Appendix 4.10.2.2

Compliance Methodology for TRU Waste From
Missouri University Research Reactor (MURR)
Columbia, MO

1.0 INTRODUCTION

This appendix presents how records and database information (process knowledge) have been used to qualify seven drums of Missouri University Research Reactor (MURR) contact-handled (CH) transuranic (TRU) waste as payload for transport in the CNS 10-160B cask. The methods for determining each restricted parameter, the factors influencing the parameter values, and the methods used by MURR for demonstrating compliance, are provided in the following sections.

This appendix also includes the following as attachments:

- Content code MR 121A (Attachment A)
- Chemical Lists for the above mentioned content code (Attachment A)
- Methods for Determining Gas Generation Rates and Decay Heat Values and summary of drum compliance (Attachment B).

2.0 PURPOSE

The purpose of this appendix is to describe the process knowledge used to qualify the CH-TRU waste belonging to MURR prior to transport in the CNS 10-160B cask. This appendix is based on the format and requirements for TRU waste identified in Appendix 4.10.2 of the CNS 10-160B cask Safety Analysis Report (SAR). It incorporates acceptable methods and process knowledge applicable to content code MR 121A described in this appendix.

Section 3.0 describes the TRU waste payload. Sections 4.0 through 11.0 discuss each payload parameter, and the process knowledge/methods employed to demonstrate compliance with the CNS 10-160B cask payload requirements.

3.0 TRU WASTE PAYLOAD FOR CNS 10-160B CASK

The content code for the CH-TRU waste from MURR (MR 121A—Solid Organic Waste) is provided in Attachment A. This content code refers to seven 55-gallon drums of solid organic waste from the MURR Transuranic Management by Pyropartitioning separation (TRUMP-S) program.

Complete documentation packages, along with quality assurance/quality control records, are generated for all payload containers as summarized in this appendix. TRU waste generated from the MURR will comply with all transportation requirements using the following methods:

- Formally documented acceptable knowledge (AK)/process knowledge of the processes generating the waste

- Data packages generated for all payload containers that document the contents and properties of the waste in the container including the absence of prohibited items and compliance with packaging requirements

- Measurement of required parameters to ensure compliance with limits.

4.0 PHYSICAL FORM

4.1 Requirements

The physical form of waste comprising the CNS 10-160B cask payload is restricted to solid or solidified materials in secondary containers. The total volume of residual liquid in a secondary container is restricted to less than 1% by volume. Secondary containers must be shored to prevent movement during accident conditions. Sharp or heavy objects in the waste shall be blocked, braced, or suitably packaged as necessary to provide puncture protection for the payload containers packaging these objects. Sealed containers greater than four liters in size are prohibited.

4.2 Methods of Compliance and Verification

Compliance with the physical form requirements is determined by records and data base information (process knowledge). Laboratory archive records include a list of the contents of each bag of waste. A review of this inventory indicate that the physical form requirements have been met. There is no liquid waste. Any liquid waste remaining after an experiment or activity was evaporated prior to bagging out of the glove box as waste as documented in procedure TAM-32, "Treatment of Aqueous Residue" (Reference 12.1). Waste packaging records show that sharp and heavy objects have been packaged to provide puncture protection equivalent to Type A packaging requirements, and there are no sealed or pressurized containers in the waste.

5.0 CHEMICAL FORM AND CHEMICAL PROPERTIES

5.1 Requirements

The chemical properties of the waste are determined by the chemical constituents allowed in a given content code. Specific requirements regarding the chemical form of the waste are as follows:

- Explosives, nonradioactive pyrophorics, compressed gases, and corrosives are prohibited.
- Pyrophoric radionuclides may be present only in residual amounts less than 1 weight percent.
- The total amount of potentially flammable volatile organic compounds (VOCs) present in the headspace of a secondary container is restricted to 500 parts per million.

5.2 Methods of Compliance and Verification

Compliance with the chemical form and chemical property restrictions is demonstrated through records and database information (process knowledge), chemical and physical inventory lists, and archived laboratory notebooks that describe process restrictions. No explosives were used in the experimental program. Lithium metal was the only non-radioactive pyrophoric used in the experiments. The excess lithium metal was oxidized in water, the solutions neutralized and evaporated to dryness. This solid was passed to the low-level waste stream. The plutonium and americium used in the TRUMP-S experimental program are contained in experimental residues in an oxidized state and are non-pyrophoric. Records indicate that no volatile organic materials were used in the experimental program and volatile organics are not present in the TRU waste. The chemical list for content code MR 121A is presented in Attachment A.

6.0 CHEMICAL COMPATIBILITY

6.1 Requirements

Each content code has an associated chemical list (Attachment A) based on AK information. Chemical constituents in a payload container assigned to a given content code shall conform to these approved chemical lists. Chemicals/materials that are not listed are allowed in trace amounts (quantities less than 1 weight percent) in a payload container provided that the total quantity of trace chemicals/materials is restricted to less than 5 percent (weight).

Chemical compatibility of a waste with its packaging ensures that chemical reactions will not occur that might pose a threat to the safe transport of a payload in the CNS 10-160B cask.

6.2 Methods of Compliance and Verification

Attachment B of Appendix 4.10.2 presents the methodology and results for the chemical compatibility analyses performed for the list of allowable chemicals/materials associated with the TRU waste content codes expected to be shipped in the CNS 10-160B cask. The results of these chemical compatibility analyses show that these content codes can be transported without any incompatibilities.

The chemicals present in MR 121A conform to the list of allowable materials in Attachment B of Appendix 4.10.2. Therefore, the waste meets the chemical compatibility requirements.

7.0 GAS DISTRIBUTION AND PRESSURE BUILDUP

7.1 Requirements

Gas distribution and pressure buildup during transport of TRU waste in the CNS 10-160B cask payload are restricted to the following limits:

- The gases generated in the payload must be controlled to prevent the occurrence of potentially flammable concentrations of gases within the payload confinement layers and the void volume of the inner vessel (IV) cavity. Specifically, hydrogen concentrations within the payload confinement layers are limited to 5 percent by volume during a maximum 60-day shipping period (see Attachment C of Appendix 4.10.2).

- The gases generated in the payload and released into the IV cavity must be controlled to maintain the pressure within the IV cavity below the acceptable packaging design limit of 31.2 pounds per square inch gauge (psig).

7.2 Methods of Compliance and Verification

Compliance with the CNS 10-160B cask design pressure limit for the MR 121A content code is analyzed by assuming that all gases generated are released into the IV cavity and by including the contributions from thermal expansion of gases and vapor pressure of atmospheric water.

Table 7-1 shows that the pressure increase during a period of 365 days is below the design pressure limit of 31.2 psig for MR 121A.

Table 7-1. Maximum Pressure Increase Over 365-Day Shipping Period						
Content Code	G_{eff} (RT)[a]	Void Volume (Liters)	Activation Energy (kcal/mole)	Decay Heat Limit (Watts)	G_{eff}[b]	P_{max}[c] (psig)
MR 121A	8.1	1938	2.1	0.93	14.19	17.70

[a] G value for net gas (molecules per 100 eV) at room temperature (70°F).
[b] Effective G value (molecules per 100 eV) at maximum operating temperature of 168°F calculated using the Arrhenius equation for which activation energy is an input.
[c] Maximum pressure.

Compliance with the restrictions on flammable gas concentration is discussed in Section 10.0.

8.0 PAYLOAD CONTAINER AND CONTENTS CONFIGURATION

8.1 Requirements

Fifty-five-gallon drums are authorized payload containers in a CNS 10-160B cask. Up to ten 55-gallon drums of TRU waste may be packaged in the cask. Each 55-gallon drum to be packaged in the CNS cask must have a minimum of one filter vent. The minimum filter vent specifications for the seven 55-gallon drums of MR 121A are provided in Table 8-1.

Table 8-1. Minimum Filter Vent Specifications				
	Filter Specification			
Container/Filter Type	Number of Vents Required per Container	Flow Rate (ml/min of air, STP, at 1 inch of water)[a]	Efficiency (percent)	Hydrogen Diffusivity (mol/s/mol fraction at 25°C)
Drum filter	1	35	99.5	3.70E-6
Filtered Bag	1	35	NA[b]	1.075E-5

[a] Filters tested at a different pressure gradient shall have a proportional flow rate (e.g., 35 ml/min at 1 inch of water = 1 L/min at 1 psi).
[b] Filters installed in containers that are overpacked are exempt from the efficiency requirement as the drum must exhibit a ≥99.5 percent efficiency.
NA = Not applicable.

Filter vents shall be legibly marked to ensure both (1) identification of the supplier and (2) date of manufacture, lot number, or unique serial number.

The rigid polyethylene liner, if present, in a payload container shall be punctured with a minimum of a 0.3-inch diameter hole before the container is transported in the CNS 10-160B.

8.2 Methods of Compliance and Verification

Compliance with the payload container and contents configuration requirements is determined by visual examination, process knowledge and through procurement records. The MURR TRU waste is packaged within two layers of plastic, one inner plastic waste bag, and one filtered drum liner bag. The plastic bags are closed by the twist and tape method (i.e., not heat-sealed). The individual bags are placed in 55-gallon drums with a filter vent installed on each drum that meets the minimum filter vent specifications for the 55-gallon drums listed in Table 8-1. Procurement documents for the 55-gallon drums, lids, rigid liners, and filters are included in MURR archives indicating compliance with the requirements. Prior to transport, payload container filter vents shall be visually inspected for damage or defect. If a defect is identified, a nonconformance report shall be issued and the payload container shall be returned for repackaging/filter replacement prior to certification.

