268.42.⁶ Based on the DOE studies, and laboratory and pilot scale tests, EPA concluded that the glass-ceramic process is more efficient than the glass process for calcine, and it is a technology that meets the definition of a BDAT.⁶ The status of the EPA proposed decision in the 57 FR⁶ is not clear at the present time. If the decision is finalized, a DET petition will not be needed for using the HIP technology as an alternative treatment to vitrification. DOE had previously identified borosilicate glass vitrification technology as the preferred waste form for mixed HLW. The DOE's assessment was the basis for EPA to consider vitrification a BDAT for treatment of HLW.¹ The DOE has identified the glass-ceramic waste form as being similar to the Savannah River's Site glass waste product.⁶ DOE's comparison of the glass-ceramic process and the corresponding waste form with borosilicate waste has shown that the glass-ceramic method meets the definition of EPA vitrification and the performance criterion (leach rates) of borosilicate waste glass.⁶ The DET petition is needed for the RCRA hazardous waste codes which require other LDR technology-specified treatments.

3.4 Hydroceramic or Cementitious Waste from CWO

This option involves slurring the liquid SBW and other low level liquid radioactive wastes with HLW calcines retrieved from the bin sets with some form of sugar, recalcining the slurry, and mixing the new calcine with similar stabilizers and other cement additives to DCWO in containers to produce a cementitious or hydroceramic waste form. The option of HIPing the hydroceramic waste to produce a vitrified concrete waste product is under consideration. It is proposed that the cementitious waste would be suitable for disposal at the Nevada Test Site (NTS) using Greater Confinement Disposal (GCD)

facility, and the vitrified waste product could be disposed of at a HLW repository. The cementitious or HIPed waste products are considered mixed HLW. The waste acceptance requirements for the GCD facility have not been defined at the present time. The waste destined for disposal at a HLW geologic repository such as the potential Yucca Mountain repository must meet the applicable regulatory requirements and the repository WAC previously discussed in this report.

3.4.1 Yucca Mountain

In order to qualify the waste for shipment to the potential repository at Yucca Mountain, the waste must comply with all the disposal requirements previously discussed.

3.4.2 Nevada Test Site—Greater Confinement Disposal Facility

Pursuant to the NWPAA, the Yucca Mountain in Nevada was designated for characterization as the only candidate site for a HLW geologic repository. However, the DOE has continued evaluating other sites as potential HLW repositories. The Sandia National Laboratory (SNL), under contract with the DOE, has conducted a study to assess the performance of the GCD facility at NTS for potential disposal of HLW.²¹ If NWPAA dictates that the Yucca Mountain is the only site for potential disposal of HLW, why consider the GCD? According to John Cochran, project manager of the GCD project at the SNL, (personal communication, letter of 8/11/97), the simple answer is cost savings.

The performance assessments (PA) are required to evaluate the suitability of repositories for disposal of waste to isolate them from the accessible environment. The objective of the SNL study is to assess the likelihood that the GCD will comply with the EPA performance measure standards for disposal of HLW and TRU in 40 CFR 191. It is also to provide the DOE with technical data to make a decision based on the compliance with the EPA standards. Figure 2 presents a diagram of the GCD PA and the decision making process. According to Mr. Cochran, (personal communication on 7/17/97), based on the recent compliance assessment,²² the GCD facility may meet the 1985 requirements set by 40 CFR 191. The PA of the GCD facility is not based on any field data but on expert opinions and literature study; however, the assessment is preliminary and inconclusive at this time. If the GCD concept can meet the EPA standards for disposal of HLW and save millions of dollars, then this facility should receive serious consideration.

In this option it is proposed that HLW be shipped to the NTS and buried in the alluvium boreholes between the bomb test craters. The alluvium boreholes are part of the GCD facility at the NTS.

The term GCD is a disposal strategy consisting of placing the waste in the bottom of boreholes and covering it with concrete, clay, soil, gravel, or sand. The GCD term was first developed in the early 1980s as a method of disposing of LLW that was not suitable for near-surface disposal.^{p,22} Subsequently (from 1984 to 1989), the DOE Nevada Operations Office (DOE-NV) disposed of a small quantity of

^p Traditionally, LLW has been disposed of at the Shallow Land Burial (SLB) Sites which involves disposal in the uppermost portion of the earth, about 30 meters (NRC requirements for disposal of LLW, 10 CFR 61.7) at various DOE and commercial sites.

special-case⁴ transuranic waste at the GCD facility.^{21,22} However, no waste has been accepted for disposal at the GCD facility since 1989. Based on the NTS WAC,²³ only LLW and mixed LLW are currently accepted for disposal and storage from generators outside the State of Nevada. The generators must be designated by DOE Headquarter (DOE-HQ) and approved by DOE-NV. According to Wendy Clayton of DOE-NV (personal communication on 7/15/97), the INEEL is presently neither a designated nor approved generator.

The GCD facility is located in Frenchman Flat Basin at the eastern border of the NTS as shown in Figure 3. Based on the stratigraphy of the GCD facility, at the location of the GCD boreholes, the basin is filled with alluvium to a depth of about 460 meters.²¹ GCD wastes reside about 200 m above the water table. Tertiary tuffs underlie the alluvium, and its upper portion consists of fractured vitrified tuffs that serve as an aquifer in Frenchman Flat Basin.

Currently, the GCD facility is designated as injection wells²⁴ by the State of Nevada (personal communication with Mr. Cochran on 7/17/97). However, the EPA's position is that placing nuclear waste in the ground does not constitute underground injection.²⁴ The GCD boreholes where wastes are emplaced are 3-m in diameter and 36.6-m deep.²¹ The wastes have been buried in the bottom 15.3 meters of the boreholes and the remaining 21.3 meters from the top of the waste to the land surface is backfilled with native alluvium (see Figure 4).²¹ It is projected that 60 holes approximately 3-m in diameter and 60-m deep would be needed to accommodate all of the waste projected to be generated from the proposed treatment options.

3.5 Vitrified Waste Form from HAW/LAW Separation Option

This option involves calcining the HLW, dissolving all the calcine and mixing it with the liquid SBW and low-level waste to feed it to separation system. This system uses several techniques to separate the mixture into HAW and LAW streams that can be treated and ultimately disposed of. The HAW meets the NRC definition of HLW, and therefore, it can be classified as HLW. It is proposed to vitrify the HAW and to send it to a geologic repository for permanent disposal. Thus, the HAW is subject to the same regulatory requirements and repository WAC previously discussed in the section for VWO.

The LAW is planned to be grouted and shipped to a LLW disposal facility (see section 5 for disposal requirements). The LAW is actually HLW per NRC source term definition; however, based on the projected activities of the radionuclides,² the LAW is expected to meet the definition of the NRC LLW.⁵ Class A. The LAW also meets the definition of incidental waste in the NRC evaluation of HLW

⁴ Special-case waste is a type of waste that is prohibited from shallow land burial and also it does not meet the WAC for WIPP and Yucca Mountain repositories.

²⁴ *injection well*. Injection well means a well into which fluids are being injected. Injection wells are not covered under RCRA. They are regulated under the Safe Drinking Water Act (SDWA). The SDWA requirements are covered in 40 CFR 144-148.

⁵ LLW is a radioactive waste that is not classified as HLW, TRU waste, spent nuclear fuel, or byproducts as defined in DOE Order 5820.2A. In 10 CFR 61.55²⁷ the NRC includes a waste classification system which divides LLW into three classes—Class A, B, and C. The classification system is based on the overall radionuclide hazards of the waste.

separation processes at Hanford Site.²⁵ From the Hanford waste and process evaluation, NRC concluded that residual waste generated from separation processes for removal of key radioactive elements, to the maximum extent technically and economically feasible, is classified as incidental waste. This is because the waste is incidental to the processes of separating HLW and that this waste can be disposed of at a near-surface facility if the following conditions are met:

- The residual waste will have to be converted to a solid physical form at a concentration that does not exceed the limits for the NRC LLW Class C as set in 10 CFR 61.55.
- The waste must be treated, stored, and disposed of under the DOE's regulatory authority for LLW and mixed-LLW. The DOE requires that mixed waste disposal comply with all the federal, state, and local regulations. Also, the incidental waste management is to be comparable to performance objectives set out in 10 CFR 61.

The term incidental waste is not defined by regulations, and the NRC has declined to promulgate criteria for distinguishing between HLW (disposal of which is under NRC's licensing jurisdiction) and incidental waste (disposal of which is not under NRC's jurisdiction with respect to DOE).⁹ The NRC believes that the determination for incidental waste must be made on a case-by-case basis and by way of adjudication instead of rule making.⁹ It is assumed that a determination will be made by government authorities (e.g., NRC and DOE) that LAW is LLW Class A not HLW because it meets the definition of NRC LLW Class A.

Mercury is present in the wastes that will be fed to the separations system. It is planned to optimize the separation processes for total or near total removal of mercury partitioned into the process solutions. The mercury in the solution will be reduced to elemental mercury in a redox reaction with formic acid. The elemental mercury will be removed and amalgamated to be sent to a LLW disposal facility if classified as LLW. There is a potential for mercury passage in sufficient concentrations in the off-gas or in the LAW and subsequently in the LAW grout even after optimization of mercury removal through separation/extraction processes. The off-gas mercury will be collected in the scrub solution as elemental mercury to be amalgamated.

Figure 2. GCD performance assessment process (from Ref. 21).

Figure 3. Location of the GCD Site (from Ref. 21).

Figure 4. Schematic diagram of typical GCD borehole (from Ref. 21).

4. MIXED TRANSURANIC WASTE

4.1 TRU Waste from TRU/LAW Separation Option

As in the HAW/LAW separation option, the calcine will be dissolved. The dissolved calcine and the remaining liquid SBW will be fed to a waste separations facility. The mixture will be separated into TRU, LAW, and HAW streams. Two treatment alternatives are being considered under this option which are designated as: 1) TRU/LAW Class C, and 2) TRU/LAW Class A/HAW. In the first alternative, the TRU waste fraction is expected to contain alpha-TRU radionuclides with half-lives greater than twenty years¹. The LAW will contain Cesium (Cs) and strontium (Sr) isotopes and radionuclides with low-level of activities. It is anticipated that the LAW in this alternative to meet the definition of NRC LLW Class C. In the second alternative, Cs and Sr will be separated as HAW, and the remaining wastes will be separated into TRU and LAW streams. The LAW is expected to meet the definition of NRC LLW Class A.

It is planned to convert the TRU waste to a solid form and to send it to the WIPP for disposal. The LAW is proposed to be grouted and transported to a LLW disposal facility. In the second alternative, the HAW will be vitrified and sent an interim storage facility to be ultimately disposed. Mercury will be captured and treated using he same processes described in Section 3.5.

All of the waste fractions, TRU, LAW, and HAW resulting from this option are actually HLW. This resultant wastes do not conform to the existing classification or definition scheme for radioactive waste. Although, it may be technically and economically feasible and attractive, it will need to receive evaluation, redefinition of types of waste, and the concurrence of the competent and applicable government authorities. If this option is chosen, steps should be taken to identify the mechanism by which redefinition and approval would be sought and obtained.

4.2 WIPP Requirements

The waste destined for disposal at the WIPP must meet the requirements of the Land Withdrawal Act (LWA) and the WIPP WAC.²⁶ The LWA requires that the waste destined for disposal at the WIPP meet the TRU definition, not contain HLW or spent nuclear fuel, and be generated from atomic energy and/or defense-related activities. It appears that the TRU waste resulting from the TRU only alternative meets the LWA requirements. The WIPP WAC contain the requirements for transportation and disposal as well as the compliance methods for both contact-handled (CH) and remote-handled (RH) TRU waste. The WIPP requirements are organized under container requirements, nuclear properties, chemical properties, gas generation, and data package. These requirements are described in detail in this subsection and summarized in Tables 3 and 4.

¹ *TRU Waste.* Per DOE Order 5820.2A, TRU waste, without regard to source or form, is a type of waste that is contaminated with alpha-emitting TRU radionuclides with half-lives grater than twenty years and concentration greater than 100 nCi/g at the time of assay.

Table 3. Summary of WIPP CH-TRU waste acceptance criteria.

Criteria	Limits
Container And Physical Properties	
Container Description	DOT Type A 55-gallon drums and SWBs
Container Weight	≤ 1000 lb/55-gallon drum ≤ 4000 lb/SWB $\leq$ Transuranic Package Transporter-II (TRUPACT-II) Weight ⁽⁴⁾
Removable Surface Contamination	20 dpm/100 cm ² Alpha 200 dpm/100 cm ² Beta-Gamma
Container Marking	Bar Code Shipping Category ⁽¹⁾
Dunnage	Empty 55-gallon drums or empty SWBs
Filter Vents	Payload containers vented
Liquids	No Liquid waste < 2 Liters total residual liquid per 55-gallon drum < 8 Liters per SWB < 1 in. (2.5 cm) in the bottom of any container
Nuclear Properties	
Nuclear Critically Pu-239 FGE	< 200 g/55-gallon Drum < 325 g/SWB < 325 g/TRUPAT-II
Pu-239 Equivalent Activity (PE-Ci)	<u>Untreated Waste</u> 80 PE-Ci/55-gallon drum 130 PE-Ci/SWB 1800 PE-Ci/55-gal. drum overpacked in SWB or DOP <u>Solidified/Vitrified Waste</u> PE-Ci/55-gallon drum
Contact Dose Rate	≤ 200 mrem/hr
Thermal Power	Report if > 0.1 watts/ft ³ (3.5 watts/m ³) < 40 watts per TRUPACT-II
TRU Alpha Activity	> 100 nCi/g of waste matrix
Chemical Properties	
Pyrophoric Materials	< 1% Radionuclide pyrophorics No nonradionuclide pyrophorics
Mixed Waste - Hazardous Constituents	Characterization Limited to EPA waste codes listed in Table 8
Chemical Compatibility	All chemicals must be allowable per the contact-handled TRUPACT-II Authorized Methods for Payload Control (CH-TRAMPAC)

Table 3. (continued)

Criteria	Limits
Explosives, Corrosives and Compressed Gases	No compressed gases No ignitable, reactive or corrosive waste
Gas Generation	
Decay Heat ⁽¹⁾	≤ wattage listed in TRUCON Tables (Appendix A)
Flammable VOCs	≤ 500 ppm in container headspace
VOC Concentration	Carbon Tetrachloride 7,510 Chlorobenzene 17,600 Chloroform 6,325 1,2-Dichloroethylene 28,750 1,2-Dichloroethane 9,100 Methylene Chloride 100,000 1,1,2,2-Tetrachloroethane 7,924 Toluene 41,135 1,1,1-Trichloroethane 100,000
Aspiration ⁽¹⁾	≥ Times shown in CH-TRUCON tables in Section 8 of Appendix 1.3.7 of TRUPACT-II SARP.
Shipping Category ⁽¹⁾	Content Codes listed in CH-TRUCON tables; and one category per TRUPACT-II
Confinement Layers ⁽¹⁾	Liner punctured/vented Number of layers known Bags closed by approved methods Sealed containers >4 liters prohibited (except for waste material type II.2)
Data	
Acceptance Data	Auditable package of data with signed Certification Statement on file WWIS data transmitted
RCRA Data	Waste Stream Profile Form Uniform Hazardous Waste Manifest ⁽²⁾ Land Disposal Restriction notification ⁽²⁾
Shipping Data	TRUPACT-II Payload Container Transportation Certification Documents Bill of Lading ⁽³⁾

Notes:

(1) Applies to TRUPACT-II payload control only

(2) Applies to mixed waste only

(3) A Uniform Hazardous Waste Manifest may be substituted

(4) ≤ 900 lb for material form 1 (see WHC-EP-0558)

Table 4. Summary of WIPP preliminary RH-TRU waste acceptance criteria.

