Washington TRU Solutions LLC

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March 4, 2005

Mr. M. Rahimi, Project Manager
NMSS/SFPO, Mail Stop O13D13
U.S. Nuclear Regulatory Commission
One White Flint North
11555 Rockville Pike
Rockville, MD 20852-2738

Subject: RESPONSE TO NRC REQUEST FOR ADDITIONAL INFORMATION ON REVISION 21 OF THE TRUPACT-II SHIPPING PACKAGE APPLICATION, DOCKET NO. 71-9218 (TAC No. L23774), AND REVISION 4 OF THE HalfPACT SHIPPING PACKAGE APPLICATION, DOCKET NO. 71-9279 (TAC No. L23775)

Reference 1: Letter from M. L. Caviness to M. Rahimi dated October 4, 2004, subject: Application for Revision 21 of the TRUPACT-II Shipping Package, Docket No. 71-9218, and Revision 4 of the HalfPACT Shipping Package, Docket No. 71-9279

Reference 2: Letter from M. Rahimi to M. L. Caviness dated December 21, 2004, subject: Request for Additional Information on TRUPACT-II and HalfPACT Amendment Requests

Dear Mr. Rahimi:

Washington TRU Solutions LLC, on behalf of the U.S. Department of Energy (DOE), hereby submits an amendment to Revision 21 of the application for a Certificate of Compliance (CoC) for the TRUPACT-II Packaging, U.S. Nuclear Regulatory Commission (NRC) Docket No. 71-9218, and Revision 4 to the application for a CoC for the HalfPACT Packaging, NRC Docket No. 71-9279 (Reference 1). The amendment is in response to the Request for Additional Information (RAI) (Reference 2). This letter includes the following attachments:

- Attachment A – Enclosures to Letter
- Attachment B – Responses to RAI
- Attachment C – References
- Attachment D – Revised Documents.

Technical changes necessary to specifically address the RAI are indicated by red-lining in the margin of the documents ("|") and are summarized in Attachment B. All technical changes made to the documents in the original submittal of this application are also indicated by red-lining in the margin of the documents ("|").

As noted in previous application submittals, an NRC/DOE agreement exists to waive applicable review fees.

If you have any questions regarding this submittal, please contact Ms. J. A. Biedscheid at (505) 878-1343 or Mr. B. A. Day at (505) 234-7414.

Sincerely,

Phillip C. Gregory

P. C. Gregory, Manager
Packaging Engineering

:clm

Attachments

cc: M. A. Italiano, CBFO

February 2005

ATTACHMENT A

ENCLOSURES TO LETTER

Attachment B	Responses to RAI
Attachment C	References
Attachment D	Revised Documents (Two hard copies and seven CDs in Adobe PDF Format)

ATTACHMENT B

RESPONSES TO RAI

CH-TRU Payload Appendices, Appendix 6.12

1-1 Provide the reason(s) for the changes in Table 6.12-3 in the proposed Revision 1 of CH-TRU Payload Appendices.

Since the flammable G value for content code LA 154 has not changed, one would expect no changes in the values in Table 6.12-3 from Revision 0 to Revision 1.

Response:
As stated in Attachment B of the original submittal (dated October 4, 2004), based on operational experience at Los Alamos National Laboratory (LANL), the limits for all content codes (including Content Code LA 154) were uniformly calculated for a final evacuation pressure of 2 torr (i.e., limits for Content Code LA 154 were re-calculated at 2 torr instead of the original final evacuation pressure of 50 mtorr). Performing the calculations for 2 torr results in lower allowable gas generation limits, but facilitates more efficient site implementation of the process.

1-2 Provide the reason(s) for proposing content-dependent G_{net} values (G_{net} = 8.40 for low dose, G_{net} = 3.47 for intermediate dose, G_{net} = 1.67 for high dose), as discussed in the Shaw Environmental report when, in fact, the pressure increase calculations for contents LA154, SQ154, and SR154 all make use of G_{net} = 8.4 as shown in Tables 6.12-6, 6.12-7, and 6.12-8.

If the intention is to use a bounding value, no time/effort should have been spent in the Shaw report trying to justify a dose-dependent approach for the G_{net}. This only adds confusion to an application that is already very large in its scope and content.

Response:
While the gas generation limits proposed by this application use the bounding low-dose G_{net} value of 8.40, the report was prepared to encompass results for G_{net} values that potentially have other applications, including the following:

- TRU waste management site safety analyses to ensure the safe management of TRU waste containers as part of site operations involving container storage and movement activities

Attachment B *(Continued)*

Responses to RAI

- The TRUPACT-II SAR Addendum for ARROW-PAK (submitted by letter from P. C. Gregory to M. Rahimi, subject: Application for Revision of the TRUPACT-II Certificate of Compliance, NRC Docket No. 71-9218, dated January 31, 2005), which uses the intermediate-dose G_{net} value.

1-3 Describe the process for calculating Temperature Corrected Effective G Values shown in Tables 6.12-6, 6.12-7, and 6.12-8.

Using the equation from Appendix 3.1 on page 3.1-8, the staff cannot reproduce the values that are shown.

<u>Response</u>:
The process for calculating the temperature-corrected effective G value is documented below for Content Code LA 154A. The same process was used to calculate the temperature-corrected effective G value for each content code listed in Tables 6.12-6, 6.12-7, and 6.12-8.

As documented in Section 3.4.4.2.1 of the TRUPACT-II Safety Analysis Report (SAR), Section 3.1.2.3.1.2 of CH-TRU Payload Appendix 3.1, "Radiolytic G Values for Waste Materials," and Section 3.2.3 of CH-TRU Payload Appendix 3.2, "Effective G Values for CH-TRU Waste Material Types," the temperature-corrected effective G value, $G(T_{AC})$, is calculated from the Arrhenius equation as:

$$G(T_{AC}) = G(T_{RT})\exp\left[(E_a / R)\{(T_{AC} - T_{RT})/(T_{AC}\, x\, T_{RT})\}\right]$$

where:

$G(T_{AC})$	=	Effective G value of the target material at the average contents temperature (molecules of gas generated per 100 eV of energy), molecules/100 eV
$G(T_{RT})$	=	Effective G value of the target material at room temperature, molecules/100 eV
E_a	=	Activation energy for the target material, kcal/g-mole
R	=	Gas law constant, $1.99(10)^{-3}$ kcal/(g-mole K)

T_{AC} = Absolute temperature of the target material at the average contents absolute temperature, K. In the case of Content Code LA 154A, the average contents absolute temperature is 149.1 °F = 65.06 °C = 338.21 K.

T_{RT} = Absolute room temperature, K (i.e., 298.15 K corresponding to 25 °C)

The maximum possible effective G value at room temperature, $G(T_{RT})$, is 8.4 molecules/100 eV and the activation energy, E_a, is 2.1 kcal/g-mole (as shown in Table 6.12-6). Substitution of the parameter values for Content Code LA 154A in the previously defined Arrhenius equation yields the temperature-corrected effective G value, $G(T_{AC})$:

$$G(T_{AC}) = 8.4 \text{ molecules/100 eV} \exp[(2.1 \text{ kcal/g-mole}/1.99(10)^{-3} \text{ kcal/(g-mole K)}) \{(338.21 \text{ K} - 298.15 \text{ K})/(338.21 \text{ K} \times 298.15 \text{ K})\}]$$

$$G(T_{AC}) = 8.4 \text{ molecules/100 eV} \exp[0.4192]$$

$$G(T_{AC}) = 12.8 \text{ molecules/100 eV}$$

The temperature-corrected effective G value of 12.8 molecules/100 eV at the average contents temperature of 149.1 °F (338.21 K) matches the value reported in the 7th column of Table 6.12-6 of CH-TRU Payload Appendix 6.12, "Use of TRUPACT-II for Shipment of High-Wattage CH-TRU Waste," for Content Code LA 154A.

1-4 Explain Equation 9 on page 6.12-22, providing details about all its terms.

The staff cannot understand the (27 - 4)slpm and the (10 - 1)psi terms. The staff does not see where the 3.7E-6 mol/s/mol value is being used.

<u>Response</u>:
Equation 9 is used to establish the minimum flow coefficient across filter vents with a hydrogen diffusion coefficient of 3.7E-6 mol/s/mol fraction. The flow coefficient for these filters is based on experimental data of flow versus pressure drop as presented in the reference cited as Footnote 2 of CH-TRU Payload Appendix 6.12, "Use of TRUPACT-II for Shipment of High-Wattage CH-TRU Waste":

Attachment B *(Continued)*

Responses to RAI

S. H. Peterson, July 1988, *Determination of Hydrogen Flow and Diffusion Properties of Selected Graphite Filters*, Westinghouse R&D Center, Pittsburgh, Pennsylvania.

Peterson (July 1988) is the source of the volumetric flowrates of 27 and 4 standard liters per minute (slpm) at differential pressures of 10 and 1 pounds per square inch (psi), respectively. These data are the result of measured pressure-induced flow across a filter vent with a hydrogen diffusion coefficient of 3.7E-6 mol/s/mol fraction. The minimum flow coefficient across filter vents, $K_{C,vent(3.7E-6)}$, in Equation 9 was calculated as the difference in the two measured volumetric flowrates [(27-4) slpm] divided by the difference in the corresponding differential pressures [(10-1) psi]. The volumetric flow coefficient in units of slpm/psi is then converted into a molar flow coefficient by using the conversion factors of 14.7 psi/atm, 22.4 L/mole at STP (0 °C and 1 atm pressure), and 60 s/min.

1-5 Provide a reference for the hydrogen diffusivity values ($K_{d,sb}$ = 5.6E-7, $K_{d,lb}$ = 1.0E-6, $K_{d,SWBlb}$ = 8.0E-6) used in Equation 10 on page 6.12-22.

The 5.6E-7 value can be found in Appendix 6.8, Table 6.8-5 but not the other two values.

Response:
The hydrogen diffusivity value for the small bag corresponds to the release rate of 5.6E-7 mol/s/mol fraction shown in Section 6.8.1 of CH-TRU Payload Appendix 6.8, "Gas Release Testing."

The hydrogen diffusivity value of the SWB liner bag closure corresponds to the reciprocal of the resistance value shown in Table 6.10-1 of CH-TRU Payload Appendix 6.10, Effect on Decay Heat Limits of Overpacking Payload Containers:

$$K_{d,SWBlb} = R^{-1}_{eff,SWBlb} = (125{,}660\ s/mol)^{-1} = 8.0\ x\ 10^{-6}\ mol/s\ /\ mol\ fraction$$

The hydrogen diffusivity value assigned to the drum liner bag, $K_{d,lb}$ = 1.0E-6 mol/s/mol fraction, was calculated as the difference of the lowest measured total release rate from CH-TRU Payload Appendix 6.8 and the calculated hydrogen release rate via permeation across a bag. This conservatively assigns only the closure release rate to the hydrogen diffusivity value for the drum liner bag.

Attachment B *(Continued)*

Responses to RAI

1-6 Describe the calculation that leads to the final concentration of flammable gas within the innermost confinement at the end of the ICV vacuum process. Identify all the equations, variables, initial values, and conservative assumptions. Justify the specification of a minimum of 12 hours vacuum process. Provide a table of y_{d0} values for all the content cases that are being considered. As a numerical example, clarify the calculation of y_{d0} = 0.010353 for the LA 154A content as mentioned on page 6.12-29.