9.0 ISOTOPIC CHARACTERIZATION AND FISSILE CONTENT

9.1 Requirements

The CNS 10-160B cask payload allows fissile materials, provided the mass limits of Title 10, Code of Federal Regulations, Section 71.53 are not exceeded. Plutonium content cannot exceed 0.74 TBq (20 curies) per cask.

9.2 Methods of Compliance and Verification

The CH-TRU waste was generated over eight years using a total of 3.5627 grams of Neptunium-237, 1.4701 grams of Plutonium-239, 2.4125 grams of Americium-241 and 6.097 grams of depleted Uranium. Attachment B shows the gram loading of each drum. This is the total mass of each actinide assigned to MURR TRU waste. No other fissile materials were introduced into the waste. Small quantities of these materials were dispersed in the low-level waste, as well.

10.0 DECAY HEAT AND HYDROGEN GAS GENERATION RATES

This section describes the logic and methodology used in evaluating payload characteristics that meet the hydrogen gas concentration requirement for the MR 121A content code wastes described in this section.

10.1 Requirements

The hydrogen gas concentration shall not exceed 5% by volume in all void volumes within the CNS 10-160B cask payload during a 60-day shipping period. A CNS 10-160B cask payload must be assembled of payload containers belonging to the same content code. Payload containers of different content codes with different bounding G values and resistances may be assembled together as a payload, provided the decay heat limit and hydrogen gas generation rate limit for all payload containers within the payload is conservatively assumed to be the same as that of the payload container with the lowest decay heat limit and hydrogen gas generation rate limit.

10.2 Methodology of Ensuring Compliance with Flammable Gas Concentration Limits

As stated in Section 7.2 of Appendix 4.10.2 of the CNS 10-160B SAR, chemical, biological, and thermal gas generation mechanisms are insignificant in the CNS 10-160B cask. In addition, as shown in Section 5.1 of Appendix 4.10.2, potentially flammable VOCs are restricted to 500 ppm in the headspace of the CNS 10-160B cask secondary containers. Therefore, the only flammable gas of concern for transportation purposes is hydrogen. The concentration of hydrogen within any void volume in a layer of confinement of the payload or in the cask IV has been evaluated during a 60-day shipping period (see Attachment C of Appendix 4.10.2).

Attachment A provides the MR 121A content code authorized payload for the CNS 10-160B cask. This content code has a unique and completely defined packaging configuration. Modeling the movement of hydrogen from the waste material to the payload voids, using the release rates of hydrogen through the various confinement layers, defines the relationship between generation rate and void concentration. This modeling allows determination of the maximum allowable hydrogen generation rate for the MR 121A content code to meet the 5% concentration limit, as detailed in Section 10.3. Based on hydrogen gas generation potential, quantified by hydrogen gas generation G values, the gas concentration limit can be converted to a decay heat limit, as detailed in Section 10.4. The maximum allowable hydrogen generation rate and decay heat limit for the MR 121A content code for MURR waste are listed in Table 10-1 (see Attachment A of Appendix 4.10.2 for a description of the Matrix Depletion Program and dose-dependent G values).

Table 10-1. Maximum Allowable Hydrogen Gas Generation Rate and Decay Heat Limit for MR 121A

Content Code	Maximum Allowable Hydrogen Gas Generation Rate, mole/second/drum	Maximum Allowable Hydrogen Gas Generation Rate, moles/second/cask	Maximum Allowable Decay Heat Limit, Watts/Drum (Dose <= 0.012 watt*year)	Maximum Allowable Decay Heat Limit, Watts/Cask (Dose <= 0.012 watt*yr)	Maximum Allowable Decay Heat Limit, Watts/Drum (Dose > 0.012 watt*year)	Maximum Allowable Decay Heat Limit, Watts/Cask (Dose > 0.012 watt*year)
MR121A	1.323E-8	1.323E-7	0.032	0.320	0.093	0.930

10.3 Determination of Maximum Allowable Hydrogen Generation Rate

The maximum allowable hydrogen generation rate was determined using the modeling methodology described in Appendix 4.10.2 and the following input parameters.

<u>Waste Packaging Configuration and Release Rates</u>: The waste described by content code MR 121A, is packaged within two layers of plastic, one plastic inner bag, and one filtered drum liner bag. The plastic bags are closed by the twist and tape method. The bags are placed inside a polyethylene rigid liner punctured with a minimum 0.3-inch diameter hole. The liner would then be placed directly into a 55-gallon drum with a filter vent installed on each drum meeting the minimum filter vent specifications for the 55-gallon drums listed in Table 8-1. The release rates in Table 10-2 are shown for two different temperatures (minimum and maximum operating temperature of the 10-160B) and are based on values for various waste packaging confinement layers documented in Appendices 3.6.9 and 3.6.12 of the TRUPACT-II SAR (Reference 12.2). The temperature dependence of these release rates is discussed later in this section.

Void Volume in the 10-160B IV: The cask will have a payload of 10 drums and a drum carriage. The interior volume of the cask, V_{cask}, is 4438 liters. The volume occupied by the drum carriage, $V_{carriage}$, is 143.2 liters. The external volume of a single drum, V_{drum}, is 235.7 liters. The void volume within the cask is calculated as:

$$V_{void} = V_{cask} - V_{carriage} - 10\ V_{drum}$$

$$V_{void} = 4{,}438\ liters - 143.2\ liters - 10\ (235.7\ liters)$$

$$V_{void} = 1{,}938\ liters$$

Table 10-2. Release Rates of Hydrogen Across Confinement Layers for MR 121A

Confinement Layer	Release Rate (mol/sec/mol fraction)	
	T = 233K	**T = 348.6K**
Plastic Inner Bag (twist-and-tape closure)	$3.895x10^{-7}$	$5.58x10^{-7}$ [a]
Filtered Liner Bag (twist-and-tape closure)	$7.156x10^{-6}$	$1.447x10^{-5}$ [b]
Rigid Polyethylene Drum Liner (0.3-inch diameter hole)	$4.683x10^{-5}$	$5.09x10^{-5}$
Drum Filter	$2.46x10^{-6}$	$4.98x10^{-6}$

[a] The value at 70°F is conservatively used.
[b] The value at -20°F is conservatively used.

Pressure: The pressure is assumed to be isobaric and equal to one atmosphere. The mole fraction of hydrogen in each void volume would be smaller if pressurization is considered and would result in a greater maximum allowable hydrogen gas generation rate. Furthermore, the amount of hydrogen gas generated during a 60-day shipping period would be negligible compared to the quantity of air initially present at the time of sealing the CNS 10-160B cask.

Temperature: The input parameter affected by temperature is the release rate through the different confinement layers in the payload containers and the G values for hydrogen. Release rates increase with increasing temperature as documented in Appendix 3.6.12 of the TRUPACT-II SAR (Reference 12.2). Therefore, the minimum release rates would be those at the lowest operating temperature. These are the release rates indicated in Table 10-2 for 233K. The minimum decay heat limits are determined by the ratio of the release rates and the G values. In other words, the higher the release rates, the higher the decay heat limit; the higher the G value, the lower the decay heat limit. The dependence of G values on temperature is documented in Section 10.4. For determining the decay heat limit, the temperature that yielded the minimum decay heat limit was used as the input parameter.

In summary, the temperature dependence of the input parameters was accounted for in the calculation so that, in each case, the minimum possible limit (hydrogen generation rate or decay heat limit) was obtained. This provides an additional margin of safety in the analysis.

10.4 Determination of Maximum Allowable Decay Limit

The maximum allowable decay heat limit for the CH-TRU waste content code, MR 121A, was calculated using the methodology described in Appendix 4.10.2 and the content code-specific G values described below.

G values are determined based on the bounding materials present in the payload. The maximum operating temperature yields the lowest decay heat limits for the operating temperature range of the CNS 10-160B cask. This content code represents solid organic debris consisting of various combustible and non-combustible items. The material present in this waste with the highest G value at the maximum operating temperature of the CNS 10-160B cask (168°F) is cellulosics and is therefore considered as the bounding material. The G value for hydrogen associated with cellulosics is 3.2 molecules/100eV (at 70°F) if the attained dose is less than or equal to 0.012 watt*year. The dose dependent G value for cellulosics is 1.09 molecules/100 eV if the dose attained in the drum is greater than 0.012 watt*yr. The methodology associated with the determination of dose-dependent G values pursuant to the Matrix Depletion Program is further discussed in Attachment A of Appendix 4.10.2. The G values at 70°F are adjusted to the maximum operating temperature of the CNS 10-160B cask (168°F) using the Arrhenius equation. The activation energy of the G value for cellulosics is 2.1 kcal/mole. Thus, at the maximum operating temperature of the CNS 10-160B cask (168°F), the bounding hydrogen G values for MR 121A are 5.61 molecules/100 eV (dose $\leq$ 0.012 watt*year) and 1.91 molecules/100 eV (dose > 0.012 watt*year).

Demonstration of compliance of the MURR TRU waste with the decay heat and hydrogen gas generation rate limits is shown in Attachment B.

10.5 Methodology for Compliance with Payload Assembly Requirements

The MURR TRU waste payload consists of 7 55-gallon drums of the same content code meeting the payload assembly requirements.

11.0 WEIGHT

11.1 Requirements

The weight limit for the contents of the loaded cask is 14,500 pounds.