Criteria	Limits
Container and Physical Properties	
Container Description	DOT Type A RH canister
Canister gross Weight	≤ 8000 lb/loaded canister)
Removable Surface Contamination	20 dpm/100 cm ² Alpha 200 dpm/100 cm ² Beta-Gamma
Container Marking	Canister ID
Dunnage	Limited to inside canister
Filter Vents	Canister vented
Liquids	No Liquid waste < 6 Liters total residual liquid per canister < 1 in. (2.5 cm) in the bottom of any canister
Nuclear Properties	
Nuclear Critically	< 325 g/cask
Pu-239 FGE	< 600 g/canister (may get waiver)
Pu-239 PE-Ci	≤ 1000 PE-Ci/canister
Contact Dose Rate	≤ 1000 rem/hr per canister Preapproval required if > 1000 rem/hr per canister ≤ 200 mrem/hr per cask Neutron ≤ 270 mrem/hr per canister
Thermal Power	< 300 watts per canister
TRU Alpha Activity	> 100 nCi/g of waste matrix ≤ 23 Ci/Liter
Chemical Properties	
Pyrophoric Materials	< 1% Radionuclide pyrophorics No nonradionuclide pyrophorics
Mixed Waste Hazardous Constituents	Characterization per Quality Assurance Project Plan (QAPP) and Table 3.9.2.3 Of the WIPP WAC Limited to EPA waste codes listed in Table 8
Chemical Compatibility	All chemicals must be allowable per the remote-handled TRUPACT-II Authorized Methods for Payload Control (RH-TRAMPAC)
Explosives, Corrosives and Compressed Gases	No compressed gases No ignitable, reactive or corrosive waste

Table 4. (continued)

Criteria	Limits
Gas Generation	
Decay Heat ⁽¹⁾	≤ wattage listed in RH TRU-72-B Cask SARP, Table 1.2-7
Flammable VOCs	≤ 500 ppm in canister headspace
Criteria	Limits
VOC Concentration	Carbon Tetrachloride 7,510
	Chlorobenzene 17,600
	Chloroform 6,325
	1,2-Dichloroethylene 28,750
	1,2-Dichloroethane 9,100
	Methylene Chloride 100,000
	1,1,2,2-Tetrachloroethane 7,924
	Tolulene 41,135
	1,1,1-Trichloroethane 100,000
Aspiration ⁽¹⁾	None currently identified
Shipping Category ⁽¹⁾	None currently identified
Confinement Layers ⁽¹⁾	None currently identified
Data	
Acceptance Data	Auditable package of data with signed Certification
	Statement on file
	WWIS data transmitted
RCRA Data	Waste Stream Profile Form
	Uniform Hazardous Waste Manifest ⁽²⁾
	Land Disposal Restriction notification ⁽²⁾
Shipping Data	RH-TRU 72-B cask payload Container Transportation
	Certification Documents
	Bill of Lading ⁽³⁾

(1) Applies to RH-TRU 72-B Cask payload control only

(2) Applies to mixed waste only

(3) Uniform Hazardous Waste Manifest may be substituted

4.2.1 WIPP Requirements for CH-TRU Waste

4.2.1.1 Container Requirements. Payload containers shall be DOT Type A 55-gallon drums and SWBs, and shall meet all applicable requirements of 49 CFR 173.412. Standard 55-gallon drums, SWBs, and ten-drum overpacks (TDOPs) are authorized for shipment of CH-TRU waste in the TRUPACT-II. The maximum number of containers per TRUPACT-II and the authorized packaging configurations are provided in Table 5.

Only DOT Type A 55-gallon drums and TRUPACT-II SWBs shall be unloaded at the WIPP as payload containers. The Type A requirements for payload containers used for newly generated CH-TRU waste may be verified by procurement or fabrication documentation.

Table 5. Maximum number of containers per TRUPACT-II and authorized packaging configurations.

Max. #	Authorized Packaging Configurations
14	55-gallon drums
2	SWBs
2	SWBs, each containing one bin
2	SWBs, each containing four 55-gallon drums
1	TDOP, containing ten 55-gallon drums
1	TDOP, containing one SBW
1	TDOP, containing one bin within a SWB
1	TDOP, containing four 55-gallon drums within a SWB

4.2.1.1.1 Container/Assembly Weight and Center of Gravity Individual container weights shall be limited to the weight capacities that meet the DOT Type A requirements. The weight limits that apply to CH-TRU waste payload containers, loaded TRUPACT-IIs, and TRUPACT-II shipments are specified in Table 6.

As all weight criteria must be met, different payload configurations are restricted by different requirements. For example, a payload assembly of fourteen 55-gallon drums may not weight more than 7,265 lb even though the maximum weight of a single 55-gallon drum may be 1,000 lb. Although the maximum weight of the payload assembly must not exceed 7,265 lb, the weight available for the CH-TRU waste payload assembly will be less depending on the as-built weight of the TRUPACT-II to be used (the average as-built weight of production TRUPACT-IIs is 12,705 pounds). The weight available for the CH-TRU waste payload assembly is obtained by subtracting the as-built weight of a TRUPACT-II from the maximum gross weight of 19,250 lb.

Table 6. Container/Assembly Weight Criteria.

Components	Max. Weight (lb)
Individual Payload Container	
55 gallon drum	≤ 1000
55 gallon drum overpacked in SWB	≤ 1450
SWB	≤ 4000
TDOV	≤ 6450
Payload Container Assembly	
Payload container assembly	≤ 7265
TRUPAT-II	≤ 19250
Truck (tractor/trailer)	≤ 80000

The maximum gross weight per TRUPACT-II is specified based on an approximate as-built weight of 13,050 lb and an average payload weight of 6,200 lb; this is usually the limiting weight for two TRUPACT-IIs per shipment. DOT's limit of 80,000 lb gross vehicle weight rating must also be met; this is the limiting weight for three TRUPACT-IIs per shipment.

Documented evidence shall exist that each CH-TRU waste payload container has been weighed, and that the weight of the payload container and container assembly meets the requirements. The weight of the payload container cannot exceed the weight for which the payload container has been certified in accordance with DOT Type A requirements.

4.2.1.1.2 Removable Surface Contamination Removable surface contamination on CH-TRU waste payload containers or container assemblies to be disposed in the WIPP shall not be greater than 20 disintegrations per minute (dpm) per 100 cm² for alpha-emitting radionuclides and 200 dpm per 100 cm² for beta-gamma emitting radionuclides. Beta-gamma contamination may be ≤1000 dpm/100 cm² if it meets the requirements of the DOE RADCON Manual, Table 2-2. The fixing of surface contamination to meet the above criterion is not permitted.

The Site must measure the degree of removable surface contamination for each CH-TRU waste payload container or payload container assembly prior to its shipment. The sampling methods are described in 10 CFR 835. The results of these surveys must be documented.

4.2.1.1.3 Container Marking Each CH-TRU waste payload container shall be labeled with a unique container identification number consisting of Site and container identification. The shipping category shall be labeled conspicuously on each payload container.

4.2.1.1.4 Dunnage Dunnage must complete one of the configurations specified in Table 5 if too few payload containers are available that meet all payload container and transportation requirements. An empty, 55-gallon metal drum or an empty SWB may be used as dunnage as specified in Section 13.4

of Appendix 1.3.7 of the TRUPACT-II SARP. If an empty drum is used as dunnage to complete a seven-pack in a shipment to the WIPP, the drum shall be labeled "EMPTY" or "DUNNAGE" and have a container marking.

4.2.1.1.5 Filter Vents All payload containers shall be vented. All CH-TRU waste payload containers, including overpacks, shall be vented with filters to control gas concentration and pressure. Filters must meet the specifications described in Appendix 1.3.5 of the TRUPACT-II SARP. The installation of filter vents shall be documented and verified by visual inspection.

4.2.1.1.6 Liquids Liquid waste is not acceptable at the WIPP. CH-TRU waste shall contain as little residual liquid as is reasonably achievable through pouring, pumping, and/or aspirating. Internal containers (e.g., bottles, cans, etc.) shall contain less than 1 in. or 2.5 cm of liquid in the bottom of the container. In no case shall the total liquid volume (i.e., the sum of all internal or payload container volumes) exceed 2 L in a 55-gallon drum or 8 L in a SWB. The total volume of residual liquid in a payload container shall be less than 1 volume percent of the payload container.

Radiography or visual examination shall be used to determine the presence of liquids and to estimate the quantity of liquid in retrievably-stored waste. Radiography or visual records shall include a description of the location of any liquid detected (e.g., between the rigid liner and the 55-gallon poly bag liner or in a one-gallon poly bottle) and an estimate of its volume.

For newly generated waste, visual examination and documentation of container content at the time of waste packaging, or verification (random sampling) and documentation may be used to demonstrate compliance. Sites shall have policies and procedures in place that prohibit free liquids being placed in newly generated CH-TRU waste.

4.2.1.2 Nuclear Properties Requirements

4.2.1.2.1 Nuclear Criticality (Pu-239 FGE) The fissile or fissionable radionuclide content, in terms of Pu-239 fissile-gram equivalent (FGE), of CH-TRU waste payload containers shall be no greater than 200 g per 55-gallon drum or 325 g per SWB maximum. The Pu-239 FGE shall be calculated using the methods detailed in Appendix 1.3.7 of the TRUPACT-II SARP. Table 7 defines the maximum allowable quantity of fissile material, expressed as Pu-239 FGE, for CH-TRU waste in the TRUPACT-II.

Table 7. Nuclear criticality criteria.

Component	Pu-239 FGE (g)
55 gallon drum	< 200
SWB	< 325
TDOP	< 325
TRUPACT-II	< 325

Records of calculations converting the specific activity of selected radionuclides to FGE using the methods detailed in Appendix 1.3.7 of the TRUPACT-II SARP shall be maintained.

4.2.1.2.2 Pu-239 Equivalent Activity Untreated CH-TRU waste shall not exceed 80 plutonium equivalent curies (PE-Ci) of activity per 55-gallon drum, or 130 PE-Ci of activity per SWB. Untreated CH-TRU waste in 55-gallon drums may contain up to 1800 PE-Ci of activity if overpacked in SWBs or TDOPs. 55-gallon drums containing solidified/vitrified CH-TRU waste shall not exceed 1800 PE-Ci of activity per drum.

4.2.1.2.3 Contact Dose Rate CH-TRU waste payload containers shall have a maximum contact dose rate (beta + gamma + neutron) at any point of no greater than 200 mrem/hr. Neutron contributions to the total payload container dose rate shall be reported separately in the data package.

The external dose rate of individual CH-TRU waste payload containers is limited to 200 mrem/hr on contact. The external dose rate of the loaded TRUPACT-II to be transported is limited to 200 mrem/hr contact dose rate and 10 mrem/hr at 2-m distance. Shielding only is allowed for as low as reasonably achievable (ALARA) purposes.

Documented procedures shall be used to measure dose rates on each type of payload container. The instrumentation used must be properly calibrated using sources traceable to the National Institute of Science and Technology or other nationally recognized organization. The results of these measurements shall be documented for each CH-TRU waste payload container.

4.2.1.2.4 Thermal Power Individual CH-TRU waste payload containers in which the average thermal power density exceeds 0.1 watt/ft^3 (3.5 watts/m^3) shall have the thermal power recorded in the data package. Based on the materials of construction, 40 watts is the thermal limit for total decay heat from all CH-TRU waste payload containers in a TRUPACT-II. Records of calculations converting the specific activity of selected radionuclides to decay heat using the methods detailed in Appendix 1.3.7 of the TRUPACT-II SARP shall be maintained.

4.2.1.2.5 TRU Alpha-Activity Concentration Documented evidence shall exist to show that the TRU alpha-activity concentration of any CH-TRU waste payload container is greater than 100 nCi/g of waste matrix. The weight of added external shielding and the payload containers (including any rigid liners) shall be subtracted prior to performing the nCi/g calculation.

4.2.1.3 Chemical Properties Requirements

4.2.1.3.1 Pyrophoric Materials Pyrophoric materials, other than radionuclides, shall be rendered safe by mixing them with chemically stable materials (i.e., concrete, glass) or shall be processed to remove their hazardous properties. Not more than 1 wt% of the CH-TRU waste payload in each payload container may be pyrophoric forms of radionuclides, and these shall be generally dispersed in the payload.

CH-TRU waste for shipment in TRUPACT-II shall contain less than 1 wt% of the payload container as pyrophoric radioactive materials as specified in Appendix 1.3.7 of the TRUPACT-II SARP. Nonradioactive pyrophorics shall be rendered nonreactive prior to placement in the CH-TRU waste payload container.

Documented procedures or evidence shall exist to show that the CH-TRU waste payload container contains no nonradionuclide pyrophorics and no significant quantities of radionuclide pyrophorics (i.e., <1% by weight) or other materials that could become pyrophoric compounds because of mixing. The

1% limitation on radionuclides is to allow any minor residues of uranium or plutonium that may remain in an unoxidized state in the payload.

CH-TRU wastes expected to contain any metallic radionuclides shall be treated (oxidized) to eliminate as much of the potential pyrophorics as possible, prior to placement in payload containers. A validated process (i.e., one that has been proven by test or analysis) that converts pyrophoric compounds to a nonpyrophoric form may be used to meet this requirement. This process may either change the chemical form of the pyrophoric material or mix and bind it within an inert matrix.

4.2.1.3.2 Mixed Waste Both TRU waste and TRU mixed waste are acceptable for disposal at the WIPP. However, only selected RCRA chemicals shown in Table 8 are acceptable at the WIPP. CH-TRU mixed waste shall contain hazardous constituents only as co-contaminants with TRU mixed waste. Sites must determine if their CH-TRU waste is a mixed waste. The determination shall be based on acceptable knowledge documentation and/or sampling and analysis data that indicates that the waste is hazardous as defined in 40 CFR Part 261, Subparts C and D. Hazardous components in the CH-TRU mixed waste shall be identified and recorded in the Site's data records. All CH-TRU mixed waste

Table 8. List of RCRA hazardous waste codes acceptable at the WIPP.