Response:

The calculation that leads to the final concentration of flammable gas within the innermost confinement at the end of the ICV vacuum process is documented below for Content Code LA 154A. The process is the same for all other content codes. It should be noted that this process is unchanged from that used in the application for Revision 19a of the TRAMPAC approved in July 2002 as part of CoC Revision 14.

The vacuum application (evacuation) model solves Equations (1) through (14) in Section 6.12.9 of CH-TRU Payload Appendix 6.12, "Use of TRUPACT-II for Shipment of High-Wattage CH-TRU Waste." The vacuum application model parameter values that were used are documented in Section 6.12.9.2 of CH-TRU Payload Appendix 6.12. The minimum 12-hour vacuum process is analytically based on the minimum time required to reach the required final evacuation pressure. Due to potential off-gassing of the waste contents during the evacuation process, the actual time required to reach the final evacuation pressure may be greater than 12 hours. However, the final evacuation pressure criterion ensures that the analytically determined hydrogen concentrations at the end of the evacuation process are achieved.

Sensitivity analyses have demonstrated that the concentration of flammable gas within the innermost confinement layer of a payload container after the evacuation and backfilling process, y_{d0}, is a linear function of the assumed decay heat per payload container.

For each unique content code configuration, the vacuum application model was run three times with three different payload container decay heat values. The y_{d0} values corresponding to payload container decay heats of 0.5 watt, 1.0 watt, and 1.5 watt are summarized in the following table for Content Code LA 154A.

Attachment B *(Continued)*

Responses to RAI

y_{d0} Values as a Function of Decay Heat per Payload Container for LA 154A

Decay Heat per Payload Container, Q (watts)	y_{d0} (mole fraction)
0.5	0.0070841
1.0	0.0083328
1.5	0.0095535

The linear relationship between y_{d0} and payload container decay heat (Q) for Content Code LA 154A is provided by the following y_{d0} versus Q regression equation:

y_{d0} = 2.4694E-03*Q(watt) + 5.8541E-03

The content code configuration dependent y_{d0} versus Q regression equation and Equations 31 and 32 of CH-TRU Payload Appendix 6.12 comprise the model for calculating the content code limits.

The derivation of the flammable gas generation rate limit and decay heat limit for a particular payload container is an iterative process that is performed by this model. First, a flammable gas generation rate limit (i.e., C_g) is assumed. Second, the decay heat limit (i.e., Q) corresponding to the assumed flammable gas generation rate limit is calculated using Equation 32 of CH-TRU Payload Appendix 6.12. The calculated decay heat limit is then used to calculate the y_{d0} value from the applicable y_{d0} versus Q regression equation. The y_{d0} value is then used in Equation 31 of CH-TRU Payload Appendix 6.12 to obtain a revised estimate of the flammable gas generation rate limit. The process is repeated until there is no change in the values of the y_{d0}, C_g, and Q variables. In the case of Content Code LA 154A, this process results in a y_{d0} = 0.010353, as verified through the following analysis starting with Equation 31 of CH-TRU Payload Appendix 6.12:

$$C_g = \frac{y_d - y_{d0}\exp\{-RTt_t/(PV_d r_{eff})\}}{(r_{eff} + \frac{n_{gen}t_t}{N_{tg}})\left[1-\exp\{-RTt_t/(PV_d r_{eff})\}\right]}$$

Attachment B *(Continued)*

Responses to RAI

where,

C_g	=	Flammable gas generation rate limit (mole/sec)
y_d	=	Mole fraction of flammable gas within innermost confinement layer of container at the end of the shipping period (set equal to 0.05)
y_{d0}	=	Mole fraction of flammable gas within innermost confinement layer of a container after vacuum application (0.010353 mole fraction for LA 154A)
r_{eff}	=	Total effective resistance of the confinement layers to the release of flammable gas [7,886,642 sec/mole for LA 154A calculated as sum of the resistances of 4 inner bags (4 x 1,792,115 sec/mole) + sum of the resistance of 2 drum liner bags (2 x 214,133 sec/mole) + resistance of punctured rigid drum liner (19,646 sec/mole) + resistance of 3.7E-6 mole/sec/mole fraction diffusivity filter (270,270 sec/mole)]
n_{gen}	=	Number of flammable gas generators per payload (14 drums per TRUPACT-II)
t_t	=	Shipping period duration (5 days = 432,000 sec for LA 154A)
N_{tg}	=	Total moles of gas in the ICV void volume calculated using the Ideal Gas Law (101.56 mole)
R	=	Gas constant = 0.082056 atm L mole^{-1} K^{-1}
T	=	Temperature (294 K)
P	=	Pressure (1 atm)
V_d	=	Void volume within innermost confinement layer of container (53.5 L)

Substitution of the parameter values in Equation 31 of CH-TRU Payload Appendix 6.12 results in:

$\exp\{-R\ T\ t_t/(P\ V_d\ r_{eff})\}$

$= \exp\{[(-0.082056 \text{ atm L mole}^{-1} \text{ K}^{-1})(294 \text{ K})(432{,}000 \text{ sec})]/[(1 \text{ atm})(53.5 \text{ L})(7{,}886{,}642 \text{ sec/mole})]\}$

$= \exp\{-0.024699918\} = 0.97560263$

Attachment B *(Continued)*

Responses to RAI

Such that:

$$C_g = \frac{0.05 - 0.010353*0.97560263}{(7{,}886{,}642\,\sec/mole + \frac{14*432{,}000\,\sec}{101.56\,mole})\left[1 - 0.97560263\right]}$$

C_g = 2.0581E-07 mole/sec

The decay heat limit corresponding to a C_g of 2.0581E-07 mole/sec is then calculated through Equation 32 of CH-TRU Payload Appendix 6.12 as:

$$Q = \left[(C_g\ N_A)/(G\ molecules/100eV)\right]\left[1.602(10)^{-19}\ watt - \sec/eV\right]$$

where,

Q	=	Decay heat limit per container (watt)
N_A	=	Avogadro's number (6.023(10)^{23} molecules/mole)
G	=	G_{eff}(flam gas) = effective G value for flammable gas (1.09 molecules of flammable gas generated / 100 eV emitted energy for LA 154A)

$$Q = \left[(2.0581E-07\,mole/\sec)\ (6.023E+23\,molecules/mole)\ /\ (1.09\,molecules\,x100\,eV\right]x$$
$$\left[1.602(19)^{-19}\ watt - \sec/eV\right]$$

Q = 1.8219 watt

Substitution of this decay heat limit in the y_{d0} versus Q regression equation for LA 154A results in:

y_{d0} = 2.4694E-03*1.8219 + 5.8541E-03

y_{d0} = 0.010353

Thus, the analysis confirms that these are the appropriate values of the y_{d0}, C_g, and Q variables for Content Code LA 154A.

Attachment B *(Continued)*

Responses to RAI

The mole fraction of flammable gas concentrations within the innermost confinement layer of a payload container after vacuum application (i.e., y_{d0} values) for all content codes are listed in the following table.

Content Code y_{d0} Values

Content Code	y_{d0} (mole fraction)
LA 154A	0.010353
LA 154B	0.007044
LA 154C	0.013747
LA 154D	0.005257
SQ 154A	0.008242
SQ 154B	0.005730
SQ 154C	0.002794
SQ 154D	0.001847
SQ 154E	0.012719
SQ 154F	0.004433
SQ 154G	0.009682
SQ 156A	0.010513
SQ 156B	0.007649
SQ 156C	0.005433
SQ 156D	0.003720
SQ 156E	0.012975
SQ 156F	0.004972
SQ 156G	0.011873
SQ 156H	0.012182

Note: Content Code SR 154 has been replaced with Content Code SQ 156 as detailed in the General Response to the Shaw Environmental, Inc., report RAIs.

1-7 Provide the relationship between G (molecules/100 ev) and dose (watt-years).

Equation 32 on page 6.12-29 provides the relationship between G, Q (decay heat limit per container in watts), and C_g (flammable gas generation rate per container in moles/second). However, G is assumed to be a constant value. If this amendment is attempting to demonstrate the value of G is not constant based on test results and it changes as a function of dose (watt-years), a relationship needs to be provided. If the relationship is based on

the test data, all the data points need to be provided (not just the mean, median, and 95% UTL), and at least an empirical relationship needs to be developed.

Response:
The relationship between the G value and dose (i.e., the decrease in G value with increasing dose) was originally established in the application for Revision 19 of the TRAMPAC approved in July 2001 as part of CoC Revision 12, based on a detailed study at the LANL and other supporting information (as summarized in CH-TRU Payload Appendix 3.3, "Use of Dose-Dependent G Values for CH-TRU Wastes"). The original report tabulating all data from that study and establishing the dose-dependent G values was provided as part of the Revision 19 application. As documented in Chapter 5.0 of Revision 19 of the TRAMPAC, a step function approach was used with criteria established for the dose-dependent G values (instead of using a continuous functional relationship between G value and dose). In this application, the same concept has been extended to the high-dose range for flammable gas as described in the Shaw Environmental, Inc., report.

1-8 Clarify the following statements on page 6.12-34: "The $AFGC_i$ is equivalent to 0.05 if the concentration of flammable VOCs in the headspace of the container is less than or equal to 500 parts per million volume. Otherwise, the AFGC value is calculated as the difference between the container mixture lower explosive limit and the sum of the flammable VOC concentrations within the innermost confinement layer." Provide examples when these two options apply.

Response:
The statements are equivalent to those at the bottom of page 2.4-1 and the top of page 2.4-2 of the currently approved CH-TRU Payload Appendix 2.4, "Mixing of Shipping Categories and Determination of the Flammability Index," for shipment of containers that do not undergo the vacuum application and backfilling process described in CH-TRU Payload Appendix 6.12, "Use of TRUPACT-II for Shipment of High-Wattage CH-TRU Waste." A payload container assigned to one of the content codes described in CH-TRU Payload Appendix 6.12 is classified for compliance evaluation under either the analytical category or test category, as defined in Section 5.0 of the CH-TRAMPAC. When a payload container assigned to these codes exceeds the applicable analytical limit specified in Table 6.12-3, 6.12-4, or 6.12-5, respectively, or the concentration of flammable VOCs exceeds 500 ppm, the container shall be evaluated under the test

category according to the allowable compliance methods established in Section 5.2 of the CH-TRAMPAC.

Compliance with the flammable (gas/VOC) limits can be demonstrated for a test category container assigned to the content codes in CH-TRU Payload Appendix 6.12 by either measurement or testing as for any other container evaluated for TRUPACT-II transport.

1-9 Provide details about the transportation of SQ 154 waste. Identify all the DOE labs that have this type of waste and provide their (by highway) distance to the WIPP site, together with the intended transportation time. Address the possibility of different DOE sites generating very different CH-TRU waste which, even though classified under SQ 154, may have sufficiently different radioactive/non-radioactive mixtures that would grant them different G_{flam} values. Justify the proposed G_{flam} = 1.09 as a conservative approach.