11.2 Methods of Compliance and Verification

The total weight of the TRU waste is 175 pounds, which will be distributed among the seven drums. This does not include the weight of the drums themselves, lids and filter vents, and any other bracing material required inside the drum. Each drum will be weighed prior to shipping. Based on the total measured weight of the individual payload containers and the 3 dunnage drums needed to complete the 10-drum payload, the MURR shall calculate total assembly weight and evaluate compliance with the maximum cask payload weight limit.

12.0 REFERENCES

12.1 University of Missouri, "Treatment of Aqueous Residue," TAM-32, University of Missouri Research Reactor TRUMP-S Program, Columbia, Missouri.

12.2 U.S. Department of Energy (DOE), "Safety Analysis Report for the TRUPACT-II Shipping Package," and associated TRUPACT-II Authorized Methods for Payload Control (TRAMPAC) Current Revision, U.S. Department of Energy Carlsbad Field Office, Carlsbad, New Mexico.

Attachment A

MR 121A Transuranic Content Code and Chemical List
for Missouri University Research Reactor

CONTENT CODE: MR 121A

CONTENT DESCRIPTION: Solid Organic Waste – CH-TRU Waste.

WASTE DESCRIPTION: This waste consists of a variety of combustible and noncombustible items.

GENERATING SOURCES: This waste is generated from activities supporting the Missouri University Research Reactor (MURR) Transuranic Management by Pyropartitioning Separation (TRUMP-S) program.

WASTE FORM: The waste consists of lab ware waste that includes glove box gloves, poly vials, glass laboratory apparatus, paper towels, tools, polyethylene bags, rubber gloves o-rings, wires, crucibles: all exposed to metallic actinides, salts containing actinides, or aqueous solutions containing actinides.

WASTE PACKAGING: The waste described by content code MR 121A, is packaged within two layers of plastic, one intact waste inner bag, and one filtered drum liner bag. The plastic bags are closed by the twist and tape method. The bags may be placed inside a rigid polyethylene liner punctured with a minimum 0.3-inch diameter hole. The liner would then be placed directly in a 55-gallon drum with a filter vent installed on each drum. Ten drums will then be placed into the CNS 10-160B cask.

METHODS FOR DETERMINATION OF ISOTOPIC CHARACTERIZATION: The isotopic composition of the waste is determined from measurements taken on the product material during the processing at the site. The processing organizations transmit the isotopic composition information to the site waste certification organization. Therefore, the isotopic composition of the waste need not be determined by direct analysis or measurement of the waste unless process information is not available.

FREE LIQUIDS: Liquid waste is prohibited in the drums except for residual amounts in well-drained containers. The total volume of residual liquid in a payload container shall be less than 1 volume percent of the payload container. Waste packaging procedures ensure that free liquids are less than 1 volume percent of the payload container.

EXPLOSIVE/COMPRESSED GASES: Explosives and compressed gases in the payload containers are prohibited by waste packaging procedures.

PYROPHORICS: Lithium metal was the only non-radioactive pyrophoric used in the experiments. The excess lithium metal was oxidized in water, the solutions neutralized and evaporated to dryness. This solid was passed to the low-level waste stream. The plutonium and americium used in the TRUMP-S experimental program are contained in experimental residues in an oxidized state and are non-pyrophoric.

CORROSIVES: Corrosives are prohibited in the payload container. Acids and bases that are potentially corrosive shall be neutralized and rendered noncorrosive prior to being a part of the waste. The physical form of the waste and the waste generating procedures ensure that the waste is in a nonreactive form.

CHEMICAL COMPATIBILITY: A chemical compatibility study has been performed on this content code, and all waste is chemically compatible for materials in greater than trace (>1% by weight) quantities.

ADDITIONAL CRITERIA: Each drum is fitted with a minimum of one filter vent.

MAXIMUM ALLOWABLE HYDROGEN GENERATION RATES - OPTION 1: The maximum allowable hydrogen generation rate limit is 1.323E-08 moles per second per drum and 1.323E-07 moles per second per CNS 10-160B cask.

MAXIMUM ALLOWABLE DECAY HEAT LIMIT - OPTION 2: The maximum allowable decay heat limit is 0.032 watts per drum and 0.32 watts per CNS 10-160B cask if dose $\leq$ 0.012 watt*yr and 0.093 watts per drum and 0.93 watts per CNS 10-160B cask if dose > 0.012 watt*yr.

MISSOURI UNIVERSITY RESEARCH REACTOR CONTENT CODE MR 121A
SOLID ORGANIC WASTE
MATERIALS AND CHEMICALS >1%

CARDBOARD
CELLULOSICS
CLOTH
CONCRETE
DIATOMACEOUS EARTH (FLOOR DRY)
DIRT
EQUIPMENT (including vacuum cleaner, motors, and dosimeter system)
FILTERS
GLASS
METALS (including mercury, brass, lead shielding, lead shot, silver, stainless steel, aluminum, iron, copper beryllium, and zirconium)
OTHER INORGANICS
PAINT CHIPS (including barium, cadmium, chromium, and lead)
PAPER
PLASTER-OF-PARIS
PLASTIC
PLEXIGLAS
RADSORB
RUBBER
SOIL
WOOD

Attachment B

Methodology for Determination of Decay Heats
and Hydrogen Gas Generation Rates for
MR 121A Content Code
for Missouri University Research Reactor

The mass of each isotope assigned to each of the seven drums of content code MR 121A is listed in Table B-1 below. These mass numbers are from the total mass of each isotope computed in this section. The numerical values of the decay heat in watts per gram for each isotope are from Table 3-1 of the TRUPACT-II TRAMPAC (Reference 12.2). The computed decay heat for each isotope and the total decay heat for each of the seven drums is given in Table B-1, below. U-238 is not included in the table because its contribution to the decay heat is insignificant.

Table B-1 Mass and Decay Heat per Isotope, by Drum

Isotope	Mass (g)	Decay Heat (watts/g)	Decay Heat (watts/isotope)
Drum No. 1			
Np-237	2.1706	2.09E-05	4.537E-05
Pu-239	0.2282	1.95E-03	4.450E-04
Am-241	0.3431	1. 16 E-0 1	3.980E-02
Drum Decay Heat (watts/Drum)			4.029E-02
Drum No. 2			
Np-237	0.0381	2.09E-05	7.963E-07
Pu-239	0.6725	1.95E-03	1.311 E-03
Am-241	0.2957	1.16E-01	3.430E-02
Drum Decay Heat (watts/Drum)			3.561 E-02
Drum No. 3			
Np-237	0.1191	2.09E-05	2.489E-06
Pu-239	0.1036	1.95E-03	2.020E-04
Am-241	0.3469	1.16E-01	4.024E-02
Drum Decay Heat (watts/Drum)			4.044E-02
Drum No. 4			
Np-237	0.0199	2.09E-05	4.159E-07
Pu-239	0.1702	1.95E-03	3.319E-04
Am-241	0.3474	1.16E-01	4.030E-02
Drum Decay Heat (watts/Drum)			4.063E-02
Drum No. 5			
Np-237	0.4979	2.09E-05	1.041E-05
Pu-239	0.1554	1.95E-03	3.030E-04
Am-241	0.3521	1.16E-01	4.084E-02
Drum Decay Heat (watts/Drum)			4.115E-02
Drum No. 6			
Np-237	0.443	2.09E-05	9.259E-06
Pu-239	0	1.95E-03	0.000E+00
Am-241	0.3527	1.16E-01	4.091E-02
Drum Decay Heat (watts/Drum)			4.092E-02
Drum No. 7			
Np-237	0.268	2.09E-05	5.601 E-06
Pu-239	0.1459	1.95E-03	2.845E-04
Am-241	0.3747	1.16E-01	4.347E-02
Drum Decay Heat (watts/Drum)			4.376E-02

Error Assignment for Decay Heat Calculation

It is required that an error be assigned to the calculated decay heat for each payload container and to the entire payload. The error in actinide mass assigned to each waste bag is the source of error in the decay heat calculation. The inventory controls on the special nuclear materials used in the TRUMP-S project are the following TAM Procedures.

- TAM-21 "Transfer of Actinides"
- TAM-23 "Inventory Control of Actinides"
- TAM-24 "Quality Assurance"
- TAM-25 "Mixed Actinide Inventory"

The analytical balance used in the experiments was capable of ± 0.1 mg precision. The balance was standardized to ± 1.0 mg before every transfer of actinides into the glove box. This procedure assured the performance of the balance during experiments. This balance was used to assign actinide mass to all experimental materials assigned to waste bags at the conclusion of each experiment. Using these procedures, the SNM inventory for the eight years of the project closed to within 0.0079 g for americium, 0.0038 g for plutonium and 0.0007 g for neptunium.

Based on these procedures and the SNM inventory record, it is conservative to assume that the mass of actinide in each bag is known to ±1.0 mg. If it is further assumed that all of the mass is americium, which has a significantly higher decay heat than the other actinides, the error in the decay heat calculation will be ±1.16 x 10-4 watt/bag. The maximum number of waste bags assigned to any drum is six, so the maximum error in the decay heat will be 6.96 x 10-4 watt/drum. Drum 7 has the highest decay heat, of 0.04376 watt; with an added error of 0.000696 watt, the maximum decay heat for any drum would be 0.044456 watt. It can be concluded that all drums are below the decay heat limit of 0.093 watt/drum if the dose > 0.012 watt*year. Since each drum is below the decay heat, including error in the decay heat calculation, the payload decay heat will also be below the payload decay heat limit. For the entire 10-160B payload assembly of seven drums of waste and three dunnage drums (see Section 11.0), the total 10-160B payload will have a decay heat value of 0.2828 watts (including error) and therefore is less than the payload assembly limit of 0.93 watts (computed as 10 drums at 0.093 watt per drum) if dose per drum > 0.012 watt*year.