F001	D008	D027	D038
F002	D009	D028	D039
F003	D010	D029	D040
F004	D011	D030	D043
F005	D018	D032	P015
D004	D019	D034	F006
D005	D021	D035	F007
D006	D022	D036	F009
D007	D026	D037	

exhibiting corrosive, reactive, or ignitable characteristics shall be treated to remove the hazardous characteristic. Ignitable, corrosive, and reactive wastes are defined in 40 CFR 261.21, 261.22, and 261.23, respectively.

Each CH-TRU mixed waste payload container must be assigned one or more EPA hazardous waste codes. Only the EPA hazardous waste codes listed in the WIPP RCRA Part A Permit Application may be managed at the WIPP. Table 8 lists the WIPP acceptable EPA hazardous waste codes.

4.2.1.3.3 Chemical Compatibility CH-TRU mixed waste shall contain no chemicals which would cause adverse reactions with other payload containers during handling or disposal. To comply with environmental requirements, waste must be evaluated to ensure that no adverse reactions could take place during transport, and that the chemical/material or any products of reaction are compatible with its container and packaging as well as other chemicals in the waste. Documentation must show compliance with chemical compatibility requirements. Appendix 1.3.7 of the TRUPACT-II SARP, Tables 5.1–5.6 contain a list of chemicals that could potentially be present in a CH-TRU waste.. A chemical

compatibility analysis has been performed for the chemicals in these tables and ensures that these wastes meet the requirements for operations, TRUPACT-II, and environmental compliance.

4.2.1.3.4 Hazardous Constituents For compliance with 40 CFR Part 268, the type and quantity of hazardous constituents must be reported and recorded in the Site's data package and in the WIPP Waste Information System (WWIS) database. Hazardous constituents included in the target analyte lists and TICs, as defined in the QAPP, shall be reported.

4.2.1.3.5 Explosives, Corrosives, and Compressed Gases The CH-TRU waste and TRUPACT-II payload shall contain no explosives, corrosives or compressed gases. 49 CFR 173.50 defines explosives; 40 CFR 261.22 defines corrosives; and 49 CFR 173.115 defines compressed gases. Explosive or corrosive chemical constituents are prohibited, and pressurized containers are not allowed in a TRUPACT-II payload.

Documented procedures, radiography, or visual examination shall be used to ensure that individual CH-TRU waste payload containers contain no pressurized vessels. For newly generated waste, documented procedures shall be used to exclude explosive or corrosive items, compounds, or combinations of materials that could form explosive or corrosive constituents within the payload container. If explosive materials are present, they must be treated or diluted such that a detonation is not possible. Corrosive materials, if present, must be treated to render them noncorrosive.

4.2.1.4 Gas Generation Requirements

4.2.1.4.1 Decay Heat The decay heat must be less than the wattage limits shown in the TRUPACT-II SARP, Section 1.2.3.3.8. or in the TRUCON tables (see Appendix A) for the specified payload shipping category. If individual payload containers exceed the limit, these containers must be tested in accordance with Appendix 1.3.7 of the TRUPACT-II SARP, Attachment 2.0, "Gas Generation Test Plan to Qualify Test Category Waste for Shipment in the TRUPACT-II."

4.2.1.4.2 Flammable VOCs The total concentration of potentially flammable VOCs is limited to 500 ppm in the headspace of a CH-TRU waste payload container. Documented procedures shall be used to ensure that the total concentration of potentially flammable VOCs is less than or equal to 500 ppm in the headspace of a CH-TRU waste payload container. Content codes that do not identify any of the flammable VOCs in the chemical lists do not have to implement additional controls to meet this requirement.

4.2.1.4.3 VOC Concentrations No waste shall be managed at the WIPP that contains headspace-gas VOC concentrations resulting in emissions not protective of human health and the environment. Sites shall report the results of VOC head space gas sampling for each TRU Waste payload container using the WWIS. Reported VOC concentrations levels will then be evaluated by the WIPP to ensure that VOC averages for each repository room do not exceed the limits defined in Table 9.

A container that has been analyzed and reported to contain higher VOC concentrations than the average limits may be approved for disposal by the WIPP contractor on a case-by-case basis.

Table 9. VOCs and their concentration limits.

Compound	Max. Headspace Concentration (PPM)
carbon tetrachloride	7,510
chlorobenzene	17,600
chloroform	6,325
1,2-dichloroethylene*	28,750
1,2-dichloroethane*	9,100
methylene chloride	100,000
1,1,2,2-tetrachloroethane	7,924
tolulene	41,135
1,1,1-trichloroethane	100,000

*These compounds are also restricted to 500 ppm total per payload container by the RH 72-B SARP.

4.2.1.4.4 Aspiration Sites that add filters to unvented payload containers of CH-TRU waste shall aspirate the payload containers for a sufficient period of time prior to transport to ensure equilibration of any potentially flammable gases that may have accumulated in the closed containers. Options for determining aspiration time include determination based on the date of drum closure and headspace gas sampling at the time of venting or during aspiration.

Documented procedures shall be used to ensure that an unvented CH-TRU waste payload container has had a filter installed and been aspirated for a sufficient period of time to ensure equilibration of any potentially flammable gases prior to transport.

4.2.1.4.5 Shipping Category All CH-TRU waste payload containers in a single TRUPACT-II shall belong to the same shipping category as defined in Section 13.0 of Appendix 1.3.7 of the TRUPACT-II SARP. Each payload container shall belong to one of the content codes defined in the CH-TRUCON. Documented procedures shall be used to ensure that all CH-TRU waste payload containers to be transported in a single TRUPACT-II belong to one of the content codes defined in the CH-TRUCON and to the same shipping category.

4.2.1.4.6 Confinement Layers TRUPACT-II Requirements The requirements applicable to the layers of confinement in TRUPACT-II containers are defined in Section 8.0 of Appendix 1.3.7 of the TRUPACT-II SARP. These requirements include:

- Rigid 55-gallon drum liners, if present, shall be punctured or have a filter vent
- Maximum number of confinement layers for the waste shall be known and must comply with the CH-TRUCON
- Bags shall be closed by one of the following methods:

- Twist-and-tape closure—the use of wire or plastic ties to aid twist and tape closure is allowable.
- Fold-and tape closure—the use of wire or plastic ties to aid fold and tape closure is allowable.
- Heat-seal closure with a vented bag—heat-sealed unvented bags are prohibited.

Documented procedures shall be used to ensure that the requirements specified in Section 8.0 of Appendix 1.3.7 of the TRUPACT-II SARP are met. The number of layers and bag closure shall be visually verified for newly generated waste; for stored waste, acceptable knowledge or sampling may be used.

4.2.1.5 Data Package Requirements

4.2.1.5.1 Acceptance Data—An auditable package of data, with a signed certification statement indicating that the CH-TRU waste meets the requirements of the current WAC, shall be maintained at the Site. Required WWIS data must be entered and approved by the WIPP prior to shipping waste to the WIPP.

4.2.1.5.2 RCRA Data—Sites shall prepare and transmit a “Waste Stream Profile Form” to the WIPP for each waste stream in accordance with Appendix E. Sites shall prepare a “Uniform Hazardous Waste Manifest” in accordance with 40 CFR 26 and an “LDRs Notification” in accordance with 40 CFR Part 268 for each shipment of CH-TRU mixed waste.

4.2.1.5.3 Shipping Data—Sites shall prepare a “TRUPACT-II Payload Container Transportation Certification Document,” have procedures in place for certifying a TRUPACT-II payload, and shall prepare a “Bill of Lading” for CH-TRU waste shipments in accordance with 49 CFR Part 172, Subpart C; or a “Uniform Hazardous Waste Manifest” in accordance with 40 CFR 262.23.

4.2.2 WIPP Requirements for RH-TRU Waste

Bases on the WIPP WAC, the RH-TRU criteria have not been finalized. These criteria (see Table 4) are preliminary and for information only. They are intended to provide technical guidance to site generators. Final requirements will not be available until the RH-TRU 72-B Cask requirements have been finalized, the RH-TRU 72-B Cask SARP is approved by the NRC, and the WIPP Safety Analysis Report (SAR) is updated. The RH-TRU 72-B Cask is intended to be used for transportation of RH-TRU waste canisters to the WIPP. The specific requirements for the RH-TRU 72-B Cask are provided here as noted in the WIPP WAC.

4.2.2.1 Container Requirements.

4.2.2.1.1 Container Description—Canisters shall be noncombustible and as a minimum, meet the structural requirements and design conditions for Type A packaging as contained in 49 CFR 173.412. In addition, all RH-TRU canisters shall be certified in accordance with DOT Specification 7A, Type A, and shall meet the Type A packaging specification from the time of RH-TRU waste certification to disposal in the WIPP.

RH-TRU canisters shall be no larger than a nominal 26-in (0.66 m) diameter with a maximum length of 10 ft, 1 in. (3.1 m), including the pintle, per Rockwell International Drawing RI-H-2-91273. For RH-TRU 72-B cask, the RH canister configured with the axial lifting pintle shall be used.

4.2.2.1.2 Canister Gross Weight RH-TRU canisters shall weigh no more than 8,000 lb when loaded. For RH-TRU waste, the canister weight may be calculated based on the weight of the empty canister plus the weight of RH-TRU waste that will be placed in the canister. The weight of the canister cannot exceed the weight for which the canister has been certified in accordance with 49 CFR 173.463.

4.2.2.1.3 Removable Surface Contamination Removable surface contamination on RH-TRU canisters to be disposed in the WIPP shall not be greater than 20 dpm/100 cm² for alpha-emitting radionuclides and 200 dpm/100 cm² for beta-gamma emitting radionuclides. Beta-gamma contamination may be ≤1000 dpm/100 cm² if it meets the requirements of the DOE RADCON Manual, Table 2-2. Fixing surface contamination to meet the above criterion is not permitted.

The site must measure the degree of removable surface contamination for each RH-TRU canister prior to its shipment. The sampling methods are described in DOE-EH-0256T, *DOE RADCON Manual*. The results of these surveys must be documented.

4.2.2.1.4 Container Marking RH canisters shall be uniquely identified by means of an identification number consisting of a Site and package identification permanently attached to the canister in a conspicuous location using characters at least 2 inches high.

For RH-TRU 72-B Casks, there shall be an identification number consisting of 2-in. high characters, raised or indented into the surface by forging, die-stamping, or welding on the top closure and on the outside surface of the top crush ring. The identification number shall begin with the Site's two-letter identifier code (consistent with Table E-1) and a four-digit sequential number (e.g., IN0001 or LA0003).

4.2.2.1.5 Dunnage Dunnage may be used to fill voids inside the RH-TRU canister placed inside a RH-TRU 72-B Cask. Dunnage shall be reported as part of the waste volume.

4.2.2.1.6 Filter Vents All canisters shall be vented with filters to control gas concentration and pressure. Filters must meet the specifications described in Appendix 1.3.5 of the SARP. The placement of filter vents shall be documented and verified by visual inspection.

4.2.2.1.7 Liquids Liquid waste is not acceptable at the WIPP. RH-TRU waste shall contain as little residual liquid as is reasonably achievable through pouring, pumping, and/or aspirating. Internal containers (e.g., bottles, cans, etc.) should contain less than 1 in. or 2.5 cm of liquid in the bottom of the container. In no case shall the total liquid volume (i.e., sum of all internal or payload container volumes) exceed 6 L in a canister. The total volume of residual liquid in a canister placed inside a RH-TRU 72-B Cask shall be not greater than 1 volume percent of the canister.

Radiography (when feasible), visual examination, or acceptable knowledge shall be used to determine the presence and quantity of liquid. Inspection records shall include a description of the location of any liquid detected and an estimate of its volume. Sites shall have in place policies and procedures that prohibit free liquids being placed in newly generated RH-TRU waste.

4.2.2.2 Nuclear Properties Requirements

4.2.2.2.1 Nuclear Criticality (Pu-239 FGE) The fissile or fissionable radionuclide content of RH-TRU canister shall not exceed 600 g total of Pu-239 FGE. The fissile or fissionable radionuclide content of RH-TRU waste in an RH-TRU 72-B Cask, including two times the measurement error, shall be less than 325 grams of Pu-239 FGE.

Assay data shall be presented to show that the FGE content complies with the limits for both a canister and a cask. For newly generated RH-TRU waste, documented procedures controlling the loading of contents into the canister's inner containers may be substituted for assay data.

4.2.2.2.2 Pu-239 Equivalent Activity RH-TRU waste canisters shall not exceed 1,000 PE-Ci of activity. Documented analyses shall be available to show that each RH-TRU canister is within the limit.

4.2.2.2.3 Canister/Cask Contact Dose Rates The RH-TRU canister limit is based on the total RH-TRU waste volume at the WIPP, not on the site's number of RH-TRU canisters. No more than 5% of the RH canisters received at the WIPP are allowed to have dose rates >100 rem/hr. Prior approval by the WIPP is required before RH-TRU canisters having dose rates >100 rem/hr but ≤1000 rem/hr may be shipped to the WIPP. All RH-TRU canisters shall have a maximum contact dose rate at any point no greater than 1,000 rem/hr. Neutron contributions are limited to 270 mrem/hr. Neutron contributions of greater than 20 mrem/hr to the total canister dose rate shall be reported in the data package.

The external dose rate on the loaded RH-TRU 72-B Cask is limited to 200 mrem/hr at the surface of the cask and 10 mrem/hr at 2 m distance from the cask.

4.2.2.2.4 Thermal Power—The thermal power generated by RH-TRU waste materials in any RH-TRU canister shall not exceed 300 watts. The thermal power shall be recorded in the RH-TRU waste data package. Documented evidence shall be presented that each RH-TRU canister meets the indicated limits based on the radionuclide distribution and quantity of radioactive material present.

4.2.2.2.5 TRU Alpha Activity Concentration—For purposes of RH-TRU waste certification, the lower limit of >100 nCi/g of TRU radionuclides in the waste shall be interpreted as >100 nCi/g of waste matrix. The weight of internal containers (including any rigid liners) shall be subtracted prior to performing the nCi/g calculation. A propagated measurement error may be included in the calculation of the lower limit of activity concentration (e.g., measurement plus error >100 nCi/g). The maximum activity concentration for a RH-TRU canister shall not exceed 23 Ci/L. The concentration may be averaged over the canister.

Documented evidence shall exist to show that the TRU alpha activity concentration of any RH-TRU canister is greater than 100 nCi/g of waste matrix and that the activity of RH-TRU waste does not exceed 23 Ci/L.

4.2.2.3 Chemical Properties Requirements

4.2.2.3.1 Pyrophoric Materials—Pyrophoric materials, other than radionuclides, shall be rendered inert by mixing them with chemically stable materials (e.g., concrete, glass) or shall be

processed to remove their hazardous properties. Not more than 1 wt% of the payload in each RH-TRU canister may be pyrophoric forms of radionuclides, and these shall be generally dispersed in the payload.