Response:
The "SQ" content codes exist to accommodate any site needing to make a small quantity shipment in the TRUPACT-II or HalfPACT. It is anticipated that the SQ 154 code will be used for the TRUPACT-II shipment of small quantities of waste on a case-by-case basis from the sites listed in CH-TRU Payload Appendix 3.6, "Shipping Period – Controlled Shipments." In terms of shipping distances, the shipment of all SQ 154 waste is subject to the requirements of Section 6.2.3 of the CH-TRAMPAC for shipments designated as controlled shipments (as stated in Section 6.12.7). As a clarification, CH-TRU Payload Appendix 3.6 has been revised to state that the controlled shipment period applies only when the shipping distance to WIPP is bound by that shown in Table 3.6-1 (i.e., 1,847 miles). Table 3.6-1, which provides normal transportation times, is reproduced below:

Table 3.6-1 — Normal Transit Times

To WIPP From	Distance (Miles)	Transit Time in Hours (Miles per Hour)				Transit Time in Days (Miles per Hour)			
		40	45	50	55	40	45	50	55
RFETS	666	16.7	14.8	13.3	12.1	0.7	0.6	0.6	0.5
INEEL	1484	37.1	33.0	29.7	27.0	1.5	1.4	1.2	1.1
Hanford	1847	46.2	41.0	36.9	33.6	1.9	1.7	1.5	1.4
LANL	352	8.8	7.8	7.0	6.4	0.4	0.3	0.3	0.3
SRS	1447	36.2	32.2	28.9	26.3	1.5	1.3	1.2	1.1
LLNL	1345	33.6	29.9	26.9	24.5	1.4	1.2	1.1	1.0
NTS	1017	25.4	22.6	20.3	18.5	1.1	0.9	0.8	0.8
ORNL	1493	37.3	33.2	29.9	27.1	1.6	1.4	1.2	1.1
Mound	1460	36.5	32.4	29.2	26.5	1.5	1.4	1.2	1.1
ANL	1404	35.1	31.2	28.1	25.5	1.5	1.3	1.2	1.1

SQ 154 waste shipments are subject to the requirements specified in CH-TRU Payload Appendix 6.12, "Use of TRUPACT-II for Shipment of High-Wattage CH-TRU Waste," including compliance with the Waste Material Type III.1 requirements. The G_{flam} of 1.09 is applicable based on the Waste Material Type III.1 chemical composition requirements that all SQ 154 waste must meet. If a site has waste that does not comply with the Waste Material Type III.1 chemical composition requirements (to be eligible for the G value of 1.09), it cannot be shipped under SQ 154. While different sites may have different CH-TRU waste, they must fall under the Waste Material Type III.1 envelope to be eligible for the SQ 154 designation. As such, chemicals and/or materials that are not bound by the G value for Waste Material Type III.1 cannot be classified as SQ 154. This methodology is identical to the current grouping of content codes under waste material types.

As detailed in the General Response to the Shaw Environmental, Inc., Report RAIs, the application has been revised to add Content Code SQ 156 (in place of Content Code SR 154). Content Code SQ 156 is subject to the same requirements as Content Code SQ 154 with regard to shipping distances and compliance with the Waste Material Type III.1 requirements. The use of Content Code SQ 156 is subject to additional criteria as specified in Section 6.12.6.2.3 of CH-TRU Payload Appendix 6.12.

Attachment B *(Continued)*

Responses to RAI

Shaw Environmental, Inc., Report

General Response:

Specific responses to each RAI pertaining to the Shaw Environmental, Inc., report are provided below. Major changes to the Shaw Environmental, Inc., report resulting from the responses to the RAI are described by this General Response.

In response to RAIs 1-5, 1-6, and 1-7, the Shaw Environmental, Inc., report has been revised to use only data qualified under the WIPP Certification Program protocols to derive the high-dose range flammable gas G value. All TRU waste to be disposed of at WIPP is subject to the characterization requirements and associated quality assurance (QA) requirements as described in the CH-TRAMPAC and the WIPP Waste Acceptance Criteria (WIPP-WAC) documents. Decay heat and hydrogen value measurements are subject to the WIPP QA Program requirements referenced by the WIPP-WAC. In addition, to address the issue of applicability of the high-dose range flammable gas G value, the site-specific content code SR 154 has been replaced with a generic content code, SQ 156. Content Code SQ 156 has been developed using the high-dose range flammable gas G value with the following requirements to be met by a site for its assignment to a given waste population:

1. The site must document the basis for grouping containers into a population, based on similar gas generation characteristics (e.g., grouping of containers generated from the same process).

2. The site must collect sufficient data on a subpopulation of waste containers in the population in accordance with WIPP Certification Program protocols such that the flammable gas G value for the population is shown to be statistically bound by that for Content Code SQ 156, as measured by the 95th UTL. The methodology for determining the subpopulation size to result in sufficient data is as described in Section 5.2.5.5.2 of the CH-TRAMPAC, "Statistics for Required Subpopulation Size." The determination of flammable gas G values from gas generation data is as described in the Shaw Environmental, Inc., report.

3. The site must request DOE-CBFO approval of site-specific use of Content Code SQ 156, based on the above data and documentation. Use of Content Code SQ 156 and the high-dose range G value shall be formally approved by DOE-CBFO for each site and population of waste.

Attachment B *(Continued)*

Responses to RAI

These requirements have been added to Section 6.12.6.2.3 of CH-TRU Payload Appendix 6.12.

The Shaw Environmental, Inc., report has been revised to update the flammable gas G value for the high-dose range based on the above logic. In addition, the application has been revised to add Content Code SQ 156 in place of Content Code SR 154. The population of containers from the Savannah River Site will have to meet the above requirements in order to use the high-dose range G value and Content Code SQ 156.

1-1 Provide clarifications, as described below, on the last paragraph on page 7 of the report.

Provide reference and/or justification for the 82% factor that is applied as well as the suggested net (G = 10.2) and flammable (G = 3.2) gas G values for cellulose. Justify the discrepancy between the derived G values for cellulose (G_{net} = 8.364, G_{flam} = 2.624) and the values (G_{net} = 8.4, G_{flam} = 3.4) presented in the Summary Table, on page 2 of the report. Provide a strong argument (based on experimental data and unlike Section 3 of the report) that justifies that the same scale factor that is applied to the low dose range (less than 0.012 watts*year) can be extended to the mid- and high-dose range. Justify the discrepancy between the "proposed" same scaling factor (8.364/2.624 ≅ 3.2) and the inferred ratio values from Table 5 of the report:

Bounding Flammable and Net Gas G Values for TRU Wastes (Waste Material Type III.1)			
Dose Range	**Bounding Flammable Gas G Value**	**Bounding Net Gas G Value**	***Scaling factor***
low dose (Dose ≤ 0.012 watt*year)	**3.40**	**8.40**	***2.5***
Intermediate dose (0.012 < Dose ≤ 1.2 watt*year)	**1.09**	**3.47**	***3.2***
High Dose (Dose > 1.2 watt*year)	**0.49**	**1.67**	***3.4***

Response:
The 82% factor and the net and flammable gas G values for cellulose are the same as those currently established in Attachment A of the approved CH-TRU

Attachment B *(Continued)*

Responses to RAI

Payload Appendix 3.2, "Effective G Values for CH-TRU Waste Material Types." In the Shaw Environmental, Inc., report, the G_{flam} value of 3.4 (round-up of 3.362) is from polyethylene (see Table 3.2-3 of CH-TRU Payload Appendix 3.2). The G_{net} value of 8.4 (round-up of 8.364) is from cellulose (see Table 3.2-3 of CH-TRU Payload Appendix 3.2). The apparent discrepancy is due to the fact that the bounding G_{flam} value of 3.4 is for polyethylene, and the bounding G_{net} value of 8.4 is for cellulose. Section 3.0 of the Shaw Environment, Inc., report was intended only for completeness and to establish the decrease in G values (flammable and net gas) as a viable and expected phenomenon.

The Shaw Environmental, Inc. report has been revised to apply the standard scaling factor for the low-dose G_{net} to G_{flam} ($\cong$ 3.2) to the intermediate-dose and high-dose ranges. The intermediate-dose G_{flam} value of 1.09 (previously approved in the application for Revision 19 of the TRUPACT-II SAR) is scaled by a factor of 3.1875 (8.364/2.624) to give an intermediate-dose G_{net} of 3.47. The high-dose G_{flam} value of 0.53 (in the revised Shaw Environmental, Inc. report), that is based on actual drum data from the WIPP Waste Information System database, is scaled by the factor 3.1875 to give a high-dose G_{net} value of 1.69.

Section 4.0 of the Shaw Environmental, Inc., report has been revised to better present the experimental data that demonstrates that both flammable gas (hydrogen) and net gas production are a function of dose and to justify that the scaling factor of 3.1875 can be applied to both the intermediate- and high-dose ranges and provides conservative values for net gas G values for these ranges.

1-2 Discuss the fact that Table 4 in the report shows scaling factors higher than the proposed 8.364/2.624 $\cong$ 3.2 value. Clarify whether this Table is based on measured data and if so, provide the reason for proposing a lower scaling factor value when inferring the net gas G value based on a measured flammable gas G.

Flammable and Net Gas G Values Statistics for Dose > 1.2 Watt*Year (Waste Material Type III.1)			
Statistic	**Flammable Gas G Value**	**Net Gas G Value**	***Scaling factor***
Mean Value	**0.09**	**0.34**	***3.8***
Median Value	**0.03**	**0.11**	***3.7***
95% UTL Value	**0.49**	**1.67**	***3.4***

Attachment B *(Continued)*

Responses to RAI

Justify the reason for Table 5 agreeing with the 95% UTL values presented in Table 4; while, at the same time, disagreeing with the 95% UTL values presented in Table 3.

<u>Response</u>:
The Shaw Environmental, Inc., report has been revised to apply a uniform scaling factor for the intermediate-dose and high-dose range G_{net} values. This scaling factor (8.364/2.624) is applied solely to the G_{flam} values, either previously approved (1.09 for intermediate-dose range) or established by the Shaw Environmental, Inc., report from the 95th UTL of actual drum data (0.53 for the high-dose range). In addition, the Shaw Environmental, Inc., report has been revised to clarify that the high-dose range G_{flam} value of 0.53 results from drum flammable gas generation rate measurements.

1-3 Provide <u>all</u> the MDP data for which the "Mole fraction Flammable gas in Test Cylinder" was measured as indicated in Section 5.3 of this report. Identify the type of waste, the dose and the associated Mole Fraction for each case.

<u>Response</u>:
Details of the MDP testing previously referred to in Section 5.3 of the Shaw Environmental, Inc., report are provided in the Idaho National Engineering and Environmental Laboratory Report, "TRUPACT-II Matrix Depletion Program Final Report," INEL/EXT-98-00987, Rev. 1, prepared for the U.S. Department of Energy, Idaho Operations Office, Idaho Falls, Idaho (1999). CH-TRU Payload Appendix 3.3, "Use of Dose-Dependent G Values for CH-TRU Wastes," provides a summary of the MDP report, and the MDP report was provided with the application for Revision 19 of the TRAMPAC, approved in July 2001 as part of CoC Revision 12, which resulted in the currently used G values.