Appendix 4.10.2.3

Compliance Methodology for TRU Waste From Energy Technology Engineering Center (ETEC)

1.0 INTRODUCTION

This appendix presents acceptable methods of preparation and characterization to qualify drums of Energy Technology Engineering Center (ETEC) contact-handled (CH) transuranic (TRU) and remote-handled (RH) TRU waste, as defined by the U.S. Department of Energy (DOE) (Reference 12.1), as payload for transport in the CNS 10-160B cask. The methods for determining or measuring each restricted parameter, the factors influencing the parameter values, and the methods used by ETEC for demonstrating compliance, are provided in the following sections.

This appendix also includes the following as attachments:

- Content codes ET 121A, ET 121B, ET 126A, ET 126B, ET 325A, ET 325B, and ET 326A (Attachment A)

- Chemical Lists for the above mentioned content codes (Attachment A).

2.0 PURPOSE

The purpose of this appendix is to describe the acceptable methods that shall be used to prepare and characterize the CH-TRU and RH-TRU waste belonging to ETEC in order to demonstrate compliance with the TRU waste payload requirements prior to transport in the CNS 10-160B cask. This appendix is based on the format and requirements for TRU waste identified in Appendix 4.10.2 of the CNS 10-160B cask Safety Analysis Report (SAR). It incorporates acceptable methods applicable to the content codes listed in Attachment A.

Section 3.0 describes the TRU waste payload for ETEC. Sections 4.0 through 11.0 discuss each payload parameter and the method(s) for demonstrating compliance with the CNS 10-160B cask payload requirements being employed by ETEC.

3.0 TRU WASTE PAYLOAD FOR CNS 10-160B CASK

The CH-TRU waste is classified into four content codes, ET 121A, ET 121B, ET 126A and ET 126B. The RH-TRU waste is classified into three content codes, ET 325A, ET 325B and ET 326A. These content codes describe the TRU waste materials in terms of processes generating the waste, the packaging methods used in the waste container(s), and the generating site. The ETEC content codes for the CH-TRU and RH-TRU waste from ETEC are provided in Attachment A.

ETEC has developed formal procedures that ensure the generation, packaging, and repackaging of waste under rigorous controls. To demonstrate compliance with the payload requirements, complete documentation packages, along with quality assurance/quality control records, are generated for all payload containers. TRU waste generated from the ETEC will comply with all transportation requirements using the following methods:

- Formally documented acceptable knowledge (AK)/process knowledge of the processes generating and packaging the waste

- Data packages generated for all payload containers that document the contents and properties of the waste in the container

- Measurement of required parameters to ensure compliance with limits.

4.0 PHYSICAL FORM

4.1 Requirements

The physical form of waste comprising the CNS 10-160B cask payload is restricted to solid or solidified materials in secondary containers. The total volume of residual liquid in a secondary container is restricted to less than 1% by volume. Secondary containers must be shored to prevent movement during accident conditions. Sharp or heavy objects in the waste shall be blocked, braced, or suitably packaged as necessary to provide puncture protection for the payload containers packaging these objects. Sealed containers greater than four liters in size are prohibited.

4.2 Methods of Compliance and Verification

The waste consists primarily of inorganic and organic debris, homogeneous material (fines) with a small organic component, and a small quantity of solidified oils. The oils were collected during decontamination and decommissioning activities and were solidified using Petroset-II during repackaging. The contents of each waste container were recorded on lot followers during packaging or repackaging according to approved procedures that precluded prohibited items. Unique numbers were used to identify the waste containers, their contents, and their associated lot followers, and to track post-packaging activities.

The contents of the ET 121A, ET 121B, ET 126A, ET 126B, ET 325A and ET 325B waste stream containers were verified using computed tomography (CT). One prohibited item was found and removed. Waste stream ET 326A is a remote-handled homogeneous waste, and randomly selected 1-gal cans from that waste stream were opened for content verification and sampling for radiological and chemical characterization.

5.0 CHEMICAL FORM AND CHEMICAL PROPERTIES

5.1 Requirements

The chemical properties of the waste are determined by the chemical constituents allowed in a given content code. Specific requirements regarding the chemical form of the waste are as follows:

- Explosives, nonradioactive pyrophorics, compressed gases, and corrosives are prohibited
- Pyrophoric radionuclides may be present only in residual amounts less than 1 weight percent
- The total amount of potentially flammable volatile organic compounds (VOCs) present in the headspace of a secondary container is restricted to 500 parts per million (ppm).

5.2 Methods of Compliance and Verification

For repackaged waste, the contents of repackaged containers were closely examined during the repackaging process to ensure the absence of explosives, pyrophorics, compressed gases, and corrosives. CT results were used to verify the absence of prohibited items.

For containers not undergoing repackaging, the absence of explosives, pyrophorics, compressed gases, and corrosives was verified by analysis of CT results or random sampling (e.g., the 1 –gallon cans of drain line residue, a homogeneous waste).

Compliance with the 500 ppm limit on flammable VOCs is demonstrated through acceptable knowledge/process knowledge of the processes generating and packaging the waste. The debris waste streams (i.e. content codes ET 121A, ET 121B, ET 325A and ET 325B) have no VOC contributing contents. Solvents used in the solidification process of the solidified oil waste stream (i.e. content codes ET 126A and ET 126B) are locked up in the solidification medium and will not exceed the 500 ppm limit. VOC analyses were performed for a large, representative set of samples from the drain line residue waste streams (ET 326A) and no VOCs were detected.

6.0 CHEMICAL COMPATIBILITY

6.1 Requirements

Each content code has an associated chemical list (Attachment A) based on process knowledge. Chemical constituents in a payload container assigned to a given content code shall conform to these approved chemical lists. Chemicals/materials that are not listed are allowed in trace amounts (quantities less than 1 percent [weight]) in a payload container provided that the total quantity of trace chemicals/materials is restricted to less than 5 percent (weight).

Chemical compatibility of a waste with its packaging ensures that chemical reactions will not occur that might pose a threat to the safe transport of a payload in the CNS 10-160B cask.

6.2 Methods of Compliance and Verification

Attachment B of Appendix 4.10.2 presents the methodology and results for the chemical compatibility analyses performed for the list of allowable chemicals/materials associated with the TRU waste content codes expected to be shipped in the CNS 10-160B cask. The results of these chemical compatibility analyses show that these content codes can be transported without any incompatibilities. The chemicals present in the ETEC content codes conform to the list of allowable materials in Attachment B of Appendix 4.10.2. Therefore, the waste meets the chemical compatibility requirements.

7.0 GAS DISTRIBUTION AND PRESSURE BUILDUP

7.1 Requirements

Gas distribution and pressure buildup during transport of TRU waste in the CNS 10-160B cask payload are restricted to the following limits:

- The gases generated in the payload must be controlled to prevent the occurrence of potentially flammable concentrations of gases within the payload confinement layers and the void volume of the inner vessel (IV) cavity. Specifically, hydrogen concentrations within the payload confinement layers are limited to 5 percent by volume during a maximum 60-day shipping period (see Attachment C of Appendix 4.10.2).

- The gases generated in the payload and released into the IV cavity must be controlled to maintain the pressure within the IV cavity below the acceptable packaging design limit of 31.2 pounds per square inch gauge (psig).

7.2 Methods of Compliance and Verification

Compliance with the CNS 10-160B cask design pressure limit for the ETEC content codes is analyzed by assuming that all gases generated are released into the IV cavity and by including the contributions from thermal expansion of gases and vapor pressure of atmospheric water.

Table 7-1 shows that the pressure increase during a period of 365 days is below the design pressure limit of 31.2 psig for all the ETEC content codes.

Table 7-1. Maximum Pressure Increase Over 365-Day Shipping Period

Content Code	G_{eff} (RT)[a]	Void Volume (Liters)	Activation Energy (kcal/mole)	Decay Heat Limit (Watts)	G_{eff}[b]	P_{max}[c] (psig)
ET 121A	8.1	1938	2.1	0.57	14.19	14.07
ET 121B	8.1	1938	2.1	2.26	14.19	31.13
ET 126A	4.1	1938	0.8	0.21	5.08	9.08
ET 126B	4.1	1938	0.8	0.95	5.08	11.75
ET 325A	8.1	1938	2.1	1.07	14.19	19.12
ET 325B	8.1	1938	2.1	2.26	14.19	31.13
ET 326A	2.05	1938	0.8	5.91	2.54	18.99

[a] G value for net gas (molecules per 100 eV) at room temperature (70°F).
[b] Effective G value (molecules per 100 eV) at maximum operating temperature of 168°F calculated using the Arrhenius equation for which activation energy is an input.
[c] Maximum pressure.

Compliance with the restrictions on flammable gas concentration is discussed in Section 10.0.

8.0 PAYLOAD CONTAINER AND CONTENTS CONFIGURATION

8.1 Requirements

Fifty-five-gallon drums are authorized payload containers in a CNS 10-160B cask. Up to ten 55-gallon drums of TRU waste may be packaged in the cask. Each 55-gallon drum to be packaged in the CNS cask must have a minimum of one filter vent. The minimum filter vent specifications for the 55-gallon drums of ETEC waste are provided in Table 8-1.

The test methods used to determine the compliance of filter vents with the performance-based requirements of flow rate, efficiency, and hydrogen diffusivity shall be directed by procedures under a quality assurance program.

Filter vents shall be legibly marked to ensure both (1) identification of the supplier and (2) date of manufacture, lot number, or unique serial number.