Documented procedures or evidence shall exist to show that the RH-TRU canister contains no nonradionuclide pyrophorics and no significant quantities of radionuclide pyrophorics (i.e., <1 wt%) or other materials that could become pyrophoric compounds because of mixing. The 1% limitation on radionuclides is to allow any minor residues of uranium or plutonium that may remain in an unoxidized state in the payload. RH-TRU wastes expected to contain metallic radionuclides are to be treated prior to placement in canisters (oxidized) to eliminate as much of the potential pyrophorics as possible. A validated process (i.e., one that has been proven by test or analysis) that converts pyrophoric compounds to a nonpyrophoric form may be used to meet this requirement. This process may either change the chemical form of the pyrophoric material or mix and bind it within an inert matrix.

4.2.2.3.2 Mixed Waste The mixed waste requirements for RH-TRU wastes are the same as those described for CH-TRU wastes.

4.2.2.4 WIPP Operations and Safety Requirements.

4.2.2.4.1 Chemical Compatibility Like CH-TRU mixed waste, RH-TRU mixed waste shall contain no chemicals that would cause adverse reactions with the canisters during handling or disposal. Any chemical/material in the RH-TRU waste in excess of 1 wt% shall conform to the allowable chemicals in each "waste material type" as defined in the RH-TRUCON. Waste must be evaluated to ensure that no adverse reactions could take place during transport and that the chemical/material or any products of reaction are compatible with the RH-TRU 72-B Cask construction materials.

RH-TRU mixed waste must be compatible with its container and packaging materials as well as other waste. They must be listed in the RH-TRUCON and be limited to the chemical amounts shown in the RH-TRUCON Chemical List for the applicable Content Code.

4.2.2.4.2 Hazardous Constituents The hazardous constituents requirements for the RH-TRU waste are the same as those described for the CH-TRU waste.

4.2.2.4.3 Explosives, Corrosives, and Compressed Gases The requirements for the RH-TRU waste are the same as those described for the CH-TRU waste.

4.2.2.5 Gas Generation Requirements

4.2.2.5.1 Decay Heat The decay heat limits for canisters in each shipping category are presented in the RH-TRU 72-B Cask SARP, Table 1.2-7. Calculations must be performed as specified in Section 10.0 of Appendix 1.3.7 of the RH-TRU 72-B Cask SARP. Documented evidence shall exist to show that the RH-TRU canister and payload assembly to be transported meet the decay heat limits specified.

4.2.2.5.2 Flammable VOCs The total concentration of potentially flammable VOCs is limited to 500 ppm in the headspace of a RH-TRU canister in the RH-TRU 72-B Cask. Content Codes that do not identify any of the flammable VOCs in the chemical lists do not have to implement additional controls to meet this requirement.

Documented procedures shall be used to ensure that the total concentration of potentially flammable VOCs is less than or equal to 500 ppm in the headspace of a RH-TRU waste canister.

4.2.2.5.3 VOC Concentrations The requirements are the same as those identified for the CH-TRU waste.

4.2.2.5.4 Aspiration, Shipping Category, Confinement Layers None currently identified.

4.2.2.6 Data Package Requirements Acceptance Data

The requirements identified for the CH-TRU waste are applicable to the RH-TRU waste canisters and the RH-TRU 72-B Cask.

A preliminary evaluation of the TRU waste indicates that the waste is considered RH-TRU. This is based on the estimated values of container's contact dose rates ranging from 1,400 to 4,000 mrem/hr per canister at contact and a maximum neutron dose rate of 56 rem/hr per canister.

The LWA requires that the waste destined for disposal at the WIPP meet the TRU definition, not contain HLW or spent nuclear fuel, and be generated from atomic energy/defense-related activities.

The TRUEX separation process is believed to be capable of removing the TRU waste from the HLW and the SBW. The stripped effluent from the TRU only separation option is expected to contain the TRU elements and to meet the definition of TRU waste. Based on the projected activities of the radionuclides in the TRU waste portion,¹ the waste meets the definition of TRU waste. Mike Brown of WIPP-Carlsbad office (meeting on July 24, 1997) believes that the separation process is capable of producing a TRU waste form that will not be considered HLW. However, the TRU waste is considered HLW by source term definition. Therefore, a determination must be made to ensure that the TRU fraction is no longer considered HLW.

4.3 RCRA Disposal Requirements

The hazardous constituents in the TRU waste are reportedly RCRA characteristics (corrosive, toxic metals). The waste will also carry listed chemicals. The toxic metals include Ag, As, Ba, Cd, Cr, Hg, Ni, Pb, and Se.² Under the LWA, the WIPP is exempt from the LDR requirements. However, the WIPP WAC and the "WIPP Part A Permit" specify that only a selected number of RCRA waste codes are acceptable at the WIPP (see Table 8). Therefore, the following waste codes from Table 1 are not acceptable at the WIPP:

D002	U012	U138	U220
F027?	U019	U140	U225
P098	U044	U159	U226
P104	U080	U171	U227
P105	U088	U188	U228
P106	U108	U196	U165
P119	U122	U210	P048
P120	U123	U211	
U002	U133	U229	

According to Craig Snider, the WIPP Office of Regulatory Compliance, (personal communication on 08/01/97), all the RCRA waste codes in the TRU waste, regardless of the WIPP waste acceptability status, must be reported to the WIPP prior to the waste shipment.^u The determination of hazardous contaminants shall be based on acceptable knowledge and/or sampling and analysis data indicating that the waste is hazardous as defined in 40 CFR 261, subparts C and D. It is also required that an LDR notification be transmitted to the WIPP for each shipment of mixed waste. The notification must contain hazardous waste characterization records and records showing types and quantities of all hazardous constituents that require LDR treatments in accordance with 40 CFR Part 268.

^u Per phone conversation with Mike Brown (the WIPP contact) and Craig Tyler (the RWMC WIPP contact) 9/18/97, a full list of potential RCRA chemicals in the TRU waste was submitted to Mr. Brown, as requested. This informal reporting could hopefully provide us with some information about the WIPP decision on the waste codes currently unacceptable at the WIPP.

5. MIXED LOW-LEVEL WASTE

5.1 Grout Waste Form from Separation Options

The separation options will generate up to three waste streams, defined as TRU waste, HAW, and LAW. It is proposed for the LAW to be grouted and disposed of at a LLW disposal facility. As previously stated, the LAW is actually HLW per NRC definition. However, as the projected activities of the radionuclides indicate,² the LAW meets the definition of the NRC LLW Class A in one of the separations options and Class C in the other, based on the NRC classification of LLW (Table 10). The LAW also meets the definition of incidental waste in the NRC evaluation of HLW separations processes in the Hanford Site (see section 3.5 for details).²⁵

Table 10. NRC LLW classification for selected radionuclides.³

Radionuclide	Concentration		
	Class A	Class B	Class C
H-3	40 Ci/m ³	—	—
Ni-63	3.5 Ci/m ³	70 Ci/m ³	700 Ci/m ³
Sr-90	0.04 Ci/m ³	150 Ci/m ³	7,000 Ci/m ³
Cs-137	1 Ci/m ³	44 Ci/m ³	4,600 Ci/m ³
C-14	0.8 Ci/m ³	0.8 Ci/m ³	8 Ci/m ³
Tc-99	0.3 Ci/m ³	0.3 Ci/m ³	3 Ci/m ³
I-129	0.008 Ci/m ³	0.008 Ci/m ³	0.08 Ci/m ³
Pu-241	350 nCi/g	350 nCi/g	3,500 nCi/g
Alpha-emitting radionuclides with half-lives >5 years	10 nCi/g	10 nCi/g	100 nCi/g

5.1.1 RCRA Disposal Requirements

The chemical constituents in the LAW (LLW Class A or C) are reportedly characteristics (corrosive, toxic metals).² The waste will also carry listed waste codes. The toxic metals are Ag, As, Ba, Cd, Cr, Hg, Ni, Pb, and Se. The waste must be treated to comply with the LDRs. and delisted prior to disposal. No listed or hazardous waste is accepted for disposal at the potential LLW disposal facilities identified in this study.

5.1.2 LLW Disposal Facilities

5.1.2.1 Commercial LLW Disposal Facilities. The LLW commercial disposal facilities identified in this study include the Barnwell Waste Management Facility Site in South Carolina, the Envirocare of Utah, Inc. and the US Ecology at Richland Facility in Washington. Currently, the Barnwell and the US Ecology facilities are not permitted to accept any DOE generated (non-commercial) LLW. This is due to

the current NRC or Agreement State regulations and legislation that govern LLW waste disposal in the existing commercial facilities. Based on waste acceptance criteria of the Envirocare Utah, Inc.²⁷, the INEEL waste with very low level of radioactivity can be accepted for disposal in the facility. The estimated activities of the radionuclides in the LLW-Class A and C grout exceed the limits specified in the Envirocare acceptance criteria.

5.1.2.2 DOE LLW Disposal Facilities. The DOE LLW facilities that could potentially be used for disposal of the LLW grout are the INEEL Radioactive Waste Management Complex (RWMC), the NTS, and the Hanford Site.

It is DOE policy that DOE generated LLW be disposed at the site where it is generated, if practical, or if onsite disposal is not available, at another DOE disposal facility. The DOE Environmental Management (EM) Office has initiated a study to evaluate the potential and preferred disposal sites for DOE generated LLW for which on site disposal is not available. As result of this evaluation, the NTS and Hanford Site are considered preferred disposal sites for the DOE generated LLW.²⁸ The DOE determines which facilities are authorized to accept waste from the various DOE waste generators. The procedure and protocol for submitting requests for approval and waste disposal have been dictated by the DOE. DOE Order 5820.2A provides a set of general criteria for disposal of the DOE LLW. The remainder of this section presents the DOE general disposal requirements as established in the Order, and a detailed description of disposal criteria for the RWMC, Hanford Site, and NTS.

5.1.3 DOE General LLW Disposal Criteria

DOE Order 5820.2A, Chapter III, provides a set of general criteria for disposal of LLW. These criteria are as follows:

- Generators must receive advance approval from the waste receiving facility to ship a waste package, and shall certify prior to shipment that the waste meets the receiving facility's waste acceptance criteria (DOE 5820.2A III 3.g.(3)).
- Generators of LLW shall implement a waste certification program to provide assurance that the waste acceptance criteria used by any disposal facility are met (DOE 5820.2A III 3.e(3)). The certification and shipping papers document physical and chemical characteristics of the waste and waste forecast shipment projection as required by DOE Order 5820.2A Chapter III.
- Waste characterization shall ensure that the physical characteristics of the waste are known and recorded during all stages of the waste management process (DOE Order 5820.2A III 3.d). Generator's documents prepared for waste characterization shall, at a minimum, include the following:
 - Physical and chemical characteristics of the waste and any void-filling material or sorbent
 - Volume and weight of the waste
 - Major radionuclides distribution, concentration, and activity in the waste matrix
 - Method of assay or analysis used to determine radionuclide distribution and concentration
 - Packaging data

- The generator must assure that waste accepted for disposal at a LLW disposal facility is treated and does not contain the RCRA listed and characteristic waste codes. The hazardous constituents must be regulated by the appropriate regional EPA authorities under RCRA (DOE Order 5820.2A III 2.d). LLW resulting from treated mixed waste (40 CFR 268) must meet the following requirements:
 - Does not exhibit characteristic hazards.
 - Meets all applicable LDR waste treatment standards.
 - Is documented appropriately with necessary LDR notifications and certifications.
- Waste will not be accepted for disposal when it contains free liquid in excess of 1% of the waste volume, or 0.5% of the waste volume processed to a stable form (DOE Order 5820.2A III 3.i.(5)(b)).
- Waste capable of detonation, explosive decomposition, or reaction at normal pressures and temperature, or of explosive reaction with water will not be accepted for disposal (DOE Order 5820.2A III 3.i.(5)(c)).
- Waste capable of generating toxic gases, vapors, or fumes harmful to persons handling the waste will not be accepted for disposal (DOE Order 5820.2A III 3.i.(5)(d)).
- Gaseous waste will not be accepted for disposal if it is packaged at a pressure in excess of 1.5 atmospheres (DOE Order 5820.2A III 3.i.(5)(e)).
- Pyrophoric waste will not be accepted for disposal (DOE Order 5820.2A III 3.i.(5)(f)).
- Waste exceeding the LLW Class C limit, as defined in 10 CFR 61.55, is not accepted for disposal in a LLW disposal facility, except as special cases and with evaluation and approval from the DOE. Disposal system for such waste must be justified by a specific performance assessment through the National Environmental Policy Act (NEPA) and with the concurrence of EM-30 (DOE Order 5820.2A III.i.(4)).
- Waste must not be packaged for disposal in cardboard or fiberboard boxes, unless such boxes meet the DOT requirements and contain stabilized waste with a minimum of void space (DOE Order 5820.2A III 3.i.(5)(a)).
- Waste package must meet applicable requirements of DOT (49 CFR 173, subpart I) and 10 CFR 71 as follows:
 - Design—Type A packaging shall be designed to meet Title 49 CFR 173.410, “General Design Requirements”, and Title 49 CFR 173.412, “Additional Design Requirements for Type A Packages.” Type B packaging must meet the applicable requirements of Title 10 CFR 71.
 - Nuclear Safety—The quantity of fissile radioactive material shall be limited so that an infinite array of such packages will remain subcritical. This quantity shall be determined on the basis of a specific nuclear safety analysis, considering credible accident situations, and taking into account the actual materials in the waste.

- Radiation levels—49 CFR 173.441, “Radiation Level Limitations,” establishes the following limits:
 - Except as provided in section (b), for each package, the radiation level does not exceed 200 mrem/hour at any point on the external surface of the package.
 - A package which exceeds the radiation level limits specified in section (a) must be transported by exclusive use shipment, in which case the limit is 1,000 mrem/h. The conditions for the exclusive use shipment are as follows:
 - The shipment is made in a closed transport vehicle (a closed transport vehicle means a transport vehicle equipped with a securely attached exterior enclosure that, during normal transportation, restricts unauthorized access to the cargo space
 - The package is secured within the vehicle so that its position remains fixed during transportation
 - There are no loading or unloading operations between the beginning and end of the transportation.
- Activity limits—40 CFR 173.431, “Activity Limits for Type A and Type B Packages” requires specific curie contents for radionuclides.
- Nuclear heating—40 CFR 173.442, “Thermal Limitations” specifies the temperature limits of the accessible external package. A package of Class 7 (radioactive) material must be designed, constructed, and loaded so that (a) the heat generated within the package by the radioactive contents will not, during conditions normally incident to transport, affect the integrity of the package; and (b) the temperature of the accessible external surfaces of the loaded package will not, assuming still air in the shade at an ambient temperature of 38°C (100°F), exceed either 50°C (122°F) in other than an exclusive use shipment; or 85°C (185°F) in an exclusive use shipment.

The following subsections contain the criteria for waste acceptance and disposal at the RWMC, the NTS, and the Hanford Site. These criteria are based on the current DOE LLW management policies and practices as stated in DOE Order 5820.2A (above), EPA (Federal and State), and DOT requirements. Any waste streams that do not meet these basic requirements must be evaluated on a case-by-case bases and must not compromise the performance objectives for the disposal site or violate any permit requirements.