The new values proposed for use in the Shaw Environmental, Inc., report are the net gas G values for the intermediate- and high-dose ranges (arrived at by scaling the value for flammable gas by the same factor as for the low-dose range) and the flammable gas G value for the high-dose range (arrived at by using measured data from the WIPP Waste Information System database). As such, the MDP data was not used in deriving these values, and Section 5.3 has been deleted from the Shaw Environmental, Inc., report.

1-4 Identify what exactly is provided in Section 5.0 of the report that indicates a further classification can be made for containers that have a dose > 1.2 watt*year, as mentioned in the start of Section 6.0 of the report. Justify how this dose threshold (1.2 watt*year) was chosen and not any other value.

<u>Response</u>:
As the flammable and net gas G values continuously decrease with dose, a step function in the G values with dose as established by the MDP study for the 0.012 watt*year criterion is a more conservative approach than using a continuous function to represent the dose dependence. For all matrices tested under the MDP, the intermediate-range dose-dependent G values were, in fact, achieved within a maximum dose of 0.006 watt*year. For purposes of compliance evaluations, this dose was doubled to establish a criterion (that includes a factor of safety of two) for the step function in the flammable gas G value from the low-dose value to the intermediate-dose value (i.e., ≥0.012 watt*year). High-wattage TRU waste containers have decay heats that are at least an order of magnitude greater than typical TRU waste containers. Thus, the high-dose range criterion of 1.2 watt*year was selected to be 100 times (two orders of magnitude) the intermediate-dose range criterion. The Shaw Environmental, Inc., report has been revised to clarify the selection of 1.2 watt*year for the high-dose range lower limit as 100 times the existing 0.012 watt*year limit for the intermediate-dose range. This forces the categorization of the waste into these three groupings, with the established watt*year criteria having to be met as a prerequisite for the use of the G value. This concept is similar to the use of broad definitions for waste material types, which require that set criteria be met (e.g., compliance with the allowable chemical lists) for a given waste form to be eligible for assignment to a waste material type (and its associated G_{flam} value).

1-5 Discuss the fact that Table 6 in the report shows 2 cases (SR520741 & SR510325) which present very high dose (decay heat of 6.46 watts & 6.29 watts for over 20 years, respectively) and yet the effective flammable gas G values are very small (0.003 & 0.002 respectively). Also from Table 6, discuss the fact that case SR526779, with the lowest dose (decay heat of 0.239 watts for almost 20 years) shows, in fact, the highest flammable G value (G = 0.378). Identify the contents of all 6 cases presented in Table 6, and justify why these 6 cases were chosen.

Attachment B *(Continued)*

Responses to RAI

The report attempts to simplify the relationship between decay heat and flammable gas generation when, in fact, it is the content of a given drum that plays the most significant role. If a drum does not have hydrogen- or carbon-bearing materials in the mixture, no flammable gases will be released due to radiolysis. Table 6 clearly seems to indicate that the population of SRS drums is not as homogenous when it comes to internal content.

Response:
As stated in the General Response to the RAI on the Shaw Environmental, Inc., report, the proposed Content Code SR 154 has been replaced with Content Code SQ 156. Content Code SQ 156 uses the reduced high-dose range flammable gas G value. For a site to use Content Code SQ 156, a population with similar gas generation characteristics must be defined, gas generation data for a subpopulation must be collected under the WIPP Certification Program protocols, and the 95^{th} UTL of the flammable gas G value for this population must be shown to be bound by the flammable gas G value for Content Code SQ 156. Section 6.12.6.2.3 of CH-TRU Payload Appendix 6.12, "Use of TRUPACT-II for Shipment of High-Wattage CH-TRU Waste," has been revised to describe the specific methodology by which a site may request use of Content Code SQ 156 with a high-dose range flammable G value.

While it is true that the contents of a container will dictate the actual gas generation in that container, the use of waste material types and G values is a simple, conservative approach for grouping the containers into bounding categories. The use of 95^{th} UTL values accounts for data variability among individual waste containers within a population of waste.

1-6 Provide a detailed supporting calculation that shows the evaluation of the Flammable Gas Generation Rate (FGGR) for drum SR610641 identified in Appendix A of the report. Address the precision with which each measured data (ppm, watts, etc.) is known.

The decay heat for this specific drum is quoted up to four significant digits (i.e., 0.3728 watts). Is this based on measurement or process knowledge?

Response:
As stated in the General Response to the RAI on the Shaw Environmental, Inc., report, the Shaw Environmental, Inc., report has been revised to use only measured data generated under the WIPP Certification Program protocols to

derive a flammable gas G value for the high-dose range. The data used in deriving the high-dose range G value are summarized in Appendix A of the Shaw Environmental, Inc., report. QA requirements for precision, accuracy, and other data quality objectives for headspace measurements and assay are described in the CH-TRAMPAC and the WIPP-WAC document.

1-7 Describe the differences between the flammable gas G value data shown in Table 4 and the data shown in the Appendix A Table. Identify how much the 192 high-wattage and high-dose SRS drums contribute for these two statistical tables. Provide detailed information (such as content, years closed, origin of waste) about <u>all</u> the 192 SRS drum cases including the flammable and net G values. Identify how these G values were determined (inferred from measured data or by simply assuming a scaling factor). Discuss what guarantees that these 192 cases bound <u>all</u> the 3000 drums of high-wattage CH-TRU that are expected to be shipped from the Savannah River.

The Table in Appendix A indicates a very disperse population of experiments with the Mean Value 10 orders of magnitude higher than the Median Value! One would expect that the data do not belong to the same statistical population and yet, a 95% UTL value is proposed. Question 5 of this RAI also indicates that there are tremendous differences among the SRS drums that were chosen for the study.

<u>Response</u>:
As stated in the General Response to the RAI on the Shaw Environmental, Inc., report, the Shaw Environmental, Inc., report has been revised to use only measured data generated under the WIPP Certification Program protocols to derive a flammable gas G value for the high-dose range. The use of high-dose flammable gas G value is now subject to the specific requirements described in the General Response to the RAI on the Shaw Environmental, Inc., report. Criteria for ensuring that the data belong to the same statistical population have also been included in Section 6.12.6.2.3 of CH-TRU Payload Appendix 6.12, "Use of TRUPACT-II for Shipment of High-Wattage CH-TRU Waste."

Attachment B *(Continued)*

Responses to RAI

1-8 Address the influence of transportation upon the dose-dependent G assumption. Provide a physical explanation for the results described in Appendix 3.5 of the CH-TRU Payload Appendices where it is concluded that agitation does not affect does-dependent G values.

The report solely relies on the physical phenomenon of localized depletion for justifying a decrease in gas production because no "replenishing of the source" takes place within a Type III.1 waste material (solid organic materials). The radioactive sources are considered immobile. Once in motion, however, enough relocation of waste material may occur to actually cause an increase in the G values, since the radioactive material may be moved near to a still non-exposed hydrogen- and carbon-bearing material (such as cellulose).

Response:
In response to Shaw Environmental, Inc., Report RAI 1-8, CH-TRU Payload Appendix 3.3, "Use of Dose-Dependent G Values for CH-TRU Wastes," has been revised to restore the section entitled "Effects of Agitation on Dose-Dependent G Values" that was inadvertently omitted in the application for Revision 20, including Revision 0 of the CH-TRU Payload Appendices. This section has been added as Section 3.3.4 in CH-TRU Payload Appendix 3.3.

1-9 Identify the minimum amount of time (in years) that must have passed before a drum can be classified as low-, intermediate-, or high-dose wattage.

Decay heat alone does not qualify the level of dose the internal waste material has been exposed to.

Response:
As correctly noted in the RAI, decay heat alone does not allow the determination of dose range for the container. The decay heat and the time history of the container are evaluated individually at the time of shipment to determine which dose range is applicable to the container. The dose on the waste is defined as the product of the container decay heat and elapsed time from waste generation to compliance evaluation expressed in units of watt*year. The evaluation of the dose is performed on a container-by-container basis. Specifically, the elapsed time (in years) between the date of container closure and the date of decay heat compliance evaluation is calculated. The elapsed time is then multiplied by the reported decay heat of the container to obtain the dose (watt*year).

ATTACHMENT C

REFERENCES

The following reference document has been revised in response to the Request for Additional Information on the application for Revision 21 of the TRUPACT-II Safety Analysis Report (SAR), Revision 4 of the HalfPACT SAR, Revision 2 of the Contact-Handled Transuranic Waste Authorized Methods for Payload Control (CH-TRAMPAC), and Revision 1 of the CH-TRU Payload Appendices:

Shaw Environmental, Inc., February 2005, *High-Dose Criterion for Flammable Gas G Values and Dose-Dependent Net Gas G Values for Contact-Handled Transuranic Wastes*, Shaw Environmental, Inc., Albuquerque, New Mexico.

High-Dose Criterion for Flammable Gas G values and Dose-Dependent Net Gas G values for Contact-Handled Transuranic Wastes

Prepared for
Washington TRU Solutions LLC
Carlsbad, New Mexico

Prepared by
Shaw Environmental, Inc.
Albuquerque, New Mexico

February 2005

1.0 Summary

Dose-dependent G values for flammable gas, based on a dose criterion of >0.012 watt*year, are currently established for use in the Contact-Handled Transuranic Waste Authorized Methods for Payload Control (CH-TRAMPAC) for contact-handled transuranic (CH-TRU) waste transportation. The purpose of this report is to extend this concept to high-wattage wastes (Waste Material Type III.1, Solid Organic Materials, with high loadings of Pu-239 and/or Pu-238) that meet a higher dose criterion (>1.2 watt*year). Based on a high-dose criterion, these high-wattage wastes are eligible for the use of lower G values in calculating flammable gas limits. Based on the information presented in this report, the following matrix of new intermediate-dose and high-dose bounding G values (Table 1) is proposed for use for Waste Material Type III.1 containers.

Table 1. Bounding Flammable and Net Gas G values for TRU Wastes (Waste Material Type III.1)

Dose Range	Bounding Flammable Gas G value (molecules/100 eV)	Bounding Net Gas G value (molecules/100 eV)
Intermediate Dose (0.012 watt*year < Dose ≤ 1.2 watt*year)	1.09 [a]	3.47 [b]
High Dose (Dose > 1.2 watt*year)	0.53 [c]	1.69 [b]

[a] Current G value established in CH-TRU Authorized Methods for Payload Control (CH-TRAMPAC) for use in calculating flammable gas limits.
[b] Established in this report from Equation (2).
[c] Established in this report from the 95th Upper Tolerance Limit of drum data from the Waste Isolation Pilot Plant Waste Information System database.

2.0 Introduction

2.1 Background

Gas generation, concentration, and pressure during transport of transuranic (TRU) wastes are restricted as follows (Reference 1):

- The hydrogen generated must be limited to a molar quantity that would be no more than 5 percent by volume of the innermost layer of confinement (or equivalent limits for other flammable gases).
- The total amount of gases generated in the payload are controlled to maintain the pressure within the shipping package to below the acceptable design pressure of the package.