Table 8-1. Minimum Filter Vent Specifications				
	Filter Specification			
Container Type	Number of Vents Required per Container	Flow Rate (ml/min of air, STP, at 1 inch of water)[a]	Efficiency (percent)	Hydrogen Diffusivity (mol/s/mol fraction at 25°C)
Drum	1	35	99.5	3.70E-6
Filtered Bag	1	35	NA[b]	1.075E-5

[a] Filters tested at a different pressure gradient shall have a proportional flow rate (e.g., 35 ml/min at 1 inch of water = 1 L/min at 1 psi).

[b] Filters installed in containers that are overpacked are exempt from the efficiency requirement as the drum must exhibit a ≥ 99.5 percent efficiency.

The rigid polyethylene liner, if present, in a payload container shall be punctured with a minimum of a 0.3-inch diameter hole before the container is transported in the CNS 10-160B.

8.2 Methods of Compliance and Verification

Compliance with the payload container and contents configuration requirements is determined by visual observation, process knowledge, procurement records, and repackaging activities that ensure compliance. For content codes ET 121A, and ET 126A the waste is packaged directly into two plastic inner bags closed by the twist and tape method and then placed into a 55-gallon drum. For content code ET 325A, the waste is packaged in up to two plastic inner bags. The first bag (if present) may be closed by the twist and tape method and the second bag is vented/filtered. For content codes ET 121B, ET 126B, and ET 325B, the waste is packaged directly into two plastic inner bags both of which are vented/filtered and then placed into a 55-gallon drum. The bags may be placed inside a rigid polyethylene liner punctured with a minimum 0.3 inch diameter hole. The liner would then be placed directly inside a 55-gallon drum with a filter vent installed on each drum. For ET 326A, the waste is packaged directly into 55-gallon drums or will be packaged in closed 1-gallon paint cans that may be placed in larger metal cans that allow free transport of gas. The larger metal cans may be placed inside a rigid polyethylene liner punctured with a minimum 0.3-inch diameter hole. The liner would then be placed directly inside a 55-gallon drum installed with a filter vent. The drums may be lined with thick annular concrete shields. Bottom and top concrete shields plus thick steel lids may also be used inside the drums. Inner containers greater than 4 liters in volume are punctured or vented to allow free gas release. Up to ten drums of waste will then be placed into the CNS 10-160B cask.

The requirements for the rigid liner and filter vent shall be controlled administratively or by puncturing the lids during repackaging activities and visually inspecting them prior to drum closure.

9.0 ISOTOPIC CHARACTERIZATION AND FISSILE CONTENT

9.1 Requirements

The CNS 10-160B cask payload allows fissile materials, provided the mass limits of Title 10, Code of Federal Regulations, Section 71.53 are not exceeded. Plutonium content cannot exceed 0.74 TBq (20 curies) per cask.

9.2 Methods of Compliance and Verification

The isotopic composition of the waste is derived from several sources, using a number of different procedures, depending upon the waste stream generation process and available historical information. It is derived from historical counting data and survey information for waste from nuclear fuel development activities; from a combination of survey data, decay-plus-ingrowth analysis, and the known initial fuel composition for decladding waste from a single spent fuel source; and by extensive sampling and radiological analysis for other materials.

10.0 DECAY HEAT AND HYDROGEN GAS GENERATION RATES

This section describes the logic and methodology used in evaluating payload characteristics that meet the hydrogen gas concentration requirement for the ETEC content codes described in this section.

10.1 Requirements

The hydrogen gas concentration shall not exceed 5% by volume in all void volumes within the CNS 10-160B cask payload during a 60-day shipping period. A CNS 10-160B Cask payload must be assembled of payload containers belonging to the same content code. Payload containers of different content codes with different bounding G values and resistances may be assembled together as a payload, provided the decay heat limit and hydrogen gas generation rate limit for all payload containers within the payload is conservatively assumed to be the same as that of the payload container with the lowest decay heat limit and hydrogen gas generation rate limit.

10.2 Methodology of Ensuring Compliance with Flammable Gas Concentration Limits

As stated in Section 7.2 of Appendix 4.10.2, chemical, biological, and thermal gas generation mechanisms are insignificant for the ETEC waste streams in the CNS 10-160B cask. In addition, as shown in Section 5.1 of Appendix 4.10.2, potentially flammable VOCs are restricted to 500 ppm in the headspace of the CNS 10-160B cask secondary containers. Therefore, the only flammable gas of concern for transportation purposes is hydrogen. The concentration of hydrogen within any void volume in a layer of confinement of the payload or in the cask IV has been evaluated during a 60-day shipping period (see Attachment C of Appendix 4.10.2).

Attachment A provides the ETEC content codes authorized as payload for the CNS 10-160B cask. Each content code has a unique and completely defined packaging configuration. Modeling the movement of hydrogen from the waste material to the payload voids, using the release rates of hydrogen through the various confinement layers, defines the relationship between generation rate and void concentration. This modeling allows determination of the maximum allowable hydrogen generation rate for the ETEC content codes to meet the 5% concentration limit, as detailed in Section 10.3. Based on hydrogen gas generation potential, quantified by hydrogen gas generation G values, the gas concentration limit can be converted to a decay heat limit, as detailed in Section 10.4. The maximum allowable hydrogen generation rate and decay heat limits for the ETEC content codes are listed in Table 10-1 (see Attachment A of Appendix 4.10.2 for a description of the Matrix Depletion Program and dose-dependent G values).

10.3 Determination of Maximum Allowable Hydrogen Generation Rate

The maximum allowable hydrogen generation rates were determined using the modeling methodology described in Appendix 4.10.2 and the following input parameters.

Waste Packaging Configuration and Release Rates: For content codes ET 121A, and ET 126A the waste is packaged directly into two plastic inner bags closed by the twist and tape method and then placed into a 55-gallon drum. For content code ET 325A, the waste is packaged in up to two plastic inner bags. The first bag (if present) may be closed by the twist and tape method and the second bag is vented/filtered. For content codes ET 121B, ET 126B, and ET 325B, the waste is packaged directly into two plastic inner bags both of which are vented/filtered and then placed into a 55-gallon drum. The bags may be placed inside a rigid polyethylene liner punctured with a minimum 0.3 inch diameter hole. The liner would then be placed directly inside a 55-gallon drum with a filter vent installed on each drum. For ET 326A the waste is packaged directly into 55-gallon drums or will be packaged in closed 1-gallon paint cans that may be placed in larger metal cans that allow free transport of gas. The larger metal cans may be placed inside a rigid polyethylene liner punctured with a minimum 0.3-inch diameter hole. The liner would then be placed directly inside a 55-gallon drum installed with a filter vent. The drums may be lined with thick annular concrete shields. Bottom and top concrete shields plus thick steel lids may also be used inside the drums. Inner containers greater than 4 liters in volume are punctured or vented to allow free gas release. Up to ten drums of waste will then be placed into the CNS 10-160B cask.

Table 10-1. Maximum Allowable Hydrogen Gas Generation Rates, Decay Heat Limits, and Total Activity Limits

Content Code	Maximum Allowable Hydrogen Gas Generation Rate, mole/second/ drum	Maximum Allowable Hydrogen Gas Generation Rate, moles/second/ cask	Maximum Allowable Decay Heat Limit, Watts/ Drum (Dose <= 0.012 watt*year)	Maximum Allowable Decay Heat Limit, Watts/Cask (Dose <= 0.012 watt*yr)	Maximum Allowable Decay Heat Limit, Watts/ Drum (Dose > 0.012 watt*year)	Maximum Allowable Decay Heat Limit, Watts/ Cask (Dose > 0.012 watt*year)
ET 121A	8.054E-9	8.054E-8	0.019	0.19	0.057	0.57
ET 121B	3.697E-8	3.697E-7	0.086	0.86	0.252	2.26
ET 126A	8.054E-9	8.054E-8	0.021	0.21	0.021	0.21
ET 126B	3.697E-8	3.697E-8	0.095	0.95	0.095	0.95
ET 325A	1.323E-8	1.323E-7	0.038	0.38	0.107	1.07
ET 325B	3.697E-8	3.697E-7	0.104	1.04	0.290	2.26
ET 326A	4.659E-8	4.659E-7	0.239	2.39	0.591	5.91

The release rates in Table 10-2 are shown for two different temperatures (minimum and maximum operating temperature of the CNS 10-160B) and are based on release rate values for various waste packaging confinement layers documented in Appendices 3.6.9 and 3.6.12 of the TRUPACT-II SAR (Reference 12.2). The temperature dependence of these release rates is discussed later in this section.

Void Volume in the 10-160B IV: The cask will have a payload of 10 drums and a drum carriage. The interior volume of the cask, V_{cask}, is 4438 liters. The volume occupied by the drum carriage, $V_{carriage}$, is 143.2 liters. The external volume of a single drum, V_{drum}, is 235.7 liters. The void volume within the cask is calculated as:

$$V_{void} = V_{cask} - V_{carriage} - 10\ V_{drum}$$

$$V_{void} = 4{,}438\ liters - 143.2\ liters - 10\ (235.7\ liters)$$

$$V_{void} = 1{,}938\ liters$$

Pressure: The pressure is assumed to be isobaric and equal to one atmosphere. The mole fraction of hydrogen in each void volume would be smaller if pressurization is considered and would result in a greater maximum allowable hydrogen gas generation rate. Furthermore, the amount of hydrogen gas generated during a 60-day shipping period would be negligible compared to the quantity of air initially present at the time of sealing the CNS 10-160B cask.