5.1.3.1 RWMC WAC. The “INEEL Reusable Property, Recyclable Materials, and Waste Acceptance Criteria”²⁹ contains the criteria that apply to CH and RH LLW for shipping to and disposal at the RWMC. As required by the DOE Order 5820.2A, waste acceptance package certification documenting the waste characteristics must be submitted to the RWMC for advance approval to ship a waste package, and shall certify, prior to shipment, that the waste meets the receiving WAC for disposal. In addition to

meeting all the other general DOE criteria established in the DOE Order 5820.2A, the following acceptance criteria must be met before shipping waste to the RWMC for disposal:

5.1.3.1.1 Criteria for CH-LLW

The criteria for CH-LLW are itemized as follows:

- Radionuclides concentration limits in each waste package must meet the values listed in Table 11. The waste exceeding the limits will require a case by case evaluation and approval from the RWMC prior to disposition.
- Nuclide reporting requirements for waste being sent to the RWMC are as follows:
 - Radionuclides listed in Tables 1 and 2, Column 1 of 10 CFR 61.55 are reported in values greater than 0.01 times the limit (except for C-14)
 - Radionuclides with half-lives of less than 5 years, except for Cm-242, are reported when their concentrations are greater than $7 \mu\text{Ci}/\text{cm}^3$ of waste.
 - Radionuclides not identified above are reported when their concentrations are greater than 1% of the total activity in the waste form.
- Absorbents and stabilizing agents used to eliminate free liquids have undergone the generator's bench-scale testing which demonstrates that:
 - Performance is as specified by the vendor, or an improved specific-use methodology has been developed (best management practice [BMP])
 - Liquids do not separate from the absorbents or stabilizing agents due to ambient temperature cycles ranging from -50°F to 110°F and pressure cycles ranging from 24 to 26 inches of mercury (DOE Order 5820.2A).
- Dry-loaded waste packages such as drums, boxes, or inserts having a potential for free liquid have:
 - An optimum absorbent or stabilizing agent used to ensure immobilization of free liquid (BMP)
 - An absorbent or stabilizing agent placed inside the innermost waste bag or container where the free liquid is suspect (BMP)
 - Absorbents and stabilizing agents placed as close as practical to inaccessible liquid (BMP).
- Tritium waste has been prepared for disposal to prevent exceeding an equivalent package release rate of 40 Ci/m/y. (DOE Order 5820.2A, Chapter III, 3.a and b, and i(4)).
- Waste package exterior surfaces of wooden boxes are painted with white, exterior, fire-retardant paint approximately 0.007-in. thick, and have a flame-spread rating of 25 to 75 per

American Society for Testing and Materials (ASTM) E-84. All other packages are painted or coated with material that enhances the package lifetime and decontamination ability (BMP).

- Fissile material concentration does not exceed the fissile material threshold value concentrations listed in Table 12. Waste exceeding the limits stated in Table 12 will require a case-by-case evaluation and approval from the RWMC facility manager prior to disposition.
- Packages for LLW pass the requirements in 49 CFR 173.475, "Quality Control Inspection Requirements to Qualify for Shipment."
- Standard containers for LLW are any of the following: (BMP)
 - UN 1A2 drums as follows:
 - 55-gal drum
 - 30-gal drum
 - 71-gal square drum
 - 6M Shipping Packages (ES-51526).
 - ANL-E, DOT 7A Type A Steel Bin
 - INEEL wooden boxes
 - M-III Bin
 - Mark III DOT 7A Type A Concrete Box
 - DOT 7A Type A Steel Boxes.
- Waste packages comply with requirements of Table 13 shown below.

Table 11. Performance assessment waste volume concentration limits for CH-LLW disposal.

Radionuclide	Waste Volume Concentration Limit Ci/m ³
I-129	0.007
Pu-241	250 nCi/g]
U-233	0.002
U-234	0.00003
U-235	0.0005
U-238	0.0003
transuranics	> 10 nCi/g but < 100 nCi/g

Table 12. Fissile material waste matrix groups.

Group	Polyethylen e	Cellulose	Metal(Al) a	Concrete	Brick	Glass/ Slag	Graphite	Salt
TVC ^{b,c,d}								
g/lb	3.10	1.30	0.82	0.56	0.23	0.09	0.02	5.53
g/kg	6.82	2.86	0.07	1.23	0.51	0.20	0.04	12.17
TVC ^d U-233								
g/lb	4.98	2.16	0.38	0.62	0.34	0.15	0.03	4.27
g/kg	11.0	4.75	0.84	1.36	0.75	0.33	0.07	9.39

Waste matrix group assignments are determined by the RWMC. Contact a GI for assistance.

a. To be conservative the threshold value for metal is calculated on aluminum.

b. Threshold value concentration (TVC).

c. For all fissile radioisotopes except U-233.

d. Fissile limit for each waste package is 380 grams.

Table 13. CH-LLW disposal criteria at the RWMC.

Characteristic	DOT Steel or UN 1A2 Drum	INEEL Wooden Boxes	Criterion Basis
Gross weight	DOT limit or ≤ 20 lb/gal ^a	$\leq 12,000$ lb/box	(BMP)
Dimension	5-gal minimum	$4 \times 4 \times 4$ ft	—
	55-gal	$2 \times 4 \times 8$ ft	—
	71-gal preferred	$4 \times 4 \times 8$ ft (soils prohibited)	—
Radiation Limit	< 500 mrem/h at 1 m	< 500 mrem/h at 1 m	(BMP)
Fissionable material	See Table 12	See Table 12	(RWMC SAR)
Liner (minimum)	N/A	3-ply reinforced plastic	(BMP)
Lid gasket	Secured	Secured ^j	(49 CFR 173.24)

Characteristic	DOT 7A Type A B-25 Bin	M-III Bin	Criterion Basis
Gross weight	$\leq 6,000$ lb/bin	$\leq 8,000$ lb/bin	(Design)
Dimensions	$4 \times 4 \times 6$ ft	$4 \times 5 \times 6$ ft	(Design)
Radiation limit	< 500 mrem/h at 1 m	< 500 mrem/h at 1 m	(BMP)
Fissionable material	See Table 12	See Table 12	(RWMC SAR)
Liner (minimum)	N/A	N/A	(BMP)
Lid gasket	Mfg. installed	Neoprene gasket	(49 CFR 173.24)

Characteristic	DOT 7A Type A Mark III Concrete Box	DOT 7A Type A Steel Boxes	Criterion Basis
Gross weight	$\leq 21,800$ lb/box	$\leq 12,000$ lb/box	(Design)
Dimensions	$4 \times 4 \times 8$ ft	$4 \times 4 \times 6, 7, \text{ or } 8$ ft	(Design)
Radiation limit	< 500 mrem/h at 1 m	< 500 mrem/h at 1 m	(BMP)
Fissionable material	See Table 12	See Table 12	(RWMC SAR)
Liner (minimum)	N/A	N/A	(BMP)
Lid gasket	By design	Mfg. installed	(49 CFR 173.24) ⁱ

a. DOT limit for a UN 1A2 55-gal drum is 1,000 lb, and a UN 1A2 71-gal square drum is 1,300 lb. The 20-lb/gal limit for the 55- and 71-gal drums qualifies for a DOT strong, tight container. This limit is permitted because the drums passed the DOT 7A drop test at that loaded weight.

5.1.3.1.2 Criteria for RH-LLW

In addition to meeting the criteria described above, except for radiation limits and authorized containers, the following acceptance criteria shall also be met before shipping RH-LLW to the RWMC for disposal.

- Remote-handled waste container labels are permanently affixed, the container identification number is located on the container top and visible and legible through remote visual verification equipment. This number is directly traceable to INEEL Form L-0435.20, "Stored, Disposed, or Processed Radioactive Waste and database record (BMP)."
- Standard containers for remote-handled LLW are any of the following: (BMP)
 - RWMC 55-ton insert
 - Test Reactor Area (TRA) resin system (commercial)
 - Mark III DOT 7A Type A Concrete Box
 - HFEF-5 Waste Canister
 - Other:
 - Argonne National Laboratory-West (ANL-W) 55-gal crimp-head drum
 - Nuclear Reactor Facility (NRF) and TRA concrete vaults
 - NRF-A1W sealed resin columns waste package
 - Sodium Loop Safety Facility waste package
 - NRF Expanded Core Facility Water Pit Demineralizer Type V Tank Assembly
 - Remote Analytical Laboratory 30-gal insert
 - 6M Shipping Packages (ES-51526).
- Waste packages comply with requirements of Table 14.

5.1.3.2 NTS WAC. The waste acceptance standards discussed here are based on the NTS WAC document.²³ Waste will be accepted for disposal at the NTS only from generators who are designated by DOE Headquarters (DOE-HQ) and subsequently approved by the DOE-NV. Presently, the INEEL is neither a designated nor approved generator.

Only LLW and mixed LLW are accepted for disposal at the NTS from the DOE-NV approved generators outside the State of Nevada. The criteria for mixed LLW disposal at the NTS from outside generators have not been finalized at this time (personal communication with Wendy Clayton of the DOE-NV on 7/15/97). The approval process is a series of steps the generator and the DOE-NV follow resulting in generators receiving approval to ship waste to the NTS. The generator must have DOE-HQ approval before initiating the approval process with DOE/NV.

The criteria for LLW acceptance at the NTS are based on DOE LLW management policies and practices (DOE Order 5820.2A), EPA requirements, State of Nevada regulations, and applicable DOT regulations.

Table 14. RH-LLW disposal criteria at the RWMC.

Characteristic	55-ton Insert	TRA Resin System	Criterion Basis
Gross weight	≤ 12,000 lb/insert	≤ 20,000 lb/package	(Design/NRC License)
Dimension	4 ft dia × 8 ft	6 ft dia × 7 ft	(Design)
Radiation limit ^a	> 500 mrem/h at 1 m	> 500 mrem/h at 1 m	(RWMC)
Fissionable material ^b	See Table 12	See Table 12	(RWMC SAR)

Characteristic	Mark III Concrete Box	HFEF-5 Canister	Criterion Basis
Gross weight	≤ 21,800 lb/box	≤ 1,000 lb/canister	(Design)
Dimension	4 × 4 × 8 ft	—	(BMP)
Radiation limit ^a	> 500 mrem/h at 1 m	> 500 mrem/h at 1 m	(BMP)
Fissionable material ^b	See Table 12	See Table 12	(RWMC SAR)
Lid gasket	By design	Seal welded or bolted with Viton™ seal, no leakage	(RWMC EDF)

Characteristic	Other	Criterion Basis
Gross weight	Package design limit	(Design)
Radiation limit ^a	> 500 mrem/h at 1 m	(BMP)
Fissionable material ^b	See Table 12	(RWMC SAR)
Lid gasket	Container design	(Design)

a. The radiation level of the package is ≥ 500 mrem/h at 1 meter to qualify as remote-handled waste. An upper limit has not been defined.

b. Fissionable material limits are based on assumed low-density waste contaminated with small amounts of volumetric averaged fissionable material. Low-density waste is waste consisting of materials such as paper, polyethylene wrap, tape, glass, rags, blotting paper, scrap metal, and piping. Volumetric average is defined as concentrations obtained by dividing the total fissionable material content of a container by its volume.

All official interactions and coordinating activities relating to the approval process between the generator and the DOE-NV should take place through the generator's oversight office. An NTS WAC compliant program must be developed and completed by the generator for obtaining the DOE-NV approval. Prior to that, the DOE-NV Waste Management Division must be contacted to verify that waste is acceptable at the NTS. The WAC compliant program includes preparing a waste acceptance package that documents the waste characteristics and quality assurance requirements for waste certification.

In addition to the DOE general disposal criteria listed above, DOE-NV has adopted the following waste package criteria to ensure safe and efficient operations at the NTS.

- **Closure**—The package closure shall be sturdy enough that it will not come open under normal handling conditions.
- **Strength**—The disposal package (packaging and content) shall be capable of supporting a uniformly distributed load of $1,644 \text{ kg/m}^2$ ($3,375 \text{ lb/ft}^2$). This is required to support other waste packages and earth cover without crushing during stacking and covering operations.
- **Handling**—All waste packages shall be provided with permanently attached or removable skids, cleats, offsets, rings, handles, or other auxiliary lifting devices to allow handling by means of forklifts, cranes, or similar handling equipment. Removable skids are preferred to assist in meeting NTS performance objectives for reducing disposal cell subsidence. Lifting rings and other auxiliary lifting devices on the package are, permissible, provided they are recessed, offset, or hinged in a manner that does not inhibit stacking the packages. The lifting devices must be designed to a 5:1 safety factor based on the ultimate strength of the material.
- **Size**—Use boxes that are in width, height, length, $\pm 1/2$ in. respectively, $1.2 \times 1.2 \times 2.1\text{-m}$ ($4 \times 4 \times 7\text{-ft}$) or $1.2 \times 0.6 \times 2.1\text{-m}$ ($4 \times 2 \times 7\text{-ft}$), or use 208-liter (55-gallon) drums. Innovative packaging will be considered, however, the NTS operating personnel must be consulted to ensure equipment compatibility.
- **Weight**—In addition to the weight limits set for specific packaging designs, the NTS imposes limits of 4,082 kg (9,000 pounds) per box and 544 kg (1,200 pounds) per drum.
- **Loading**—Waste packages shall be loaded to ensure that the interior volume is as efficiently and compactly loaded as practical. High density loading will allow efficient disposal space utilization and provide a more stable waste form that will reduce subsidence and enhance the long-term performance of the disposal site.

5.1.3.3 Hanford Site WAC. Based on the Hanford WAC,³⁰ the Hanford Site can only accept waste from approved DOE EM-30 offsite generators. According to Rudolph Guercia of the Hanford Waste Programs Division (personal communication on 7/28/97), the INEEL is an approved generator.

Prior to shipping waste to the Hanford Site, the waste generator shall prepare and submit the required waste certification documents for evaluation and advance approval, and the generator shall certify that the waste meets the receiving facility's waste acceptance criteria (DOE 5820.2A III 3.g.(3)). In addition to the DOE general LLW disposal criteria previously discussed, and as part of the Hanford Site certification documentation practices, the following information and its basis (e.g., measurement, process knowledge) are required.

The generator must supply the Hanford Site with documents containing the waste category according to the waste classification given in Table 15. Once the radionuclide composition of a waste stream is accurately known, the limits shown in Table 15 must be used to determine the Hanford radionuclide disposal category for each container. For waste which contains a mixture of radionuclides, a sum of fractions approach should be used to make the category determination. To determine the waste disposal category, the activity of each radionuclide is divided by its Category 1 limit in Table 15 and the resulting fractions are added. If the sum of fractions is ≤ 1.0 the waste is classified as Category 1. If the sum of fractions is > 1.0 the waste is Category 3 or greater than Category 3. Category 3 determination is made by the same general method as the Category 1 determination.

Category 3 waste shall be stabilized by enclosing it in a high-integrity container or by processing it into a stable waste form. It has been determined by the Hanford Site that the stabilization of category 3 is necessary to protect worker health and the environment. Category 3 LLW may be stabilized using an NRC or Hanford-approved process to meet stability criteria. This entails thorough mixing of the waste with a solidification medium such as Portland cement or various polymers with the end product intended for burial without a package.