As discussed in Appendices 6.1, 6.5, and 6.6 of the CH-TRU Payload Appendices (Reference 2), the primary mechanism for potential gas generation in TRU wastes is radiolysis. Using the gas generation rates of flammable and net (total) gas due to radiolysis, compliance with the above restrictions may be determined. The gas generation potential of a waste material, or "G value," is defined as the number of molecules of gas generated per 100 electron volts (eV) of energy absorbed. For a waste container with contents of a given waste type, the applicable flammable and net gas G values may be used in establishing gas generation, concentration, and pressure limits.

The flammable and net gas G values currently authorized in the CH-TRAMPAC and TRUPACT-II Safety Analysis Report (SAR) (Reference 3) for Waste Material Type III.1, Solid Organic Materials (comprised of materials like paper, plastic, cellulose, etc.), are as follows:

- For flammable gas, a bounding G value of 3.4 molecules/100 eV is used when the dose (measure of energy absorbed) is less than or equal to 0.012 watt*year. For a dose greater than 0.012 watt*year, results of the matrix depletion program (MDP) summarized in Appendix 3.3 of the CH-TRU Payload Appendices show that gas generation rates decrease with increased dose and a G value of 1.09 molecules/100 eV is used (Reference 2).

- For net gas, a bounding G value of 8.4 molecules/100 eV is currently used in Section 3.4.4.2 of the TRUPACT-II SAR (Reference 3) for all cases.

2.2 Purpose and Scope

The purpose of this report is to establish a conservative upper bound on flammable and net gas G values for high-wattage TRU wastes based on dose criteria. The data and analysis presented show that a further decrease in G value for flammable gas (i.e., lower than that currently in use) can be established for higher doses. A high dose value of 1.2 watt*year (100 times the MDP value of 0.012 watt*year) was selected.

This report establishes the intermediate-dose (i.e., >0.012 and ≤1.2 watt*year) net gas G value and high-dose (i.e., >1.2 watt*year) flammable and net gas G values for Waste Material Type III.1 containers.

3.0 Theoretical Considerations

Theoretical considerations of chemical structures for molecules, bond energies, and radiolysis show that flammable and net gas G values should decrease with increasing dose as the bonds within the local range of the radioactive sources are dissociated. The discussion herein focuses on cellulose, which is a common matrix in Waste Material Type III.1 and, in general, is bounding for gas generation.

Cellulose $(C_6H_{10}O_5)_n$ is a "long-chain" polymer polysaccharide carbohydrate linear macromolecule consisting of monomeric units of beta-glucose. The chemical structure of cellulose is depicted in Figure 1. Cellulosic materials commonly present in TRU wastes include paper, cloth, wood, and Benelex, which is composed of wood fiber plus phenolic resin. Other commercial materials that contain cellulosics include cellophane, cellulose acetate (rayon, molded items, paints, coatings), and ethyl cellulose (paints and molded items).

The factor controlling the interactions of materials such as cellulose with radiation is the chemical structure. Chemical bonds are not broken randomly even though the excitation energy may exceed the bond dissociation energy. Energy may be absorbed at one location on a molecule and then transferred to another location on the molecule, which results in a break of the chemical bond at the new location.

Based on the cellulose chemical structure, the types of bonds and the bond energies required to dissociate the various bonds are listed in Table 2. Different bond dissociation energies are reported depending on the functional group and the source of the information. The last column of Table 2 presents average values of the various bond energies based on the cited references. These average values are used in the following discussion. Based on the types of bonds present, the gas products expected from the radiolysis of cellulose include carbon dioxide (CO_2), hydrogen (H_2), carbon monoxide (CO), and methane (CH_4). The number and percentage of bond types, the energy (from the last column of Table 2), and percentage of total energy required to dissociate the bond types in cellulose are presented in Table 3. The fact that a variety of gases are generated indicates that most, if not all, of the bonds in the cellulose molecule are susceptible to radiolytic dissociation. Hydrogen may be generated by the breaking of C-H and O-H bonds that allow the hydrogen atoms to recombine into the diatomic hydrogen gas molecule. As shown in Table 3, these bonds represent approximately 50% of the bonds and 46% of the energy required to completely breakdown a cellulose monomer. Thus, there should be an equal likelihood of breakage of the other two types of bonds (i.e., C-C and C-O). The fact that CO, CO_2, and CH_4 are produced indicates that the C-C and C-O bonds are also broken, and the matrix will eventually be depleted of all atoms of C, H, and O in the vicinity of the radioactive source. The matrix depletion phenomenon manifests on a gross scale as a decrease in the flammable and net gas G values as a function of cumulative dose from initial maximum G values.

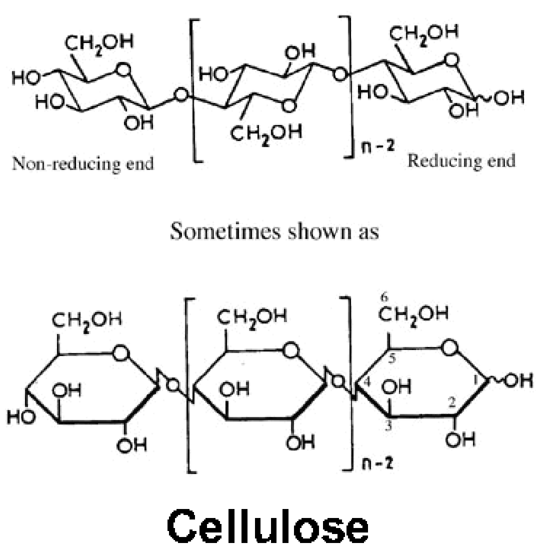

Figure 1. Chemical Structure of Cellulose

Table 2. Dissociation Energies for Bond Types in Cellulose

Bond Type	Bond Dissociation Energy (kcal/mole)			
	(Reference 4)	(Reference 5)	(Reference 6)	Average Value[a]
O-H	102	102	100-102 (alcohols)	102
C-H	80	81	91-99 (alkanes)	85
C-C	145	-	78-84 (alkanes)	113
C-O	70	-	89-90 (alcohols)	80

[a] The average value is calculated from the value reported from Reference 4, Reference 5, and the midpoint from Reference 6.

Table 3. Number and Percentage of Bond Types and Energy and Percentage of Total Energy Required to Dissociate Bond Types in Cellulose

Bond Type	Number per Cellulose Monomer	Percentage of Total Bonds	Energy Required (kcal/mole)	Percentage of Total Energy
O-H	3	14.3	306	15.7
C-H	7	33.3	595	30.6
C-C	5	23.8	565	29.0
C-O	6	28.6	480	24.7
Total	21	100.0	1946	100.0

4.0 Literature Review of Radiolysis Experiments for Net Gas

Numerous radiolysis experiments have demonstrated that, in addition to flammable gas G values, net gas G values also similarly decrease with increasing dose. Details of these experiments are presented in Section 3.1.4.3.1 of Appendix 3.1 of the CH-TRU Payload Appendices (Reference 2) for cellulose. A summary of the relevant data is presented below.

Kazanjian measured gas consumption and generation from Pu-238 alpha irradiation of both wet and dry Kimwipes (paper tissues commonly used in laboratories). The G values decreased as the dose increased. The net gas G value decreased from ~1.1 initially to ~0.5 at 6.0E23 eV (0.0031 watt*year) for dry Kimwipes, and from ~0.6 initially to ~0.3 at an absorbed dose of 4.5E23 eV (0.0023 watt*year) for wet Kimwipes. All G values were significantly lower for wet Kimwipes compared to the values for dry Kimwipes. This is attributed to some of the alpha decay energy being absorbed by water rather than by the cellulose. Thus, the net gas G values decreased to half of the initial values while still in the low-dose range (i.e., ≤ 0.012 watt*year).

Zerwekh also performed alpha radiolysis experiments on dry and wet mixtures of cellulosic materials. The dry mixture consisted of paper wipes, paper tissues, embossed paper towel with polyethylene backing, cheesecloth, and cotton laboratory smock material. The net gas G values for dry cellulosic materials decreased to approximately half of the initial values after about 750 days at an absorbed dose of 1.2E25 eV (0.061 watt*year).

Bibler conducted alpha radiolysis experiments using a 5-M nitric acid Cm-244 solution, which was absorbed by paper tissue that was dried and folded to surround the Cm-244 deposit. A net gas G value of 1.9 was measured during the first five hours of one experiment, with the first measurement taken at an absorbed dose of ~4E19 eV (~2.03E-7 watt*year). The net gas G value decreased to a value of 0.6 at an absorbed dose of 2.5E23 eV (0.0013 watt*year). Three different concentrations of Cm-244, with up to a factor of 4 difference, were used in the experiments, and all observations appeared to fit the same curve of decreasing net gas G value versus absorbed dose. In these experiments, the net gas G value decreased to less than one third of the initial value at approximately 10% of the intermediate dose criterion (i.e., ≤ 0.012 watt*year).

Kosiewicz measured net gas G values for paper of ~1.9 at very low absorbed dose and ~1.5 at a total absorbed dose of ~5E23 eV (~0.0025 watt*year). The net gas G value decreased to half its initial value after an absorbed dose of ~2.5E24 eV (~0.013 watt*year). One set of experiments on paper was conducted in an argon atmosphere to measure the initial net gas G value at low dose. Data points were reported at absorbed dose as low as ~0.5E23 eV (~0.00025 watt*year) for 0.016 Curie of Pu-238 per gram of waste. A net gas G value of 1.4 was estimated. A similar experiment with air as the initial atmosphere reached a maximum net gas G value of 1.4 at ~4E23 eV (~0.0020 watt*year). The first measured net gas G value was approximately 30% lower than the maximum value.

The cellulose net gas G value of 10.2 (which equates to an effective net gas G value of approximately 8.4 (8.364 rounded up) based on 82% of the energy being released from the plutonium particles [Appendix 3.2 of the CH-TRU Payload Appendices provides the source for the 82% factor] [Reference 2]) currently used in all net gas calculations is based on gamma radiolysis experiments conducted by Ershov under conditions in which the oxygen was either absent or depleted. This net gas G value is approximately four units higher than any other experimentally determined value either with oxygen absent or present. The corresponding maximum flammable gas G value for cellulose of 3.2 (2.624 effective flammable gas G value) is also based on gamma radiolysis experiments conducted by Ershov. Thus, the ratio of net gas to flammable gas (hydrogen) G values is 8.364:2.624 or 3.1875 based on the maximum measured values.

For other cellulose radiolysis experiments conducted under an oxygen depleted regime, the net gas G value ranged from 0.5 to 6 as shown in Table 3.1-30 of CH-TRU Payload Appendix 3.1 (Reference 2). When oxygen was present, the net gas G value ranged from 0.6 to 6.2 as shown in Table 3.1-31 of CH-TRU Payload Appendix 3.1. The net gas G values for cellulose undergoing alpha radiolysis in the presence and absence of oxygen for nine experiments were all less than 2 and the flammable gas G value was on the average 60% of the net gas G value. Thus, the net gas to flammable gas G value ratio for alpha radiolysis is 1.7.

In summary, investigations of radiolytic gas generation have repeatedly demonstrated that both flammable gas (hydrogen) and net gas production are a function of dose. In fact, experiments have demonstrated that the net gas G value decreases by a factor of two or three from the initial value while still within the low-dose range. Because the net to flammable G value ratio of 3.1875 is higher for gamma radiation than the 1.7 value for alpha radiation, a ratio of 3.1875 is considered bounding for all doses and types of radiation. While the above discussion focuses on selected studies for cellulose, similar experiments for other materials are documented in Appendix 3.1 of the CH-TRU Payload Appendices (Reference 2).