Temperature: The input parameter affected by temperature is the release rate through the different confinement layers in the payload containers and the G values for hydrogen. Release rates increase with increasing temperature as documented in Appendix 3.6.12 of the TRUPACT-II SAR (Reference 12.2). Therefore, the minimum release rates would be those at the lowest operating temperature. These are the release rates indicated in Table 10-2 for 233K. The minimum decay heat limits are determined by the ratio of the release rates and the G values. In other words, the higher the release rates, the higher the decay heat limit; the higher the G value, the lower the decay heat limit. The dependence of G values on temperature is documented in Section 10.4. For determining the decay heat limit, the temperature that yielded the minimum decay heat limit was used as the input parameter.

In summary, the temperature dependence of the input parameters was accounted for in the calculation so that, in each case, the minimum possible limit (hydrogen generation rate or decay heat limit) was obtained. This provides an additional margin of safety in the analysis.

Table 10-2. Release Rates of Hydrogen Across Confinement Layers

Confinement Layer	Release Rate (mol/sec/mol fraction)	
	T = 233K	**T = 348.6K**
Plastic Inner Bag (twist-and-tape closure)	3.895×10^{-7}	5.58×10^{-7} [a]
Plastic Inner Bag (vented/filtered with a 1.075x10-5 mole/sec/mole fraction filter at 294 K)	7.156×10^{-6}	1.447×10^{-5}
Rigid Polyethylene Drum Liner (0.3-inch diameter hole)	4.695×10^{-5}	5.09×10^{-5}
Drum Filter	2.46×10^{-6}	4.98×10^{-6}

[a] The value at 70°F is conservatively used.

10.4 Determination of Maximum Allowable Decay Limits

The maximum allowable decay heat limits for the ETEC waste content codes were calculated using the methodology described in Appendix 4.10.2 and the content code-specific G values and waste data described below:

10.4.1 G Value Data

G values for TRU wastes are content specific. G values are determined based on the bounding materials present in the payload. The following G values were used for each of the content codes based on the presence of the bounding materials. The G values at 70°F are adjusted to the maximum operating temperature of the CNS 10-160B cask (168°F) using the Arrhenius equation. The maximum operating temperature yields the lowest decay heat limits for the operating temperature range of the CNS 10-160B cask.

Table 10-3 summarizes the bounding G values for hydrogen and the activation energies for the G values for these different content codes at the temperature that provides the minimum decay heat limit (i.e., 348.6K, the maximum operating temperature). Materials determining these bounding G values are also listed in Table 10-3. These G values are further discussed by content code below.

Dose-dependent G values for the authorized content codes are provided in Table 10-4 at the temperature that provides the minimum decay heat limit (i.e., 348.6K, the maximum operating temperature). The methodology associated with the determination of dose-dependent G values pursuant to the Matrix Depletion Program is further discussed in Attachment A of Appendix 4.10.2.

Table 10-3. Summary of Bounding G Values (Dose ≤ 0.012 watt*year)

Content Code	Waste Material	Maximum Hydrogen Gas G Value at 70°F (molecules/ 100 eV)	Bounding Hydrogen Gas G Value (molecules/100 eV)			Activation Energy (kcal/mole)
			α-radiation	β-radiation	γ-radiation	
ET 121A ET 121B	Cellulose	3.2		5.61		2.1
ET 126A ET 126B	Polyethylene	4.1		5.08		0.8
ET 325A ET 325B	Cellulose	3.2	4.60	5.61	5.61	2.1
ET 326A	50% Polyethylene	2.05	2.08	2.54	2.54	0.8

Table 10-4. Summary of Bounding G Values (Dose > 0.012 watt*year)

Content Code	Waste Material	Maximum Hydrogen Gas G Value at 70°F (molecules/ 100 eV)	Bounding Hydrogen Gas G Value (molecules/100 eV)			Activation Energy (kcal/mole)
			α-radiation	β-radiation	γ-radiation	
ET 121A ET 121B	Cellulose	1.09		1.91		2.1
ET 126A ET 126B	Polyethylene	4.1		5.08		0.8
ET 325A ET 325B	Cellulose	1.09	1.566	1.91	5.61	2.1
ET 326A	50% Polyethylene	0.32	0.33	0.40	2.54	0.8

ET 121A, ET 121B
This content code represents solid organic debris consisting of various combustible and non-combustible items. The material present in this waste with the highest G value at the maximum operating temperature of the CNS 10-160B cask (168°F) is cellulosics and is therefore considered as the bounding material for hydrogen and total gas. The G value for hydrogen associated with cellulosics is 3.2 molecules/100eV (at 70°F) if the attained dose is less than or equal to 0.012 watt*year. The dose dependent G value for cellulosics is 1.09 molecules/100 eV if the dose attained in the drum is greater than 0.012 watt*yr. The methodology associated with the determination of dose-dependent G values pursuant to the Matrix Depletion Program is further discussed in Attachment A of Appendix 4.10.2. The G values at 70°F are adjusted to the maximum operating temperature of the CNS 10-160B cask (168°F) using the Arrhenius equation. The activation energy of the G value for cellulosics is 2.1 kcal/mole. Thus, at the maximum operating temperature of the CNS 10-160B cask (168°F), the bounding hydrogen G values for cellulosics are 5.61 molecules/100 eV (dose ≤ 0.012 watt*year) and 1.91 molecules/100 eV (dose > 0.012 watt*year).

ET 126A, ET 126B
This content code represents Petroset-II-solidified oil, with some solid debris waste. All the materials in the Petroset-II and the oil/solvent mixture added to form the final waste form have hydrogen G-values less than polyethylene that is also present in greater than 1 weight percent in the waste. The maximum hydrogen G-value for mineral oils and machining oils in Appendix 3.6.8, Table 3.13-1 of the TRUPACT-II SAR (Ref **12.**__) is 2.8 molecules/100 eV. Thus, the G value for hydrogen associated with polyethylene of 4.1 molecules/100eV (at 70°F) is considered bounding for this content code. For this content code, the bounding G value is considered to be independent of the dose per Attachment A of Appendix 4.10.2.

ET 325A, ET 325B
This content code represents solid organic debris consisting of various combustible and non-combustible items. The material present in this waste with the highest G value at the maximum operating temperature of the CNS 10-160B cask (168°F) is cellulosics and is therefore considered as the bounding material for hydrogen and total gas. The G value for hydrogen associated with cellulosics is 3.2 molecules/100eV (at 70°F) if the attained dose is less than or equal to 0.012 watt*year. The dose dependent G value for cellulosics is 1.09 molecules/100 eV if the dose attained in the drum is greater than 0.012 watt*yr. The methodology associated with the determination of dose-dependent G values pursuant to the Matrix Depletion Program is further discussed in Attachment A of Appendix 4.10.2. The G values at 70°F are adjusted to the maximum operating temperature of the CNS 10-160B cask (168°F) using the Arrhenius equation. The activation energy of the G value for cellulosics is 2.1 kcal/mole. Thus, at the maximum operating temperature of the CNS 10-160B cask (168°F), the bounding hydrogen G values for cellulosics are 5.61 molecules/100 eV (dose ≤ 0.012 watt*year) and 1.91 molecules/100 eV (dose > 0.012 watt*year).

ET 326A
The bounding G values for hydrogen and total gas for this content code are provided by polyethylene, which is used only as packaging material. These G values are derived from the information presented in Appendix 3.6.7 of the TRUPACT-II SAR (Reference 12.2). The allowable materials in this content code in concentrations of greater than 1 weight percent are provided in Attachment A. All of these materials conform with the bounding G values for this content code.

10.4.2 Waste Data

RadCalc requires as input the following parameters associated with the waste for which the maximum allowable decay heat limit is being calculated:

- Physical Form – liquid, solid, or gas
- Waste Volume – volume of the waste, cm^3
- Waste Mass – mass of the waste, g
- G Value – G value of the waste, molecules per 100 eV

Liquids and gas wastes are prohibited in the CNS 10-160B cask. The volume of the waste is assumed to be 217 liters per drum (the external volume of the waste drum) and 2170 liters for 10 drums in the cask. The waste volume is used by RadCalc, along with the waste mass, to determine the volume of hydrogen generated in the cask. The mass of the waste is calculated based on the assumed bulk density of the waste. The volume of hydrogen generated is directly proportional to the mass of the waste, as discussed in Reference 12.3. The most conservative estimate of the volume of hydrogen (greatest volume) would occur at the highest possible bulk density of the waste.

For content codes ET 325A or ET 325B, the single drum of this content code has a gross weight of 268 pounds (122 kg) and the volume occupied by the drum and waste is assumed to be 55 gallons (208×10^3 cm^3). Thus, the bulk density of this content code is (122×10^3 g/ 208x103 cm^3) or 0.59 g/cm^3. A conservative bounding waste bulk density of 1.5 g/cm^3 (based on cement obtained from Reference 12.4), is used for content code ET 326A. Representative waste drum data for this content code provide waste bulk densities well below the 1.5 g/cm^3 bounding bulk density used to calculate the decay heat limits. The mass of waste in the 10-160B is calculated based on the total volume of the 10 waste drums (2170 liters).