Table 15 also provides the Category 3 limits for combustible and noncombustible waste receipt at the Hanford Site. If the waste is Category 3, the generator must determine if the waste is combustible or non-combustible. The definition of combustible and noncombustible for use in defining the limits given in Table 15 is stated as: "Noncombustible waste forms are waste forms which will not burn even on prolonged exposure to open flame and moderately intense heat. These consist of waste forms that experience no evidence of combustion or decomposition upon exposure to 1,000°F for ten minutes." All other forms are combustible.³⁰ A sum of the fractions calculation approach can be used to determine if the limits have been exceeded. Waste packages that exceed the limits indicated in Table 15 will require additional safety analysis before they can be accepted. Any additional requirements for waste that exceeds the limits will be identified as part of the waste acceptance process.

Greater than the Category 3, or greater than the NRC LLW Class C will not be accepted for disposal at the Hanford Site, but will generally be accepted for storage and eventual transfer to a federal repository. If the waste is greater than Category 3 or Class C, or if it exceeds the combustible or non-combustible limits, specific acceptance criteria must be requested from the Hanford Waste Programs Division for additional analysis and special handling and/or packaging requirements.

The radionuclides must be reported as indicated below. The concentrations reported for radionuclides must be based on best estimates and not most conservative values.

- Report all radionuclides not in Table 15, if process knowledge or analysis indicates they exist at $> 1\%$ of the total curie amount in the waste.
- Mobile radionuclide reporting (Ci/m^3) limits are identified in Table 16.
- Other than the mobile radionuclides shown in Table 16, report radionuclides from Table 15

that process knowledge or analysis indicates are present in the waste, only if they exist at $>1/100$ of the Table 15 Category 1 limit. Activities less than minimum detectable analysis limits but greater than the above limit should be reported based on scaling factors^v or process knowledge.

- Report mobile radionuclides listed in Table 16 if they exist in the waste at greater than the reporting limits in each container. If available analytical techniques cannot detect these radionuclides at these levels, the concentrations will need to be estimated by process knowledge using mathematical models, scaling factors, and/or other estimating methods. If the mobile radionuclides exceed the levels shown in Table 16 the waste may require stabilization.
- Daughter products in secular equilibrium with the parent radionuclide should not be reported. Report only the curie value of the parent radionuclide. This will make reporting consistent with the DOT practices. For the purposes of this criteria, daughter products in secular equilibrium will include only those radionuclides that have half lives less than 10 days and less than their parent radionuclide.

^v *Scaling Factors.* Radionuclides may be roughly organized into two groups. (1) those which are amenable to direct measurement by the generator (e.g., gamma energy analysis or assay equipment), and (2) those which require more costly and time consuming analysis generally beyond the capability of the generator (e.g., chemical separation and alpha/beta analysis). To simplify the determination of group 2 isotope activities, activity ratios may be established for a given waste stream which relate the concentration of readily-measured group 1 radionuclides to group 2 radionuclides. These activity ratios are known as scaling factors.

Laboratory analysis should be used whenever possible to initially determine the scaling factors for all radionuclides of interest. Because validated laboratory techniques do not exist for all Table 5 radionuclides, computer-generated scaling factors may be used to supplement laboratory scaling factors when necessary. Scaling factors should be sufficiently conservative to ensure calculated activities are worst-case.

Scaling factors may be generated which correlate radionuclide content to gross radioactivity measurements (e.g., gamma survey) or to group 1 radionuclide activities from direct measurement techniques (e.g., ¹³⁷Cs activity by gamma energy analysis). Scaling factors for Category 3 waste should be correlated to direct measurement techniques.

^w *Daughter products.* The definition of daughter products in secular equilibrium is from 49 CFR 173.433 (b)(2). These daughter product contributions have already been taken into account for category calculations.

Table 15. Category 1 and 3 activity limits for disposal.

Nuclide	Activity Limits (Ci/m ³)				
	Category 1 Waste Limit	Category 3 Waste Limit	Class C Waste Limit ^e	Category 3 Noncombustible Waste Limit	Category 3 Combustible Waste Limit
³ H ^f	9.9 E+04	c	c	4.0 E+07	5.0 E+02
¹⁰ Be	1.1 E+00	2.4 E+02	—	1.0 E+04	2.5 E+02
¹⁴ C	9.1 E-02	2.1 E+01	8.0 E+00	1.8 E+06	4.4 E+04
¹⁴ C ^a	9.1 E-01	2.1 E+02	8.0 E+01	1.8 E+06	4.4 E+04
³⁶ Cl	6.4 E-05	1.4 E-01	—	1.7 E+05	4.2 E+03
⁴⁰ K	1.8 E-03	3.8 E-01	—	3.0 E+05	7.5 E+03
⁵⁹ Ni	3.9 E+00	8.5 E+02	—	2.9 E+06	7.1 E+04
⁵⁹ Ni ^a	3.9 E+01	8.5 E+03	2.2 E+02	2.9 E+06	7.1 E+04
⁶⁰ Co	7.5 E+01	—	—	1.8 E+04	4.5 E+02
⁶⁰ Co ^{af}	7.5 E+02	—	—	1.8 E+04	4.5 E+02
⁶³ Ni	5.9 E+00	2.0 E+04	7.0 E+02	1.2 E+06	3.0 E+04
⁶³ Ni ^a	5.9 E+01	2.0 E+05	7.0 E+03	1.2 E+06	3.0 E+04
⁷⁹ Se	5.1 E-01	1.1 E+02	—	3.9 E+05	9.7 E+03
⁹⁰ Sr	1.6 E-02	5.4 E+04	7.0 E+03	1.5 E+04	3.7 E+02
⁹³ Zr	2.5 E+00	5.4 E+02	—	4.6 E+03	1.2 E+02
⁹³ Mo	8.7 E-01	2.0 E+02	—	1.3 E+05	3.2 E+03
⁹⁴ Nb	2.2 E-04	4.8 E-02	—	9.2 E+03	2.3 E+02
⁹⁴ Nb ^a	2.2 E-03	4.8 E-01	2.0 E-01	9.2 E+03	2.3 E+02
⁹⁹ Tc	2.3 E-02	5.0 E+00	3.0 E+00	4.0 E+05	1.0 E+04
¹⁰⁷ Pd	1.5 E+01	3.3 E+03	—	2.9 E+05	7.1 E+03
^{113m} Cd	7.6 E-01	—	—	1.8 E+03	4.5 E+01
^{121m} Sn	6.7 E-01	2.2 E+04	—	3.1 E+05	7.7 E+03
¹²⁶ Sn	1.6 E-04	3.4 E-02	—	3.6 E+04	9.1 E+02
¹²⁹ I	8.5 E-03	1.8 E+00	8.0 E-02	7.1 E+03	8.9 E-02
¹³³ Ba	7.1 E-01	—	—	4.6 E+05	1.2 E+04
¹³⁵ Cs	1.6 E-01	3.5 E+01	—	8.0 E+05	2.0 E+04
¹³⁷ Cs	5.5 E-03	1.2 E+04	4.6 E+03	1.2 E+05	3.0 E+03
¹⁴⁷ Sm	1.7 E-02	3.7 E+00	—	2.9 E+01	7.1 E-01

Table 15 (continued).

Nuclide	Activity Limits (Ci/m ³)				
	Category 1 Waste Limit	Category 3 Waste Limit	Class C Waste Limit ^e	Category 3 Noncombustible Waste Limit	Category 3 Combustible Waste Limit
¹⁵⁰ Eu	1.4 E-03	6.7 E+02	—	1.4 E+04	3.4 E+02
¹⁵¹ Sm	4.6 E+01	2.1 E+05	—	7.1 E+04	1.8 E+03
¹⁵² Eu	4.8 E-02	—	—	1.7 E+04	4.3 E+02
¹⁵² Gd	6.4 E-03	1.4 E+00	—	3.6 E+00	9.1 E-02
¹⁵⁴ Eu	7.5 E-01	—	—	1.3 E+04	3.3 E+02
¹⁸⁷ Re	3.6 E+01	7.8 E+03	—	6.3 E+07	1.6 E+06
²⁰⁹ Po	9.8 E-03	3.2 E+01	—	3.0 E+02	7.5 E+00
²¹⁰ Pb	3.7 E-02	2.1 E+06	—	1.8 E+02	4.5 E+00
²²⁶ Ra	1.7 E-04	4.3 E-02	—	4.4 E+02	1.1 E+01
²²⁷ Ac	4.2 E-03	3.0 E+05	—	3.1 E-01	7.7 E-03
²²⁸ Ra	1.7 E+01	—	—	8.6 E+02	2.1 E+01
²²⁹ Th	4.4 E-04	9.8 E-02	—	7.1 E-01	1.8 E-02
²³⁰ Th	2.1 E-03	1.5 E-01	—	4.6 E+00	1.2 E-01
²³¹ Pa	1.4 E-04	3.0 E-02	—	1.1 E+00	2.7 E-02
²³² Th	1.1 E-04	2.3 E-02	—	8.6 E-01	2.1 E-02
	4.6 E-04	4.6 E+00	—	5.5 E+00	1.4 E-01
²³³ U ^b	7.4 E-03	9.7 E-01	—	2.7 E+01	6.7 E-01
²³⁴ U	8.9 E-03	1.9 E+00	—	2.7 E+01	6.8 E-01
²³⁵ U	2.8 E-03	5.0 E-01	—	2.9 E+01	7.3 E-01
²³⁶ U	9.5 E-03	2.0 E+00	—	2.9 E+01	7.1 E-01
²³⁷ Np ^b	6.8 E-04	1.5 E-01	—	2.6 E+00	6.4 E-02
²³⁸ U	5.7 E-03	1.2 E+00	—	3.1 E+01	7.7 E-01
²³⁸ Pu ^b	4.7 E-03	2.4 E+01	—	5.2 E+00	1.3 E-01
²³⁹ Pu ^b	1.9 E-03	4.2 E-01	—	4.6 E+00	1.2 E-01
²⁴⁰ Pu ^b	1.9 E-03	4.3 E-01	—	4.6 E+00	1.2 E-01
²⁴¹ Am ^b	2.1 E-03	8.5 E-01	—	4.4 E+00	1.1 E-01
²⁴¹ Pu	6.1 E-02	2.5 E+01	3.5 E+03 ^d	2.4 E+02	5.9 E+00
^{242m} Am ^b	1.9 E-03	1.6 E+00	—	4.6 E+00	1.2 E-01

Table 15 (continued).

Nuclide	Activity Limits (Ci/m ³)				
	Category 1 Waste Limit	Category 3 Waste Limit	Class C Waste Limit ^e	Category 3 Noncombustible Waste Limit	Category 3 Combustible Waste Limit
²⁴² Cm ^f	—	—	2.0 E+04 ^d	2.0 E+02	5.1 E+00
²⁴² Pu ^b	2.0 E-03	4.3 E-01	—	5.0 E+00	1.2 E-01
²⁴³ Am ^b	1.0 E-03	2.3 E-01	—	4.4 E+00	1.1 E-01
²⁴³ Cm ^b	1.8 E-02	3.4 E+02	—	6.7 E+00	1.7 E-01
²⁴⁴ Cm	1.4 E-01	1.6 E+02	—	8.6 E+00	2.1 E-01
²⁴⁴ Pu ^b	6.1 E-04	1.3 E-01	—	5.0 E+00	1.2 E-01
²⁴⁵ Cm ^b	1.3 E-03	2.2 E-01	—	4.4 E+00	1.1 E-01
²⁴⁶ Cm ^b	1.8 E-03	4.2 E-01	—	4.3 E+00	1.1 E-01
²⁴⁷ Cm ^b	5.6 E-04	1.2 E-01	—	4.8 E+00	1.2 E-01
²⁴⁸ Cm ^b	5.1 E-04	1.1 E-01	—	1.2 E+00	3.0 E-02

a Limit for isotope in activated metal.

b The Category 3 limit is the lower of this value and 100 nCi/g.

c A blank in the Category 3 limit or the Class C limit indicates that no upper limit exists for this isotope.

d These limits are in nanocuries per gram of waste.

e 100 nCi/g is the Class C limit for alpha emitting transuranic nuclides with half lives greater than 5 years). f The limits for these isotopes are less than the Category 1 limit. If these isotopes are present in Category 1 waste, the waste must be checked against the combustible and noncombustible limits. The definition of combustible and noncombustible for use in defining ISB limits comes from NUREG 0782 and is stated as follows. Noncombustible waste forms are "Waste forms which will not burn even on prolonged exposure to open flame and moderately intense heat. These consist of waste forms that experience no evidence of combustion or decomposition upon exposure to 1,000°F for ten minutes." All other forms are combustible.

Table 16. Mobile radionuclide reporting (Ci/m³).

Radionuclide	Reporting limit
³ H	4.4 E+00
¹⁴ C	1.3 E-04
³⁶ Cl	9.2 E-05
⁷⁹ Se	3.4 E-05
⁹⁹ Tc	2.1 E-04
¹²⁹ I	1.0 E-06
¹⁸⁷ Re	3.3 E-02
U(all)	1.4 E-05
²³⁷ Np	1.1 E-05

5.1.2.3.1 Waste Packaging Requirements Waste containers, packaging, and shipping must meet the DOT requirements. The thermal limitation on a waste container is 3.5 watts/m^3 (0.1 watts/ft^3). Waste materials that generate heat in excess of 3.5 watts/m^3 may require special packaging and disposal requirements to prevent excessive temperatures in the buried waste. Each waste will be different depending on the nature of the waste and the waste package. Because of this variability, requirements for heat generating waste must be developed on a case-by-case basis.

Criticality safety requirements depend on the type of waste and the spacing of waste packages. These requirements must be developed on a case specific basis. Packages with less than 15 gram of fissile materials can be safely handled with no restriction for criticality safety.

The radiation limit for CH-LLW is $\leq 200 \text{ mrem/hr}$ at any point on the surface. However, a marked point with surface radioactivity up to $1,000 \text{ mrem/hour}$ on the bottom and one side may be permitted with preapproval by the Hanford Site. Such points shall be marked with large red painted dots. For RH-LLW, the limit is $>200 \text{ mrem/hr}$ at any point on the surface.

Packages used for disposal must be able to withstand the weight of three layers of 55-gal drums, each with the same weight as above. All packages must be capable of manual, forklift, or crane offloading.

6. RADIONUCLIDE MATRIX

A radiological analysis of the waste forms was performed by radiological engineers to evaluate the nuclear properties of the waste against the repositories acceptance criteria. The analysis was performed only on selected nuclear properties of the waste including, contact dose rates on containers and decay heat limits for packaging, shipping, and disposal. This evaluation provides preliminary information to identify any waste that lies outside the recognized acceptance criteria of the target disposal facility, or to identify waste which need further processing or shielding to be accepted. Table 17 presents the result of the analysis. Based on the analysis, contact dose rates of containers and decay heat limits meet the repositories acceptance criteria. Further analysis should be performed to estimate other radiological, physical, and chemical waste properties to determine acceptability within the standard criteria of the target repository.