5.0 Analysis of Flammable Gas Generation Rate Data

Flammable gas generation data from the testing of hundreds of drums of CH-TRU waste of Waste Material Type III.1 that have been disposed of at the Waste Isolation Pilot Plant (WIPP) were obtained from the WIPP Waste Information System [WWIS], which is a computerized data management system used to gather, store, and process information pertaining to CH-TRU waste destined for or disposed of at the WIPP. These data have been collected in accordance with the characterization requirements and associated QA requirements as described in the CH-TRAMPAC (Reference 1) and WIPP Waste Acceptance Criteria (Reference 7). The data were analyzed to derive an effective bounding flammable gas G value for those drums in which dose exceeded 1.2 watt*year. From the data set of containers obtained from the WWIS, 186 drums had doses >1.2 watt*year (see Appendix A for container data).

For the analyses of this data set, the dose was calculated for each drum using the decay heat of the drum at the time of gas generation testing and the difference in years between gas generation testing and drum closure (i.e., generation).

An effective flammable gas G value was calculated for each drum from the following equation derived from CH-TRU Payload Appendix 2.3 (Reference 2):

$$\text{Flammable gas } G_{eff} = \frac{CG * N_A * 100 * 1.602 \times 10^{-19} \text{ watt sec/eV}}{Q} \quad (1)$$

where,

CG	=	Flammable gas generation rate obtained through gas generation testing (mole/second)
N_A	=	Avogadro's number (6.023E23 molecules/mole)
Q	=	Decay heat of drum (watt)

6.0 Analysis of High-Dose Range (Dose > 1.2 Watt*Year) Flammable Gas G value

As documented in Section 5.0, gas generation data were analyzed to derive a flammable gas G value for Waste Material Type III.1 containers with doses >1.2 watt*year. The median, mean, and 95th UTL values for the flammable gas G values for Waste Material Type III.1 data are presented in Table 4 for the 186 containers meeting the high-dose criterion (i.e., >1.2 watt*year).

Table 4. Waste Material Type III.1 Flammable Gas G value Statistics for Dose > 1.2 Watt*Year

Statistic	Flammable Gas G value (molecules/100 eV)
Median Value	0.08
Mean Value	0.15
95th UTL Value*	0.53

* Calculated using a nonparametric bootstrap technique defined by Reference 8.

The 95th UTL value was calculated using a nonparametric bootstrap technique that is appropriate for such skewed lognormal distributions (Reference 8). Bootstrap procedures are nonparametric techniques that operate on the actual data rather than statistical parameters (such as mean and standard deviation), and do not require assumptions regarding the statistical distribution of the underlying population. In the bootstrap procedure, repeated samples of size *n* are drawn with random replacement from the given set of observations. The process is repeated 2,000 times, and each time an estimate of the 95th percentile is computed. The resulting 2,000 estimates of the 95th percentile are then used to calculate a 95th upper confidence limit of the 95th percentile. This value has a 95 percent probability of bounding the true 95th percentile of the population that was sampled.

7.0 Determination of Net Gas G values

As discussed in Section 2.1, for both the low-dose range (dose ≤ 0.012 watt*year) and the intermediate-dose range (dose >0.012 watt*year) a bounding value of 8.4 (Reference 3) has historically been used for the net gas G value. Dose-dependent net gas G values can be established for the intermediate-dose and high-dose ranges using the currently established ratio of the net gas to the flammable gas G value for the bounding net gas generating material (i.e., cellulose). When dose is less than or equal to 0.012 watt*year, the effective net gas G value of cellulosics is 82% of 10.2 (i.e., 8.364) and the effective flammable gas G value is 82% of 3.2 (i.e., 2.624) (References 1 and 2). Based on the theoretical arguments presented in Section 3.0 and supported by the experimental data presented in Section 4.0, the net gas G value may be conservatively calculated as the product of the flammable gas G value and the currently established ratio of the net gas to the flammable gas G value for the bounding net gas generating material (i.e., cellulose). Thus, the intermediate-dose and high-dose range net gas G values may be calculated as follows:

$$^{\text{Dose-Dependent}}\text{Net gas } G_{eff} = {}^{\text{Dose-Dependent}}\text{Flammable gas } G_{eff} * \frac{8.364 \text{ molecules net gas/100eV}}{2.624 \text{ molecules flammable gas/100eV}} \quad (2)$$

The intermediate-dose net gas G value (dose > 0.012 and ≤ 1.2 watt*year) is then calculated as:

$$^{\text{Intermediate-Dose}}\text{Net gas } G_{eff} = 1.09 * \frac{8.364 \text{ molecules net gas/100eV}}{2.624 \text{ molecules flammable gas/100eV}}$$

$$= 3.47$$

The high-dose net gas G value (dose > 1.2 watt*year) is calculated as:

$$^{High\text{-}Dose}\text{Net gas } G_{eff} = 0.53 * \frac{8.364 \text{ molecules net gas/100eV}}{2.624 \text{ molecules flammable gas/100eV}}$$

$$=1.69$$

8.0 Conclusions

Bounding flammable and net gas G values for intermediate-dose and high-dose ranges are presented in Table 5 (duplicate of Table 1).

The flammable gas G value of 1.09 (for dose > 0.012 and ≤ 1.2 watt*year) was determined by experimental data in the MDP and is the value currently established in the CH-TRAMPAC (Reference 1). The net gas G value for the intermediate-dose range, which is established by this report, is calculated as the product of the flammable gas G value (1.09) and the currently established ratio of the net gas to the flammable gas G value for the bounding net gas generating material (i.e., cellulose) (see equation 2). Thus, a net gas dose-dependent G value for the intermediate-dose range of 3.47 is applicable.

For the high-dose range established by this report (i.e., >1.2 watt*year), the flammable gas G value of 0.53 is valid, based on the 95th UTL of G values determined from drum data. A net gas G value of 1.69 is established for the high-dose range as the product of the flammable gas G value (0.53) and the currently established ratio of the net gas to the flammable gas G value for the bounding net gas generating material (i.e., cellulose) (see equation 2).

Table 5. Bounding Flammable and Net Gas G values for TRU Wastes (Waste Material Type III.1)

Dose Range	Bounding Flammable Gas G value (molecules/100 eV)	Bounding Net Gas G value (molecules/100 eV)
Intermediate Dose (0.012 watt*year < Dose ≤ 1.2 watt*year)	1.09 [a]	3.47 [b]
High Dose (Dose > 1.2 watt*year)	0.53 [c]	1.69 [b]

[a] Current G value established in CH-TRU Authorized Methods for Payload Control (CH-TRAMPAC) for use in calculating flammable gas limits.
[b] Established in this report from Equation (2).
[c] Established in this report from the 95th UTL of drum data from the WWIS database.

9.0 References

Reference 1. U.S. Department of Energy, “Contact-Handled TRU Waste Authorized Methods for Payload Control (CH-TRAMPAC),” U.S. Department of Energy, Carlsbad Field Office, Carlsbad, New Mexico.

Reference 2. U.S. Department of Energy, “CH-TRU Payload Appendices,” U.S. Department of Energy, Carlsbad Field Office, Carlsbad, New Mexico.

Reference 3. U.S. Department of Energy, “TRUPACT-II Shipping Package Safety Analysis Report,” U.S. Department of Energy, Carlsbad Field Office, Carlsbad, New Mexico.

Reference 4. Dean, J.A, 1999, “Lange’s Handbook of Chemistry, 15th Edition,” McGraw-Hill, Inc., New York, New York.

Reference 5. Blanksby, S.J. and G.B. Ellison, 2003, “Bond Dissociation Energies of Organic Molecules,” Accounts of Chemical Res. 2003; 36(4) pp 255 – 263, American Chemical Society, Washington, D.C.

Reference 6. Lyman W.J., W. F. Reehl, and D. H. Rosenblatt, 1982, “Handbook of Chemical Property Estimation Methods,” American Chemical Society, Washington, D.C.

Reference 7. U.S. Department of Energy, “Contact-Handled Transuranic Waste Acceptance Criteria for the Waste Isolation Pilot Plant,” Revision 2, DOE/WIPP-02-3122, U.S. Department of Energy, Carlsbad Field Office, Carlsbad, New Mexico.

Reference 8. U.S. Environmental Protection Agency (EPA), 1997, “The Lognormal Distribution in Environmental Applications,” EPA/600/R 97/006, U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C.

Appendix A

WIPP Waste Information System Drum Data
for High-Dose Criterion Drums
(Dose > 1.2 watt*year)

Appendix A
WIPP Waste Information System Drum Data
for High-Dose Criterion Drums
(Dose > 1.2 watt*year)