10.4.3 Determining Decay Heats

Decay heat shall be determined by calculations using the isotopic inventory information for fissile and nonfissile TRU radionuclides and for any non-TRU radionuclides that may be present in the TRU waste drums as determined through the methods documented in Section 9.2. The decay heats of the drums shall be calculated by combining the isotopic inventory data and the calculated decay heat for each radionuclide. The calculated value of the decay heat for an individual drum and the decay heat error (if applicable) shall be recorded in the data package for an individual payload container. If the drum meets the drum limit for the content code, it is eligible for shipment if all other transportation requirements are met. If the drum does not meet the limit, it cannot be shipped and shall be segregated for repackaging or other mitigation measures. The total decay heat for the CNS 10-160B Cask payload shall be determined by summing the decay heats of all drums making up the payload for the CNS 10-160B Cask. The total decay heat error (if applicable) is calculated as the square root of the sum of the squares of the individual decay heat error values. The total shipment decay heat value (calculated value plus total error) shall be compared to the cask limit for decay heat. The site transportation certification official (TCO) shall evaluate the compliance of individual drums and the total of all drums with the maximum limits per drum and per cask.

10.5 Methodology for Compliance with Payload Assembly Requirements

The TCO shall ensure that the CNS 10-160B Cask payload consists of payload containers belonging to the same content code. In the event that payload containers of different content codes with different bounding G values and resistances are assembled together in the CNS 10-160B cask, the TCO shall ensure that the decay heat or hydrogen gas generation rate for each payload container within the payload is less than or equal to the container with the most restrictive limits.

11.0 WEIGHT

11.1 Requirements

The weight limit for the contents of the loaded cask is 14,500 pounds.

11.2 Methods of Compliance and Verification

Each 55-gallon drum will be weighed on a calibrated scale after it is filled and closed. When the payload data sheets are completed for the shipment, they will reflect the total weight of each drum. Based on the total measured weight of the individual payload containers, ETEC shall calculate total assembly weight and evaluate compliance with the contents of the loaded cask.

12.0 REFERENCES

12.1 U.S. Department of Energy (DOE), 2002, "Contact Handled-Transuranic Waste Acceptance Criteria for the Waste Isolation Pilot Plant," Rev. 0, *DOE/WIPP-02-3122*, U.S. Department of Energy, Carlsbad Field Office, Carlsbad, New Mexico.

12.2 U.S. Department of Energy, "Safety Analysis Report for the TRUPACT-II Shipping Package," Current Revision, U.S. Department of Energy Carlsbad Field Office, Carlsbad, New Mexico.

12.3 Flaherty, J.E., A. Fujita, C.P. Deltete, and G.J. Quinn, 1986, "A Calculational Technique to Predict Combustible Gas Generation in Sealed Radioactive Waste Containers," *GEND 041*, EG&G Idaho, Inc., Idaho Falls, Idaho.

12.4 Perry, R.H., D.W. Green, and J.O. Maloney, 1984, *Perry's Chemical Engineers' Handbook*, 6th ed., McGraw-Hill Book Co., New York, New York.

Attachment A

Transuranic Content Codes and Chemical Lists For Energy Technology Engineering Center (ETEC)

CONTENT CODE: ET 121A, ET 121B

CONTENT DESCRIPTION: Solid Organic Waste

GENERATING SITE: Energy Technology Engineering Center (ETEC)

STORAGE SITE: ETEC

WASTE DESCRIPTION: This waste consists of a variety of combustible and noncombustible organic items.

GENERATING SOURCE(S): Solid organic and inorganic debris waste was generated during decontamination and decommissioning (D&D) operations at the former ETEC-associated Hot Laboratory.

WASTE FORM: The waste may include combustible items such as cloth and paper products (e.g., from the cleanup of spills), rags, coveralls and booties, plastic, cardboard, rubber, wood, surgeons gloves, and Kimwipes. The waste may also include filter waste, (e.g., dry box filters, HEPA filters, and filter cartridges); noncombustible Benelex and plexiglas neutron shielding, blacktop, concrete, dirt, and sand; leaded gloves and aprons comprised of Hypalon rubber and lead oxide impregnated neoprene; and small amounts of metal waste. This waste may also include particulate and sludge-type organic process solids immobilized/solidified with Portland cement, vermiculite, Aquaset, or Petroset.

WASTE PACKAGING:
ET 121A: The waste is packaged in up to two plastic inner bags that are closed by the twist and tape method. The bags may be placed inside a rigid polyethylene liner punctured with a minimum 0.3-inch diameter hole. The liner would then be placed directly inside a 55-gallon drum installed with a filter vent. Up to ten drums will then be placed into the CNS 10-160B cask.

ET 121B: The waste is packaged in up to two vented/filtered plastic inner bags. The bags may be placed inside a rigid polyethylene liner punctured with a minimum 0.3-inch diameter hole. The liner would then be placed directly inside a 55-gallon drum installed with a filter vent. Up to ten drums will then be placed into the CNS 10-160B cask.

METHODS FOR DETERMINATION OF ISOTOPIC CHARACTERIZATION: The required isotopic information to demonstrate compliance with the limits on fissile content, decay heat, and curie content will be determined based on acceptable knowledge, the radioassay of samples, or on total drum activity measurements, taken on the product material.

FREE LIQUIDS: Liquid waste is prohibited in the drums except for residual amounts in well-drained containers. The total volume of residual liquid in a payload container shall be less than 1 volume percent of the payload container. Waste packaging procedures ensure that free liquids are less than 1 volume percent of the payload container.

EXPLOSIVES/COMPRESSED GASES: Explosives and compressed gases in the payload containers are prohibited by waste packaging procedures.

PYROPHORICS: Nonradioactive pyrophorics in the payload containers are prohibited by waste packaging procedures. Waste packaging procedures shall ensure that all pyrophoric radioactive materials are present only in small residual amounts (less than 1 weight percent) in payload containers.

CORROSIVES: Corrosives are prohibited in the payload containers. Acids and bases that are potentially corrosive shall be neutralized and rendered noncorrosive prior to being a part of the waste. The physical form of the waste and the waste generating procedures ensure that the waste is in a nonreactive form.

CHEMICAL COMPATIBILITY: A chemical compatibility study has been performed on this content code, and all waste is chemically compatible for materials in greater than trace (>1% weight) quantities.

ADDITIONAL CRITERIA: Each drum is fitted with a minimum of one filter vent. Drum filters have a minimum hydrogen diffusivity of 3.7E-06 mole/second/mole fraction. If present, rigid liners in 55-gallon drums shall be punctured with a minimum 0.3-inch diameter hole for gas release.

MAXIMUM ALLOWABLE HYDROGEN GENERATION RATES - OPTION 1: The maximum allowable hydrogen generation rate limit for ET 121A is 8.054E-09 moles per second per drum and 8.054E-08 moles per second per CNS 10-160B cask. The maximum allowable hydrogen generation rate limit for ET 121B is 3.697E-08 moles per second per drum and 3.697E-07 moles per second per CNS 10-160B cask.

MAXIMUM ALLOWABLE DECAY HEAT LIMIT - OPTION 2: The maximum allowable decay heat limit for ET 121A is 0.019 watts per drum and 0.19 watts per CNS 10-160B cask if dose ≤ 0.012 watt*yr and 0.057 watts per drum and 0.57 watts per CNS 10-160B cask if dose > 0.012 watt*yr. The maximum allowable decay heat limit for ET 121B is 0.086 watts per drum and 0.86 watts per CNS 10-160B cask if dose ≤ 0.012 watt*yr and 0.252 watts per drum and 2.26 watts per CNS 10-160B cask if dose > 0.012 watt*yr.

ENERGY TECHNOLOGY ENGINEERING CENTER (ETEC)
CONTENT CODES ET 121A AND ET 121B
SOLID ORGANIC WASTE

MATERIALS AND CHEMICALS >1%

PLASTIC
PAPER
WOOD
CELLULOSICS
CLOTH
POLY-LINER
METAL
STAINLESS STEEL
STRIPPABLE PAINT
RUBBER
PAINT
PLEXIGLAS
VERMICULITE

MATERIALS AND CHEMICALS <1%

CLEANERS
OILS
SOLVENTS
SEALANT MATERIAL

CONTENT CODE: ET 126A, ET 126B

CONTENT DESCRIPTION: Solidified Organic Process Waste

GENERATING SITE: Energy Technology Engineering Center (ETEC)

STORAGE SITE: ETEC

WASTE DESCRIPTION: This waste consists of a variety of PETROSET-II solidified oil, with some debris waste on top.

GENERATING SOURCE(S): Waste was accumulated during the final cleanup of the NMDF and consisted primarily of oil and oil sludge that was removed from building and glove-box equipment.

WASTE FORM: In 1988, the oil was consolidated and solidified using Petroset-II in four new drums (B55-1 through B55-4). The repackaging and solidification process took place in the Hot Laboratory cells during the period of October to December, 1988.

WASTE PACKAGING:
ET 126A: The waste is packaged in up to two plastic inner bags that are closed by the twist and tape method. The bags may be placed inside a rigid polyethylene liner punctured with a minimum 0.3-inch diameter hole. The liner would then be placed directly inside a 55-gallon drum installed with a filter vent. Up to ten drums will then be placed into the CNS 10-160B cask.

ET 126B: The waste is packaged in up to two vented/filtered plastic inner bags. The bags may be placed inside a rigid polyethylene liner punctured with a minimum 0.3-inch diameter hole. The liner would then be placed directly inside a 55-gallon drum installed with a filter vent. Up to ten drums will then be placed into the CNS 10-160B cask.

METHODS FOR DETERMINATION OF ISOTOPIC CHARACTERIZATION: The required isotopic information to demonstrate compliance with the limits on fissile content, decay heat, and curie content will be determined based on acceptable knowledge, the radioassay of samples, or on total drum activity measurements, taken on the product material.