Table 17, Radionuclide matrix.

Waste Form	Dose Rate	Decay Heat
Vitrified waste from VWO	4-122 rem/hr @contact 2-49 rem/hr @ 1 meter	0.2-4.4 watts/canister
Hydroceramic waste from DCWO	4.2-174 rem/hr @contact 1.3-54 rem/hr @ 1 meter	0.1-3.2 watts/canister
Glass-ceramic waste from HWO	6-248 rem/hr @ contact 3-121 @ 1 meter	0.5-14 watts/canister
HLW/HAW separation option		
Vitrified HAW (HLW)	1-2017 rem/hr @contact 0.4-804 rem/hr @ 1 meter	9-74 watts/canister
Grouted LAW (LLW - Class A)	0.01-0.02 rem/hr @contact 0.003-0.006 rem/hr @ 1 meter	Insignificant
TRU/LAW separation option:		
TRU waste	1.4-14 rem/hr @contact 0.3-3 rem/hr @ 1 meter Max. Neutron flux 0.056 rem/hr	0.6-5 watts/canister
Grouted LAW (LLW- Class C)	0.3-123 rem/hr @contact 0.002-9.4 rem/hr @ 1 meter	0.01-0.3 watts/canister
Hydroceramic waste from CWO	70 rem/hr @contact	1.5 watts/canister
HIPed hydroceramic waste from CWO	22 rem/hr @ 1 meter	

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Appendix A

TRUCON Tables and SARP Tables for the TRUPACT-II Shipping Package

TABLE 5
Content Codes in Shipping Categories
Maximum Wattage Limit* per Payload Container and per TRUPACT-II
(See Table 6-3 for Test Category Limits)

Content Code	Shipping Category	Type of Payload Container	Layers of Plastic Bags	Maximum Wattage Limit*	
				Payload Container	TRUPACT-II
AE 111A	I.1A0	Drum	0	0.2060	2.8840
	I.1B0	SWB Overpack	0	0.1457	1.1656
AE 116A	III.1C0	SWB	0	0.5103	1.0206
AE 116B	III.1A1	Drum	1	0.0962	1.3468
	III.1B1	SWB Overpack	1	0.0758	0.6064
AW 111A	I.1A2	Drum	2	0.1594	2.2316
	I.1B2	SWB Overpack	2	0.1207	0.9656
	I.1C2b**	SWB	2	0.1056	0.2112
AW 121A	III.1A2f***	Drum	2	0.0999	1.3986
	III.1C2bf***	SWB	2	0.3329	0.6658
AW 121B	III.1A1f***	Drum	1	0.1069	1.4966
	III.1C1f***	SWB	1	0.4259	0.8518
AW 121C	III.1A2	Drum	2	0.0434	0.6076
	III.1B2	SWB Overpack	2	0.0387	0.3096
	III.1C2b**	SWB	2	0.0646	0.1292
AW 122A	II.2AM	Drum	N/A	40	40
	II.2BM	SWB Overpack	N/A	40	40
	II.2CM	SWB	N/A	40	40
	II.2E0	Pipe Overpack	N/A	40	40
AW 122B	II.1A2f***	Drum	2	0.1997	2.7958
	II.1C2bf***	SWB	2	0.6659	1.3318
AW 122C	II.1A1f***	Drum	1	0.2137	2.9918
	II.1C1f***	SWB	1	0.8518	1.7036

Refer to footnotes at end of table.

Table 5 (Continued)

Content Codes in Shipping Categories
Maximum Wattage Limit* per Payload Container and per TRUPACT-II
(See Table 6-3 for Test Category Limits)

Content Code	Shipping Category	Type of Payload Container	Layers of Plastic Bags	Maximum Wattage Limit*	
				Payload Container	TRUPACT-II
AW 122D	II.1A2	Drum	2	0.0869	1.2166
	II.1B2	SWB Overpack	2	0.0774	0.6192
	II.1C2b**	SWB	2	0.1292	0.2584
AW 127A	III.1A2	Drum	2	0.0434	0.6076
	III.1B2	SWB Overpack	2	0.0387	0.3096
ID 111A	I.2A2	Drum	2	0.1962	2.7468
	I.2B2	SWB Overpack	2	0.1486	1.1888
ID 111B	Deleted				
ID 111C	Deleted				
ID 112A	Test Category—See Table 6-3				
ID 112B	Deleted				
ID 112C	Deleted				
ID 113A	Test Category—See Table 6-3				
ID 113B	Deleted				
ID 113C	Deleted				
ID 114A	I.3A2	Drum	2	0.6375	8.9250
	I.3B2	SWB Overpack	2	0.4828	3.8624
ID 114B	Deleted				
ID 115A	II.1A4	Drum	4	0.0414	0.5796
	II.1B4	SWB Overpack	4	0.0392	0.3136
ID 115B	Deleted				
ID 115C	Deleted				
ID 116A	III.1A4	Drum	4	0.0207	0.2898
	III.1B4	SWB Overpack	4	0.0196	0.1568
	III.1C1	SWB	1	0.3515	0.7030
ID 116B	Deleted				

Refer to footnotes at end of table.

Table 5 (Continued)
Content Codes in Shipping Categories
Maximum Wattage Limit* per Payload Container and per TRUPACT-II
(See Table 6-3 for Test Category Limits)

Content Code	Shipping Category	Type of Payload Container	Layers of Plastic Bags	Maximum Wattage Limit*	
				Payload Container	TRUPACT-II
ID 116C	Deleted				
ID 117A	II.1A4	Drum	4	0.0414	0.5796
	II.1B4	SWB Overpack	4	0.0392	0.3136
	II.1C2	SWB	2	0.5361	1.0722
ID 117B	II.1A2a****	Drum	2	0.1680	2.3520
	II.1B2a****	SWB Overpack	2	0.1360	1.0880
	II.1C2	SWB	2	0.5361	1.0722
	II.1D2	Bin	2	0.4271	0.8542
ID 117C	Deleted				
ID 118A	II.1A4	Drum	4	0.0414	0.5796
	II.1B4	SWB Overpack	4	0.0392	0.3136
	II.1C1	SWB	1	0.7029	1.4058
ID 118B	II.1A2a****	Drum	2	0.1680	2.3520
	II.1B2a****	SWB Overpack	2	0.1360	1.0880
	II.1C2	SWB	2	0.5361	1.0722
	II.1D2	Bin	2	0.4271	0.8542
ID 118C	Deleted				
ID 119A	III.1A4	Drum	4	0.0207	0.2898
	III.1B4	SWB Overpack	4	0.0196	0.1568
	III.1C3	SWB	3	0.0611	0.1222
ID 119B	Deleted				
ID 119C	Deleted				
ID 121A	III.1A4	Drum	4	0.0207	0.2898
	III.1B4	SWB Overpack	4	0.0196	0.1568
	III.1C1	SWB	1	0.3515	0.7030
ID 121B	Deleted				

Refer to footnotes at end of table.

Table 5 (Continued)
Content Codes in Shipping Categories
Maximum Wattage Limit* per Payload Container and per TRUPACT-II
(See Table 6-3 for Test Category Limits)

Content Code	Shipping Category	Type of Payload Container	Layers of Plastic Bags	Maximum Wattage Limit*	
				Payload Container	TRUPACT-II
ID 121C	Deleted				
ID 122A	II.1A4	Drum	4	0.0414	0.5796
	II.1B4	SWB Overpack	4	0.0392	0.3136
	II.1C1	SWB	1	0.7029	1.4058
ID 122B	Deleted				
ID 122C	Deleted				
ID 123A	III.1A4	Drum	4	0.0207	0.2898
	III.1B4	SWB Overpack	4	0.0196	0.1568
ID 123B	Deleted				
ID 123C	Deleted				
ID 124A	II.2AM	Drum	N/A	40	40
	II.2BM	SWB Overpack	N/A	40	40
ID 124B	Deleted				
ID 124C	Deleted				
ID 125A	Deleted				
ID 126A	III.1A3	Drum	3	0.0280	0.3920
	III.1B3	SWB Overpack	3	0.0260	0.2080
ID 126B	Deleted				
ID 126C	Deleted				
ID 127A	III.1D2	Bin	2	0.2135	0.4270
ID 128A	Deleted				
ID 129A	Deleted				
ID 129B	Deleted				
ID 211A	I.2A2	Drum	2	0.1962	2.7468
	I.2B2	SWB Overpack	2	0.1486	1.1888
ID 212A	Test Category—See Table 6-3				

Refer to footnotes at end of table.

Table 5 (Continued)
Content Codes in Shipping Categories
Maximum Wattage Limit* per Payload Container and per TRUPACT-II
(See Table 6-3 for Test Category Limits)

Content Code	Shipping Category	Type of Payload Container	Layers of Plastic Bags	Maximum Wattage Limit*	
				Payload Container	TRUPACT-II
ID 213A	Test Category—See Table 6-3				
ID 215A	II.1A4	Drum	4	0.0414	0.5796
	II.1B4	SWB Overpack	4	0.0392	0.3136
ID 216A	III.1A4	Drum	4	0.0207	0.2898
	III.1B4	SWB Overpack	4	0.0196	0.1568
ID 216B	III.1A2	Drum	2	0.0434	0.6076
	III.1B2	SWB Overpack	2	0.0387	0.3096
ID 216C	III.1A5	Drum	5	0.0164	0.2296
	III.1B5	SWB Overpack	5	0.0157	0.1256
ID 217A	II.2AM	Drum	N/A	40	40
	II.2BM	SWB Overpack	N/A	40	40
ID 217B	II.1A4	Drum	4	0.0414	0.5796
	II.1B4	SWB Overpack	4	0.0392	0.3136
ID 217C	II.1A5	Drum	5	0.0328	0.4592
	II.1B5	SWB Overpack	5	0.0314	0.2512
ID 218A	II.1A5	Drum	5	0.0328	0.4592
	II.1B5	SWB Overpack	5	0.0314	0.2512
ID 218B	II.1A6	Drum	6	0.0272	0.3808
	II.1B6	SWB Overpack	6	0.0262	0.2096
ID 219A	III.1A4	Drum	4	0.0207	0.2898
	III.1B4	SWB Overpack	4	0.0196	0.1568
ID 221A	III.1A4	Drum	4	0.0207	0.2898
	III.1B4	SWB Overpack	4	0.0196	0.1568
ID 222A	II.2AM	Drum	N/A	40	40
	II.2BM	SWB Overpack	N/A	40	40

Refer to footnotes at end of table.

Table 5 (Continued)

Content Codes in Shipping Categories
Maximum Wattage Limit* per Payload Container and per TRUPACT-II
(See Table 6-3 for Test Category Limits)

Content Code	Shipping Category	Type of Payload Container	Layers of Plastic Bags	Maximum Wattage Limit*	
				Payload Container	TRUPACT-II
ID 222B	II.1A5	Drum	5	0.0328	0.4592
	II.1B5	SWB Overpack	5	0.0314	0.2512
ID 223A	III.1A4	Drum	4	0.0207	0.2898
	III.1B4	SWB Overpack	4	0.0196	0.1568
ID 224A	II.2AM	Drum	N/A	40	40
	II.2BM	SWB Overpack	N/A	40	40
ID 225A	III.1A4	Drum	4	0.0207	0.2898
	III.1B4	SWB Overpack	4	0.0196	0.1568
ID 225B	III.1A5	Drum	5	0.0164	0.2296
	III.1B5	SWB Overpack	5	0.0157	0.1256
ID 226A	III.1A4	Drum	4	0.0207	0.2898
	III.1B4	SWB Overpack	4	0.0196	0.1568
LA 111A	I.2A0	Drum	0	0.2536	3.5504
	I.2B0	SWB Overpack	0	0.1793	1.4344
LA 111B	I.2A0	Drum	0	0.2536	3.5504
	I.2B0	SWB Overpack	0	0.1793	1.4344
LA 114A	I.1A2	Drum	2	0.1594	2.2316
	I.1B2	SWB Overpack	2	0.1207	0.9656
LA 115A	II.2AM	Drum	N/A	40	40
	II.2BM	SWB Overpack	N/A	40	40
LA 116A	III.1A4	Drum	4	0.0207	0.2898
	III.1B4	SWB Overpack	4	0.0196	0.1568
LA 117A	II.1C4	SWB	4	0.0690	0.1380
LA 118A	II.2AM	Drum	N/A	40	40
	II.2BM	SWB Overpack	N/A	40	40

Refer to footnotes at end of table.

Table 5 (Continued)
Content Codes in Shipping Categories
Maximum Wattage Limit* per Payload Container and per TRUPACT-II
(See Table 6-3 for Test Category Limits)

Content Code	Shipping Category	Type of Payload Container	Layers of Plastic Bags	Maximum Wattage Limit*	
				Payload Container	TRUPACT-II
LA 123A	III.1A4	Drum	4	0.0207	0.2898
	III.1B4	SWB Overpack	4	0.0196	0.1568
LA 124A	II.2AM	Drum	N/A	40	40
	II.2BM	SWB Overpack	N/A	40	40
LA 125A	III.1C1	SWB	1	0.3515	0.7030
LA 126A	III.1A2	Drum	2	0.0434	0.6076
	III.1B2	SWB Overpack	2	0.0387	0.3096
LA 211A	I.2A0	Drum	0	0.2536	3.5504
	I.2B0	SWB Overpack	0	0.1793	1.4344
LA 211B	I.2A0	Drum	0	0.2536	3.5504
	I.2B0	SWB Overpack	0	0.1793	1.4344
LL 111A	I.1A3	Drum	3	0.0466	0.6542
	I.1B3	SWB Overpack	3	0.0426	0.3408
LL 111B	I.1A0	Drum	0	0.2060	2.8840
LL 113A	Test Category—See Table 6-3				
LL 116A	III.1A3	Drum	3	0.0280	0.3920
	III.1B3	SWB Overpack	3	0.0260	0.2080
LL 124A	II.2AM	Drum	N/A	40	40
	II.2BM	SWB Overpack	N/A	40	40
LL 124B	II.1A3	Drum	3	0.0561	0.7854
	II.1B3	SWB Overpack	3	0.0520	0.4160
LL 125A	III.1A3	Drum	3	0.0280	0.3920
	III.1C2	SWB	2	0.2680	0.5360
MD 111A	I.2A0	Drum	0	0.2536	3.5504
	I.2B0	SWB Overpack	0	0.1793	1.4344
MD 111B	I.2C0	SWB	0	1.1240	2.2480

Refer to footnotes at end of table.