Source	Container Identification	Generation Date	Sampling Date	Decay Heat (Watts)	Flammable Gas Generation Rate (mole/second)	Dose (Watt*year)	Flammable Gas G value
WWIS	ID004002639	6/12/1986	9/20/2001	7.890E-02	5.395E-09	1.205	6.597E-01
WWIS	ID004002290	2/11/1986	9/17/2001	7.760E-02	6.380E-10	1.210	7.933E-02
WWIS	ID004002806	9/15/1986	9/7/2001	8.185E-02	1.648E-09	1.226	1.943E-01
WWIS	D65476	11/30/1988	8/11/1999	1.162E-01	2.050E-09	1.243	1.702E-01
WWIS	ID004101511	11/15/1982	9/17/2001	6.636E-02	3.236E-09	1.250	4.705E-01
WWIS	D78443	1/21/1992	7/31/2001	1.317E-01	4.690E-09	1.254	3.436E-01
WWIS	ID004101679	9/8/1983	10/23/2001	7.200E-02	3.466E-09	1.305	4.645E-01
WWIS	D60580	10/2/1988	10/4/2001	1.008E-01	2.000E-09	1.310	1.915E-01
WWIS	ID001902240	8/29/1983	12/14/2001	7.169E-02	1.998E-09	1.311	2.689E-01
WWIS	D60587	3/18/1988	11/3/2000	1.045E-01	3.880E-09	1.320	3.581E-01
WWIS	D68965	6/24/1989	7/14/1999	1.324E-01	6.080E-09	1.331	4.430E-01
WWIS	ID004101058	7/25/1980	1/14/2002	6.247E-02	2.280E-10	1.341	3.521E-02
WWIS	ID000234832	9/8/1982	4/25/2001	7.214E-02	9.810E-10	1.344	1.312E-01
WWIS	ID074403770	7/12/1982	5/11/2002	6.796E-02	3.880E-10	1.348	5.508E-02
WWIS	ID000242868	4/3/1984	3/12/2002	7.648E-02	5.427E-09	1.372	6.846E-01
WWIS	ID004002446	5/5/1986	9/20/2001	9.005E-02	2.928E-09	1.385	3.137E-01
WWIS	ID004002764	9/4/1986	9/17/2001	9.400E-02	1.195E-09	1.413	1.227E-01
WWIS	ID004002804	9/5/1986	9/17/2001	9.527E-02	8.800E-10	1.432	8.911E-02
WWIS	ID004002330	2/28/1986	9/20/2001	9.284E-02	3.790E-10	1.444	3.939E-02
WWIS	ID000501780	1/20/1981	11/19/2001	7.009E-02	1.428E-09	1.460	1.966E-01
WWIS	ID004002706	6/24/1986	9/17/2001	9.632E-02	9.980E-10	1.467	9.996E-02
WWIS	ID004002467	4/11/1986	12/21/2001	9.524E-02	2.930E-10	1.495	2.968E-02
WWIS	ID004101256	4/23/1982	4/25/2001	7.941E-02	2.110E-10	1.509	2.564E-02
WWIS	ID004101658	5/28/1983	4/24/2001	8.432E-02	2.863E-09	1.510	3.276E-01
WWIS	ID004101520	11/15/1982	9/20/2001	8.050E-02	7.440E-10	1.517	8.917E-02
WWIS	ID004101387	7/16/1982	9/17/2001	8.107E-02	1.915E-09	1.554	2.279E-01
WWIS	ID004101320	6/2/1982	9/7/2001	8.080E-02	5.060E-10	1.557	6.042E-02
WWIS	ID004002448	5/5/1986	9/17/2001	1.041E-01	6.680E-10	1.600	6.193E-02
WWIS	ID004101752	3/14/1984	9/17/2001	9.169E-02	4.510E-10	1.606	4.746E-02
WWIS	D61127	4/6/1988	11/3/2000	1.296E-01	3.470E-09	1.630	2.583E-01
WWIS	ID004101542	11/8/1982	4/25/2001	9.050E-02	6.470E-10	1.671	6.897E-02
WWIS	ID004101174	6/12/1981	2/11/2002	8.212E-02	1.370E-10	1.697	1.610E-02
WWIS	ID004002811	9/18/1986	8/30/2001	1.144E-01	3.592E-09	1.710	3.030E-01
WWIS	ID004101721	3/14/1984	9/20/2001	9.761E-02	5.790E-09	1.710	5.723E-01
WWIS	ID004101733	4/3/1984	9/20/2001	9.834E-02	3.930E-10	1.717	3.856E-02
WWIS	D63680	8/26/1988	12/22/1999	1.522E-01	3.450E-09	1.723	2.188E-01
WWIS	ID004002049	9/24/1984	10/23/2001	1.011E-01	1.151E-09	1.727	1.098E-01
WWIS	ID004002037	9/24/1984	9/17/2001	1.038E-01	8.900E-10	1.762	8.275E-02
WWIS	ID004002677	6/23/1986	12/21/2001	1.146E-01	7.240E-10	1.775	6.098E-02
WWIS	ID004101151	3/27/1981	2/11/2002	8.629E-02	1.317E-09	1.802	1.473E-01
WWIS	ID004002070	9/24/1984	12/19/2001	1.046E-01	5.620E-10	1.804	5.181E-02

Appendix A
WIPP Waste Information System Drum Data
for High-Dose Criterion Drums
(Dose > 1.2 watt*year)

Source	Container Identification	Generation Date	Sampling Date	Decay Heat (Watts)	Flammable Gas Generation Rate (mole/second)	Dose (Watt*year)	Flammable Gas G value
WWIS	ID004002590	5/9/1986	1/2/2002	1.157E-01	3.704E-09	1.811	3.089E-01
WWIS	ID004002047	9/24/1984	9/17/2001	1.070E-01	5.250E-10	1.817	4.733E-02
WWIS	D72243	11/29/1989	1/12/2001	1.639E-01	2.750E-09	1.823	1.619E-01
WWIS	D56035	7/19/1987	12/10/1998	1.602E-01	6.770E-09	1.826	4.077E-01
WWIS	ID004002516	4/23/1986	8/30/2001	1.197E-01	7.641E-09	1.838	6.160E-01
WWIS	ID004101207	10/23/1981	9/7/2001	9.255E-02	1.240E-10	1.839	1.293E-02
WWIS	D53601	8/24/1987	12/10/1998	1.632E-01	7.360E-09	1.844	4.351E-01
WWIS	ID004002083	9/24/1984	4/24/2001	1.115E-01	5.001E-09	1.848	4.329E-01
WWIS	ID004101586	4/14/1983	2/11/2002	9.965E-02	2.780E-10	1.877	2.692E-02
WWIS	ID004002064	10/21/1984	10/23/2001	1.107E-01	2.571E-09	1.883	2.241E-01
WWIS	ID004002520	4/23/1986	9/17/2001	1.224E-01	8.013E-09	1.885	6.316E-01
WWIS	ID004002406	3/18/1986	8/30/2001	1.224E-01	5.755E-09	1.892	4.536E-01
WWIS	ID004101150	3/23/1981	9/17/2001	9.305E-02	5.590E-10	1.906	5.796E-02
WWIS	ID004002517	4/23/1986	9/20/2001	1.243E-01	6.834E-09	1.916	5.304E-01
WWIS	ID004002977	5/12/1987	12/21/2001	1.326E-01	3.174E-09	1.938	2.309E-01
WWIS	ID005400386	2/19/1982	1/28/2002	9.741E-02	4.265E-09	1.942	4.224E-01
WWIS	ID004002654	7/14/1986	9/17/2001	1.282E-01	6.720E-09	1.946	5.057E-01
WWIS	ID001212062	9/23/1983	11/19/2001	1.081E-01	2.860E-10	1.962	2.553E-02
WWIS	ID004101285	4/23/1982	9/7/2001	1.014E-01	8.350E-10	1.965	7.942E-02
WWIS	ID004002751	8/14/1986	9/17/2001	1.303E-01	6.210E-10	1.967	4.598E-02
WWIS	ID004101620	5/19/1983	9/7/2001	1.079E-01	4.550E-09	1.975	4.068E-01
WWIS	ID004002729	7/21/1986	12/21/2001	1.286E-01	3.100E-11	1.983	2.326E-03
WWIS	ID000243024	6/12/1984	4/28/2001	1.181E-01	2.117E-09	1.993	1.730E-01
WWIS	ID004101565	2/7/1983	9/17/2001	1.080E-01	2.766E-09	2.010	2.471E-01
WWIS	D69031	5/24/1989	12/6/2001	1.609E-01	4.010E-09	2.017	2.405E-01
WWIS	ID004002457	4/10/1986	9/17/2001	1.309E-01	6.248E-09	2.021	4.605E-01
WWIS	ID004101791	3/20/1984	8/30/2001	1.161E-01	5.610E-10	2.026	4.661E-02
WWIS	ID004101802	3/20/1984	9/17/2001	1.167E-01	5.919E-09	2.041	4.896E-01
WWIS	ID004101276	4/23/1982	5/18/2001	1.083E-01	2.540E-09	2.066	2.262E-01
WWIS	ID004101637	5/19/1983	2/12/2002	1.110E-01	5.150E-10	2.080	4.475E-02
WWIS	ID004002138	9/23/1985	9/17/2001	1.304E-01	6.400E-10	2.083	4.737E-02
WWIS	ID004101517	11/15/1982	4/24/2001	1.132E-01	1.231E-09	2.087	1.049E-01
WWIS	ID000234989	9/8/1982	3/19/2001	1.139E-01	1.617E-09	2.111	1.369E-01
WWIS	ID004002090	9/24/1984	11/5/2001	1.244E-01	9.010E-10	2.128	6.990E-02
WWIS	ID004101509	11/15/1982	9/17/2001	1.132E-01	2.770E-10	2.132	2.361E-02
WWIS	ID004101466	11/8/1982	2/11/2002	1.108E-01	6.640E-10	2.133	5.784E-02
WWIS	ID004101539	11/8/1982	9/17/2001	1.134E-01	8.580E-10	2.139	7.299E-02
WWIS	D62278	6/23/1988	11/3/2000	1.738E-01	8.400E-09	2.148	4.664E-01
WWIS	ID004101741	2/24/1984	10/23/2001	1.217E-01	7.870E-10	2.150	6.237E-02
WWIS	ID004002708	6/24/1986	9/17/2001	1.437E-01	5.390E-10	2.189	3.619E-02
WWIS	D66721	2/19/1988	12/16/1998	2.030E-01	3.360E-09	2.197	1.597E-01

Appendix A
WIPP Waste Information System Drum Data
for High-Dose Criterion Drums
(Dose > 1.2 watt*year)

Source	Container Identification	Generation Date	Sampling Date	Decay Heat (Watts)	Flammable Gas Generation Rate (mole/second)	Dose (Watt*year)	Flammable Gas G value
WWIS	ID004101784	3/20/1984	9/20/2001	1.278E-01	7.320E-10	2.237	5.527E-02
WWIS	ID004002879	10/22/1986	9/17/2001	1.504E-01	2.291E-09	2.242	1.469E-01
WWIS	ID004101552	2/2/1983	2/11/2002	1.197E-01	5.040E-10	2.277	4.062E-02
WWIS	ID004101516	11/15/1982	4/24/2001	1.245E-01	7.460E-10	2.295	5.783E-02
WWIS	ID004101099	2/11/1981	4/24/2001	1.158E-01	1.343E-09	2.340	1.118E-01
WWIS	ID004002722	8/21/1986	9/20/2001	1.571E-01	1.380E-09	2.370	8.475E-02
WWIS	D63966	9/8/1988	10/6/1999	2.147E-01	7.150E-09	2.377	3.213E-01
WWIS	D64512	9/30/1988	12/16/1998	2.332E-01	5.310E-09	2.381	2.197E-01
WWIS	ID004101221	11/4/1981	4/25/2001	1.227E-01	2.341E-09	2.388	1.841E-01
WWIS	ID002202029	3/14/1984	10/31/2000	1.443E-01	1.948E-09	2.399	1.303E-01
WWIS	ID004002632	6/12/1986	9/17/2001	1.573E-01	8.486E-09	2.402	5.204E-01
WWIS	ID000236090	2/21/1984	1/2/2002	1.354E-01	5.314E-09	2.419	3.786E-01
WWIS	ID004101816	3/19/1984	9/23/2001	1.407E-01	1.467E-09	2.464	1.006E-01
WWIS	ID004101229	3/26/1982	9/20/2001	1.284E-01	2.137E-09	2.503	1.606E-01
WWIS	ID001905170	12/4/1985	4/11/2001	1.658E-01	1.398E-09	2.545	8.135E-02
WWIS	ID04101699A	12/16/1983	8/13/2001	1.528E-01	5.780E-10	2.698	3.650E-02
WWIS	ID004101523	11/15/1982	9/17/2001	1.477E-01	8.200E-10	2.783	5.355E-02
WWIS	ID004002111	12/1/1984	9/17/2001	1.657E-01	1.826E-09	2.784	1.063E-01
WWIS	D63729	9/13/1988	5/12/1999	2.630E-01	4.990E-09	2.803	1.831E-01
WWIS	ID004101233	3/18/1982	9/20/2001	1.449E-01	4.423E-09	2.827	2.945E-01
WWIS	ID004101060	7/22/1980	2/11/2002	1.330E-01	4.420E-10	2.867	3.207E-02
WWIS	ID004101649	5/12/1983	2/12/2002	1.538E-01	2.755E-09	2.886	1.728E-01
WWIS	ID004101116	2/20/1981	2/11/2002	1.401E-01	1.623E-09	2.938	1.118E-01
WWIS	ID004101294	5/7/1982	4/25/2001	1.549E-01	1.089E-09	2.939	6.781E-02
WWIS	ID004101651	4/28/1983	4/30/2001	1.689E-01	4.324E-09	3.042	2.470E-01
WWIS	ID004101936	12/23/1986	9/17/2001	2.101E-01	4.440E-10	3.097	2.038E-02
WWIS	ID000241508	9/8/1983	12/13/2001	1.696E-01	6.569E-09	3.097	3.738E-01
WWIS	ID004101347	6/15/1982	2/11/2002	1.588E-01	9.700E-10	3.123	5.892E-02
WWIS	ID004101303	5/7/1982	4/24/2001	1.664E-01	7.020E-10	3.156	4.069E-02
WWIS	ID004101460	12/15/1982	2/11/2002	1.653E-01	8.330E-10	3.167	4.862E-02
WWIS	ID004101465	11/8/1982	4/24/2001	1.752E-01	1.754E-09	3.234	9.659E-02
WWIS	ID004002110	12/1/1984	3/4/2002	1.905E-01	7.668E-09	3.288	3.883E-01
WWIS	D72389	12/5/1989	10/25/2000	3.057E-01	5.650E-09	3.328	1.783E-01
WWIS	ID004101996	3/6/1987	9/20/2001	2.300E-01	7.320E-10	3.344	3.071E-02
WWIS	ID004002149	8/9/1985	9/17/2001	2.089E-01	2.605E-09	3.364	1.203E-01
WWIS	ID004002391	3/12/1986	9/17/2001	2.173E-01	1.612E-09	3.371	7.159E-02
WWIS	ID004101648	5/13/1983	9/17/2001	1.843E-01	5.426E-09	3.381	2.841E-01
WWIS	ID004002513	4/22/1986	1/2/2002	2.166E-01	8.840E-10	3.400	3.938E-02
WWIS	ID004101307	5/7/1982	4/25/2001	1.798E-01	1.950E-10	3.410	1.047E-02
WWIS	ID004002148	10/8/1985	9/17/2001	2.149E-01	1.476E-09	3.427	6.626E-02
WWIS	ID004002480	4/10/1986	9/20/2001	2.221E-01	7.926E-09	3.431	3.443E-01