Table 5 (Continued)
Content Codes in Shipping Categories
Maximum Wattage Limit* per Payload Container and per TRUPACT-II
(See Table 6-3 for Test Category Limits)

Content Code	Shipping Category	Type of Payload Container	Layers of Plastic Bags	Maximum Wattage Limit*	
				Payload Container	TRUPACT-II
MD 116A	III.1A3	Drum	3	0.0280	0.3920
	III.1B3	SWB Overpack	3	0.0260	0.2080
MD 117A	II.1A3	Drum	3	0.0561	0.7854
	II.1B3	SWB Overpack	3	0.0520	0.4160
	II.1C0	SWB	0	1.0206	2.0412
NT 111A	I.1A0	Drum	0	0.2060	2.8840
	I.1B0	SWB Overpack	0	0.1457	1.1656
NT 116A	III.1A2	Drum	2	0.0434	0.6076
	III.1B2	SWB Overpack	2	0.0387	0.3096
NT 211A	I.1A0	Drum	0	0.2060	2.8840
	I.1B0	SWB Overpack	0	0.1457	1.1656
NT 225A	III.1A2	Drum	2	0.0434	0.6076
	III.1B2	SWB Overpack	2	0.0387	0.3096
OR 125A	III.1A2	Drum	2	0.0434	0.6076
	III.1B2	SWB Overpack	2	0.0387	0.3096
OR 125B	III.1A2	Drum	2	0.0434	0.6076
	III.1B2	SWB Overpack	2	0.0387	0.3096
RF 111A	I.2A2	Drum	2	0.1962	2.7468
	I.2B2	SWB Overpack	2	0.1486	1.1888
RF 111B	Deleted				
RF 112A	Test Category—See Table 6-3				
RF 112B	Deleted				
RF 113A	Test Category—See Table 6-3				
RF 113B	Deleted				
RF 114A	I.3A4	Drum	4	0.1359	1.9026
	I.3B4	SWB Overpack	4	0.1272	1.0176

Refer to footnotes at end of table.

Table 5 (Continued)
Content Codes in Shipping Categories
Maximum Wattage Limit* per Payload Container and per TRUPACT-II
(See Table 6-3 for Test Category Limits)

Content Code	Shipping Category	Type of Payload Container	Layers of Plastic Bags	Maximum Wattage Limit*	
				Payload Container	TRUPACT-II
RF 114B	Deleted				
RF 115A	II.1A4	Drum	4	0.0414	0.5796
	II.1B4	SWB Overpack	4	0.0392	0.3136
RF 115B	Deleted				
RF 116A	III.1A4	Drum	4	0.0207	0.2898
	III.1B4	SWB Overpack	4	0.0196	0.1568
	III.1C1	SWB	1	0.3515	0.7030
RF 116B	Deleted				
RF 116C	III.1A2a****	Drum	2	0.0840	1.1760
	III.1B2a****	SWB Overpack	2	0.0680	0.5440
RF 117A	II.1A4	Drum	4	0.0414	0.5796
	II.1B4	SWB Overpack	4	0.0392	0.3136
	II.1C2	SWB	2	0.5361	1.0722
RF 117B	Deleted				
RF 117C	II.1A2a****	Drum	2	0.1680	2.3520
	II.1B2a****	SWB Overpack	2	0.1360	1.0880
RF 118A	II.1A4	Drum	4	0.0414	0.5796
	II.1B4	SWB Overpack	4	0.0392	0.3136
	II.1C1	SWB	1	0.7029	1.4058
RF 118B	Deleted				
RF 118C	II.1A2a****	Drum	2	0.1680	2.3520
	II.1B2a****	SWB Overpack	2	0.1360	1.0880
RF 119A	III.1A4	Drum	4	0.0207	0.2898
	III.1B4	SWB Overpack	4	0.0196	0.1568
	III.1C3	SWB	3	0.0611	0.1222
RF 119B	Deleted				

Refer to footnotes at end of table.

Table 5 (Continued)

Content Codes in Shipping Categories
Maximum Wattage Limit* per Payload Container and per TRUPACT-II
(See Table 6-3 for Test Category Limits)

Content Code	Shipping Category	Type of Payload Container	Layers of Plastic Bags	Maximum Wattage Limit*	
				Payload Container	TRUPACT-II
RF 119C	III.1A2a****	Drum	2	0.0840	1.1760
	III.1B2a****	SWB Overpack	2	0.0680	0.5440
RF 121A	III.1A4	Drum	4	0.0207	0.2898
	III.1B4	SWB Overpack	4	0.0196	0.1568
	III.1C1	SWB	1	0.3515	0.7030
RF 121B	Deleted				
RF 122A	II.1A4	Drum	4	0.0414	0.5796
	II.1B4	SWB Overpack	4	0.0392	0.3136
	II.1C1	SWB	1	0.7029	1.4058
RF 122B	Deleted				
RF 122C	II.2AM	Drum	N/A	40	40
RF 122D	II.2E0	Pipe Overpack	N/A	40	40
RF 123A	III.1A4	Drum	4	0.0207	0.2898
	III.1B4	SWB Overpack	4	0.0196	0.1568
RF 123B	Deleted				
RF 124A	II.2AM	Drum	N/A	40	40
	II.2BM	SWB Overpack	N/A	40	40
RF 124B	Deleted				
RF 124C	II.2E0	Pipe Overpack	N/A	40	40
RF 126A	III.1A4	Drum	4	0.0207	0.2898
	III.1B4	SWB Overpack	4	0.0196	0.1568
RF 126B	Deleted				
RF 126C	III.1A3f****	Drum	3	0.1875	2.6250
RF 127A	Deleted				
RF 128A	Deleted				
RF 129A	Deleted				

Refer to footnotes at end of table.

Table 5 (Continued)
Content Codes in Shipping Categories
Maximum Wattage Limit* per Payload Container and per TRUPACT-II
(See Table 6-3 for Test Category Limits)

Content Code	Shipping Category	Type of Payload Container	Layers of Plastic Bags	Maximum Wattage Limit*	
				Payload Container	TRUPACT-II
RH 112A	Test Category—See Table 6-3				
RH 114A	I.3A3	Drum	3	0.1863	2.6082
	I.3B3	SWB Overpack	3	0.1703	1.3624
RH 123A	III.1A4	Drum	4	0.0207	0.2898
	III.1B4	SWB Overpack	4	0.0196	0.1568
RH 125A	III.1A4	Drum	4	0.0207	0.2898
	III.1B4	SWB Overpack	4	0.0196	0.1568
SQ 122A	II.2AM	Drum	N/A	40	40
	II.2BM	SWB Overpack	N/A	40	40
	II.2CM	SWB	N/A	40	40
SQ 122B	II.1A1	Drum	1	0.1924	2.6936
	II.1B1	SWB Overpack	1	0.1516	1.2128
	II.1C1	SWB	1	0.7029	1.4058
SQ 122C	II.1A2	Drum	2	0.0869	1.2166
	II.1B2	SWB Overpack	2	0.0774	0.6192
	II.1C2	SWB	2	0.5361	1.0722
SQ 122D	II.1A3	Drum	3	0.0561	0.7854
	II.1B3	SWB Overpack	3	0.0520	0.4160
	II.1C3	SWB	3	0.1222	0.2444
SR 116A	III.1A3	Drum	3	0.0280	0.3920
	III.1B3	SWB Overpack	3	0.0260	0.2080
SR 116B	III.1A4	Drum	4	0.0207	0.2898
	III.1B4	SWB Overpack	4	0.0196	0.1568
SR 116C	III.1A5	Drum	5	0.0164	0.2296
	III.1B5	SWB Overpack	5	0.0157	0.1256
SR 117A	II.2CM	SWB	N/A	40	40

Table 5 (Continued)

Content Codes in Shipping Categories
Maximum Wattage Limit* per Payload Container and per TRUPACT-II
 (See Table 6-3 for Test Category Limits)

Content Code	Shipping Category	Type of Payload Container	Layers of Plastic Bags	Maximum Wattage Limit*	
				Payload Container	TRUPACT-II
SR 122A	II.1A3	Drum	3	0.0561	0.7854
	II.1B3	SWB Overpack	3	0.0520	0.4160
SR 122B	II.1A4	Drum	4	0.0414	0.5796
	II.1B4	SWB Overpack	4	0.0392	0.3136
SR 122C	II.1A5	Drum	5	0.0328	0.4592
	II.1B5	SWB Overpack	5	0.0314	0.2512
SR 125A	III.1A5	Drum	5	0.0164	0.2296
SL 111	I.1A0	Drum	0	0.2060	2.8840

* Payload containers with wattages in excess of the maximum limit shown will require gas generation testing prior to shipment in the TRUPACT-II.

** Denotes that the packaging consists of a minimum of one liner bag (see details on page x).

*** Denotes that the packaging consists of filtered bags.

**** Denotes that the packaging consists of a minimum of two liner bags (see details on page x).

SAFETY ANALYSIS REPORT

FOR THE

TRUPACT-II SHIPPING PACKAGE

DOCKET NUMBER 71-9218

Prepared by:

Nuclear Packaging, Inc.

A Pacific Nuclear Company

CONDENSED
VERSION

Table 10.1
Pu-239 FISSION GRAM EQUIVALENT, DECAY HEAT,
AND SPECIFIC ACTIVITY OF MANY RADIONUCLIDES

NUCLIDE	ATOMIC NUMBER	Pu-239 FGE	DECAY HEAT (W/g)	SPECIFIC ACTIVITY (Ci/g)
H 3	1	0.00E+00	3.28E-01	9.76E+03
C 14	6	0.00E+00	1.32E-03	4.51E+03
Na 22	11	0.00E+00	8.94E+01	6.32E+03
P 32	15	0.00E+00	1.19E+03	2.89E+05
Mn 54	25	0.00E+00	3.88E+01	7.82E+03
Fe 55	26	0.00E+00	8.49E-02	2.44E+03
Co 57	27	0.00E+00	7.29E+00	8.55E+03
Co 60	27	0.00E+00	1.76E+01	1.14E+03
Ni 63	28	0.00E+00	6.05E-03	5.98E+01
Cu 64	29	0.00E+00	7.21E+03	3.89E+06
As 73	33	0.00E+00	1.02E+01	2.25E+04
Kr 85	36	0.00E+00	5.94E-01	3.97E+02
Rb 86	37	0.00E+00	3.71E+02	8.22E+04
Sr 89	38	0.00E+00	1.01E+02	2.94E+04
Sr 90	38	0.00E+00	1.60E-01	1.38E+02
Y 88	39	0.00E+00	2.24E+02	1.41E+04
Zr 88	40	0.00E+00	4.46E+01	1.80E+04
Zr 95	40	0.00E+00	1.10E+02	2.17E+04
Ru 103	44	0.00E+00	1.05E+02	3.26E+04
Ru 106	44	0.00E+00	2.00E-01	3.38E+03
Ag 110m	47	0.00E+00	7.99E+01	4.80E+03
Cd 109	48	0.00E+00	1.68E+00	2.61E+03
Sb 125	51	0.00E+00	3.27E+00	1.04E+03
I 125	53	0.00E+00	6.38E+00	1.76E+04
I 129	53	0.00E+00	9.34E-08	1.79E-04
I 131	53	0.00E+00	4.23E+02	1.25E+05
Cs 134	55	0.00E+00	1.33E+01	1.31E+03
Cs 137	55	0.00E+00	9.74E-02	8.80E+01
Ba 133	56	0.00E+00	6.82E-01	2.53E+02
Ca 141	58	0.00E+00	4.19E+01	2.88E+04
Ca 144	58	0.00E+00	2.14E+00	3.22E+03
Pm 147	61	0.00E+00	3.44E-01	9.38E+02
Sm 151	62	0.00E+00	3.10E-03	2.66E+01
Eu 152	63	0.00E+00	1.35E+00	1.78E+02
Eu 154	63	0.00E+00	2.39E+00	2.67E+02
Eu 155	63	0.00E+00	3.42E-01	4.70E+02
Tm 168	69	0.00E+00	8.39E+01	8.44E+03
Ta 182	73	0.00E+00	5.60E+01	6.31E+03
Pb 210	82	0.00E+00	1.96E-02	7.72E+01
Po 210	84	0.00E+00	1.45E+02	4.54E+03
Ra 223	88	0.00E+00	1.83E+03	5.18E+04
Ra 226	88	0.00E+00	2.88E-02	1.00E+00
Ra 228	88	0.00E+00	2.76E-02	2.76E+02

Table 10.1
Pu-239 FISSILE GRAM EQUIVALENT, DECAY HEAT,
AND SPECIFIC ACTIVITY OF MANY RADIONUCLIDES
(CONTINUED)

NUCLIDE	ATOMIC NUMBER	Pu-239 FGE	DECAY HEAT (W/g)	SPECIFIC ACTIVITY (Ci/g)
Ac 227	89	0.00E+00	3.68E-02	7.32E+01
Th 228	90	0.00E+00	2.71E+01	8.29E+02
Th 230	90	0.00E+00	5.75E-04	2.04E-02
Th 232	90	0.00E+00	2.68E-09	1.11E-07
Pa 231	91	0.00E+00	1.46E-03	4.78E-02
U 232	92	0.00E+00	6.93E-01	2.16E+01
U 233	92	1.00E+00	2.84E-04	9.76E-03
U 234	92	0.00E+00	1.82E-04	6.32E-03
U 235	92	1.00E+00	6.04E-08	2.19E-06
U 236	92	0.00E+00	1.78E-06	6.54E-05
U 237	92	0.00E+00	1.64E+02	8.25E+04
U 238	92	0.00E+00	8.62E-09	3.40E-07
Np 237	93	1.50E-02	2.09E-05	7.13E-04
Pu 236	94	0.00E+00	1.87E+01	5.37E+02
Pu 238	94	1.13E-01	5.73E-01	1.73E+01
Pu 239	94	1.00E+00	1.95E-03	6.29E-02
Pu 240	94	2.25E-02	7.16E-03	2.30E-01
Pu 241	94	2.25E+00	3.31E-03	1.04E+02
Pu 242	94	7.50E-03	1.17E-04	3.97E-03
Pu 244	94	0.00E+00	5.22E-07	1.79E-05
Am 241	95	1.87E-02	1.16E-01	3.47E+00
Am 242m	95	3.46E+01	4.32E-03	9.83E+00
Am 243	95	1.29E-02	6.49E-03	2.02E-01
Cm 242	96	0.00E+00	1.23E+02	3.35E+03
Cm 243	96	5.00E+00	1.90E+00	5.22E+01
Cm 244	96	9.00E-02	2.86E+00	8.18E+01
Cm 245	96	1.50E+01	5.77E-03	1.74E-01
Cm 246	96	0.00E+00	1.02E-02	3.11E-01
Cm 247	96	5.00E-01	2.98E-06	9.38E-05
Cm 248	96	0.00E+00	5.53E-04	4.30E-03
Cm 250	96	0.00E+00	1.59E-01	2.10E-01
Bk 247	97	0.00E+00	3.69E-02	1.06E+00
Bk 249	97	0.00E+00	3.24E-01	1.66E+03
Cf 249	98	4.50E+01	1.54E-01	4.14E+00
Cf 250	98	0.00E+00	4.12E+00	1.11E+02
Cf 251	98	9.00E+01	5.89E-02	1.60E+00
Cf 252	98	0.00E+00	4.06E+01	5.44E+02
Es 252	99	0.00E+00	4.37E+01	1.11E+03
Es 254	99	0.00E+00	7.35E+01	1.88E+03