Appendix A
WIPP Waste Information System Drum Data
for High-Dose Criterion Drums
(Dose > 1.2 watt*year)

Source	Container Identification	Generation Date	Sampling Date	Decay Heat (Watts)	Flammable Gas Generation Rate (mole/second)	Dose (Watt*year)	Flammable Gas G value
WWIS	ID004101340	6/23/1982	9/20/2001	1.784E-01	8.600E-11	3.432	4.652E-03
WWIS	ID004101254	4/23/1982	4/24/2001	1.839E-01	1.105E-09	3.495	5.797E-02
WWIS	ID004101722	3/14/1984	1/3/2002	1.975E-01	7.906E-09	3.517	3.862E-01
WWIS	ID004002756	8/14/1986	9/17/2001	2.334E-01	5.050E-10	3.522	2.088E-02
WWIS	ID000235130	9/14/1982	10/31/2000	1.946E-01	8.550E-10	3.528	4.239E-02
WWIS	ID001902269	8/29/1983	10/23/2001	1.985E-01	7.062E-09	3.604	3.432E-01
WWIS	ID004101224	12/15/1981	4/25/2001	1.890E-01	7.890E-10	3.659	4.027E-02
WWIS	ID004002687	7/2/1986	9/17/2001	2.468E-01	1.343E-09	3.755	5.249E-02
WWIS	ID000232648	6/19/1980	10/31/2000	1.859E-01	1.359E-09	3.785	7.054E-02
WWIS	ID004101970	2/10/1987	10/23/2001	2.603E-01	1.742E-09	3.826	6.457E-02
WWIS	ID001210220	12/19/1981	9/17/2001	1.948E-01	1.040E-10	3.845	5.152E-03
WWIS	ID004101281	4/23/1982	5/17/2001	2.020E-01	6.930E-10	3.850	3.311E-02
WWIS	ID004101729	6/8/1984	2/12/2002	2.186E-01	2.170E-10	3.865	9.577E-03
WWIS	D49111	10/16/1987	11/3/2000	2.967E-01	7.990E-09	3.873	2.598E-01
WWIS	ID004101610	6/10/1983	2/11/2002	2.080E-01	1.691E-09	3.885	7.842E-02
WWIS	ID004101593	4/11/1983	5/17/2001	2.156E-01	4.660E-10	3.902	2.086E-02
WWIS	ID004002096	2/13/1985	11/16/2001	2.331E-01	9.510E-10	3.906	3.936E-02
WWIS	ID004101726	3/14/1984	9/17/2001	2.235E-01	8.393E-09	3.914	3.623E-01
WWIS	ID004101601	4/11/1983	2/11/2002	2.125E-01	1.015E-09	4.002	4.609E-02
WWIS	D68067	6/23/1989	1/13/2000	3.863E-01	2.950E-09	4.078	7.367E-02
WWIS	ID004101248	3/18/1982	2/11/2002	2.055E-01	9.740E-10	4.089	4.574E-02
WWIS	ID004101283	5/7/1982	2/11/2002	2.070E-01	1.896E-09	4.092	8.836E-02
WWIS	ID004101355	7/27/1982	9/17/2001	2.192E-01	2.950E-10	4.197	1.298E-02
WWIS	ID004101318	6/2/1982	4/25/2001	2.258E-01	1.080E-10	4.267	4.614E-03
WWIS	D15408	2/19/1988	1/13/2000	3.602E-01	3.300E-09	4.286	8.840E-02
WWIS	ID004101569	2/16/1983	2/11/2002	2.273E-01	1.270E-09	4.317	5.390E-02
WWIS	ID004101703	2/21/1984	9/17/2001	2.459E-01	8.945E-09	4.321	3.509E-01
WWIS	D55395	5/11/1988	1/21/2002	3.184E-01	4.450E-09	4.362	1.348E-01
WWIS	ID004002541	5/1/1986	9/17/2001	2.861E-01	1.521E-09	4.400	5.129E-02
WWIS	ID04101699B	1/24/1984	12/21/2001	2.476E-01	9.264E-09	4.435	3.609E-01
WWIS	ID000234899	12/9/1980	3/14/2001	2.210E-01	1.946E-09	4.478	8.494E-02
WWIS	ID004002929	4/9/1987	9/20/2001	3.137E-01	1.121E-09	4.533	3.447E-02
WWIS	ID004101239	3/18/1982	9/20/2001	2.332E-01	2.774E-09	4.550	1.147E-01
WWIS	ID004101193	8/21/1981	5/18/2001	2.324E-01	3.890E-10	4.587	1.615E-02
WWIS	D36442	3/8/1988	11/1/2000	3.673E-01	9.560E-10	4.647	2.511E-02
WWIS	ID004101270	4/23/1980	9/17/2001	2.214E-01	3.900E-11	4.739	1.699E-03
WWIS	ID004101311	7/14/1982	9/17/2001	2.494E-01	1.190E-10	4.784	4.603E-03
WWIS	ID004101445	10/14/1982	9/17/2001	2.549E-01	8.170E-10	4.824	3.093E-02
WWIS	ID000239056	6/12/1984	12/14/2001	2.759E-01	2.500E-09	4.830	8.741E-02
WWIS	ID004101714	1/6/1984	9/17/2001	2.836E-01	6.026E-09	5.019	2.050E-01
WWIS	D60373	2/16/1988	2/5/2001	3.924E-01	1.980E-09	5.091	4.868E-02

Appendix A
WIPP Waste Information System Drum Data
for High-Dose Criterion Drums
(Dose > 1.2 watt*year)

Source	Container Identification	Generation Date	Sampling Date	Decay Heat (Watts)	Flammable Gas Generation Rate (mole/second)	Dose (Watt*year)	Flammable Gas G value
WWIS	ID004101653	5/19/1983	1/14/2002	2.810E-01	8.031E-09	5.243	2.758E-01
WWIS	ID004101316	6/2/1982	9/17/2001	2.759E-01	4.130E-10	5.324	1.444E-02
WWIS	ID004101246	3/26/1982	4/30/2001	2.796E-01	1.381E-09	5.339	4.766E-02
WWIS	ID004101636	5/19/1983	2/12/2002	2.885E-01	1.218E-09	5.405	4.074E-02
WWIS	ID004101309	5/7/1982	9/20/2001	2.834E-01	1.003E-09	5.490	3.415E-02
WWIS	ID004101253	4/23/1982	11/16/2001	2.833E-01	7.830E-10	5.544	2.666E-02
WWIS	ID004101550	11/15/1982	2/11/2002	2.888E-01	9.210E-10	5.556	3.077E-02
WWIS	ID004101711	2/21/1984	2/11/2002	3.140E-01	8.539E-09	5.643	2.624E-01
WWIS	ID004101361	7/27/1982	9/17/2001	3.008E-01	1.580E-10	5.758	5.068E-03
WWIS	ID004101521	11/8/1982	9/20/2001	3.200E-01	2.085E-09	6.037	6.287E-02
WWIS	ID004101282	5/7/1982	5/18/2001	3.218E-01	2.814E-09	6.124	8.437E-02
WWIS	ID004101639	4/28/1983	2/12/2002	3.305E-01	1.504E-09	6.212	4.390E-02
WWIS	ID004101317	6/2/1982	9/17/2001	3.221E-01	4.780E-10	6.214	1.432E-02
WWIS	ID004101384	7/16/1982	3/13/2002	3.196E-01	9.800E-11	6.282	2.959E-03
WWIS	ID004101606	4/11/1983	2/11/2002	3.523E-01	1.521E-09	6.638	4.165E-02
WWIS	ID004101296	5/7/1982	9/17/2001	3.438E-01	2.002E-09	6.658	5.618E-02
WWIS	ID004101377	7/16/1982	9/17/2001	3.675E-01	1.630E-10	7.046	4.279E-03
WWIS	ID004101450	10/14/1982	9/17/2001	3.918E-01	1.584E-09	7.416	3.900E-02
WWIS	ID004101356	7/27/1982	11/19/2001	3.896E-01	2.920E-10	7.526	7.231E-03
WWIS	ID004101297	5/7/1982	2/11/2002	3.886E-01	1.802E-09	7.682	4.473E-02
WWIS	ID004101631	5/19/1983	2/12/2002	4.148E-01	1.590E-09	7.773	3.698E-02
WWIS	ID004002342	3/21/1986	8/30/2001	6.330E-01	1.520E-10	9.776	2.317E-03

ATTACHMENT D

REVISED DOCUMENTS
(Two Hard Copies and Seven CDs in Adobe PDF Format)

- *TRUPACT-II Safety Analysis Report, Revision 21 (February 2005)*
- *HalfPACT Safety Analysis Report, Revision 4 (February 2005)*
- *Contact-Handled Transuranic Waste Authorized Methods for Payload Control (CH-TRAMPAC), Revision 2 (February 2005)*
- *CH-TRU Payload Appendices, Revision 1 (February 2005)*