FREE LIQUIDS: Liquid waste is prohibited in the drums except for residual amounts in well-drained containers. The total volume of residual liquid in a payload container shall be less than 1 volume percent of the payload container. Waste packaging procedures ensure that free liquids are less than 1 volume percent of the payload container.

EXPLOSIVES/COMPRESSED GASES: Explosives and compressed gases in the payload containers are prohibited by waste packaging procedures.

PYROPHORICS: Nonradioactive pyrophorics in the payload containers are prohibited by waste packaging procedures. Waste packaging procedures shall ensure that all pyrophoric radioactive materials are present only in small residual amounts (less than 1 weight percent) in payload containers.

CORROSIVES: Corrosives are prohibited in the payload containers. The physical form of the waste and the waste generating procedures ensure that the waste is in a nonreactive form.

CHEMICAL COMPATIBILITY: A chemical compatibility study has been performed on this content code, and all waste is chemically compatible for materials in greater than trace (>1% weight) quantities.

ADDITIONAL CRITERIA: Each drum is fitted with a minimum of one filter vent. Drum filters have a minimum hydrogen diffusivity of 3.7E-06 mole/second/mole fraction. If present, rigid liners in 55-gallon drums shall be punctured with a minimum 0.3-inch diameter hole for gas release.

MAXIMUM ALLOWABLE HYDROGEN GENERATION RATES - OPTION 1: The maximum allowable hydrogen generation rate limit for ET 126A is 8.054E-09 moles per second per drum and 8.054E-08 moles per second per CNS 10-160B cask. The maximum allowable hydrogen generation rate limit for ET 126B is 3.697E-08 moles per second per drum and 3.697E-07 moles per second per CNS 10-160B cask.

MAXIMUM ALLOWABLE DECAY HEAT LIMIT - OPTION 2: The maximum allowable decay heat limit for ET 126A is 0.021 watts per drum and 0.21 watts per CNS 10-160B cask for all dose values. The maximum allowable decay heat limit for ET 126B is 0.095 watts per drum and 0.95 watts per CNS 10-160B cask for all dose values.

ENERGY TECHNOLOGY ENGINEERING CENTER (ETEC)
CONTENT CODES ET 126A AND ET 126B
SOLIDIFIED ORGANIC PROCESS WASTE

MATERIALS AND CHEMICALS >1%

PETROSET-II
AQUASET
PLASTIC
POLY-LINER
RUBBER GLOVES
VERMICULITE
METALS
SYNTHETIC RUBBER
DRY/ALARA PAINT
PAPER
VACUUM PUMP OILS (INCLUDING DC-704 OIL)
HYDRAULIC OILS (INCLUDING ENERPAC)

MATERIALS AND CHEMICALS <1%

CELLULOSICS
METALS
SYNTHETIC RUBBER
DRY/ALARA PAINT
ISOPROPANOL
FREON

CONTENT CODE: ET 325A, ET 325B

CONTENT DESCRIPTION: Solid Organic and Inorganic Waste

GENERATING SITE: Energy Technology Engineering Center (ETEC)

STORAGE SITE: ETEC

WASTE DESCRIPTION: This waste consists of Hot Laboratory debris including paper, plastic, metal and glass.

GENERATING SOURCE(S): Solid organic and inorganic debris waste was generated during decontamination and decommissioning (D&D) operations at the former ETEC-associated Hot Laboratory.

WASTE FORM: The debris waste consists of miscellaneous waste materials removed from the facility during D&D, including a small capped pipe that contains unirradiated plutonium oxide/uranium oxide pieces from ETEC's former Nuclear Materials Development Facility, canisters of paint chips surrounded by lead shielding, and a lead brick.

WASTE PACKAGING:
ET 325A: The waste is packaged in up to two plastic inner bags. The first bag (if present) may be closed by the twist and tape method and the second bag is vented/filtered. The bags may be placed inside a rigid polyethylene liner punctured with a minimum 0.3-inch diameter hole. The liner would then be placed directly inside a 55-gallon drum installed with a filter vent. Up to ten drums will then be placed into the CNS 10-160B cask.

ET 325B: The waste is packaged in up to two vented/filtered plastic bags. The bags may be placed inside a rigid polyethylene liner punctured with a minimum 0.3-inch diameter hole. The liner would then be placed directly inside a 55-gallon drum installed with a filter vent. Up to ten drums will then be placed into the CNS 10-160B cask.

METHODS FOR DETERMINATION OF ISOTOPIC CHARACTERIZATION: The required isotopic information to demonstrate compliance with the limits on fissile content, decay heat, and curie content will be determined based on acceptable knowledge, the radioassay of samples, or on total drum activity measurements, taken on the product material.

FREE LIQUIDS: Liquid waste, except for residual amounts in well-drained containers, is prohibited in the drums. The total volume of residual liquid in a payload container shall be less than 1 volume percent of the payload container. Waste packaging procedures ensure that free liquids are less than 1 volume percent of the payload container.

EXPLOSIVES/COMPRESSED GASES: Explosives and compressed gases in the payload containers are prohibited by waste packaging procedures. If present, pressurized cans shall be punctured and emptied prior to packaging.

PYROPHORICS: Nonradioactive pyrophorics in the payload containers are prohibited by waste packaging procedures. Process knowledge indicates that no non-radioactive pyrophoric material was generated in association with the waste. Waste packaging procedures shall ensure that all radioactive pyrophoric materials are present only in small residual amounts (less than 1 weight percent) in payload containers.

CORROSIVES: Corrosives are prohibited in the payload container. Acids and bases that are potentially corrosive shall be neutralized or rendered noncorrosive prior to being a part of the waste. The physical form of the waste and the waste generating procedures ensure that the waste is in a nonreactive form.

CHEMICAL COMPATIBILITY: A chemical compatibility study has been performed on this content code, and all waste is chemically compatible for materials in greater than trace (>1% by weight) quantities.

ADDITIONAL CRITERIA: Each drum is fitted with a minimum of one filter vent. Drum filters have a minimum hydrogen diffusivity of 3.7E-06 mole/second/mole fraction. If present, rigid liners in 55-gallon drums shall be punctured with a minimum 0.3-inch diameter hole for gas release.

MAXIMUM ALLOWABLE HYDROGEN GENERATION RATES - OPTION 1: The maximum allowable hydrogen generation rate limit for ET 325A is 1.323E-08 moles per second per drum and 1.323E-07 moles per second per CNS 10-160B cask. The maximum allowable hydrogen generation rate limit for ET 325B is 3.697E-08 moles per second per drum and 3.697E-07 moles per second per CNS 10-160B cask.

MAXIMUM ALLOWABLE DECAY HEAT LIMIT - OPTION 2: The maximum allowable decay heat limit for ET 325A is 0.038 watts per drum and 0.38 watts per CNS 10-160B cask if dose ≤ 0.012 watt*yr and 0.107 watts per drum and 1.07 watts per CNS 10-160B cask if dose > 0.012 watt*yr. The maximum allowable decay heat limit for ET 325B is 0.104 watts per drum and 1.04 watts per CNS 10-160B cask if dose ≤ 0.012 watt*yr and 0.290 watts per drum and 2.26 watts per CNS 10-160B cask if dose > 0.012 watt*yr.

ENERGY TECHNOLOGY ENGINEERING CENTER (ETEC)
CONTENT CODES ET 325A AND ET 325B
SOLID ORGANIC AND INORGANIC WASTE

MATERIALS AND CHEMICALS >1%

CLOTH
CONCRETE PARTICULATE
FILTERS
GLASS
METALS(e.g., aluminum, titanium, iron, copper, lead, tungsten, brass, steel and stainless steel, tantalum)
PuO/UO PIECES (unirradiated)
PAINT CHIPS (strippable paint)
PLASTIC
PAPER
VERMICULITE
WOOD

MATERIALS AND CHEMICALS <1%

CLEANERS
OILS
SOLVENTS
SEALANT MATERIAL

CONTENT CODE: ET 326A

CONTENT DESCRIPTION: Solidified Organic Process Waste

GENERATING SITE: Energy Technology Engineering Center (ETEC)

STORAGE SITE: ETEC

WASTE DESCRIPTION: This waste consists of drain line residue, including organic sludges and sludge-like materials, steel and concrete components.

GENERATING SOURCE(S): This waste is primarily dry fines and solidified sludge that were removed from the former ETEC-associated Hot Laboratory drain line system and drain tank during decontamination and decommissioning operations. The waste includes fines that are the result of cutting and grinding operations.

WASTE FORM: The waste consists of materials that were washed out of operational hot cells. The primary constituents are steel and fuel element fines (including TRU, fission products, and activated cladding residue) from declad grinding and cutting operations, sludge wastes, steel and concrete debris, sand, dirt, grinding materials, and concrete dust/particulate. The sludge wastes are, in part, the result of solidification or liquid absorption procedures using diatomaceous earth, fly ash, cement, or concrete.

WASTE PACKAGING: The waste is packaged directly into 55-gallon drums or will be packaged in closed 1-gallon paint cans that may be placed in larger metal cans that allow free transport of gas. The larger metal cans may be placed inside a rigid polyethylene liner punctured with a minimum 0.3-inch diameter hole. The liner would then be placed directly inside a 55-gallon drum installed with a filter vent. Ten drums will then be placed into the CNS 10-160B cask. The drums may be lined with thick annular concrete shields. Bottom and top concrete shields plus thick steel lids may also be used inside the drums. Inner containers greater than 4 liters in volume are punctured or vented to allow free gas release. Up to ten drums will then be placed into the CNS 10-160B cask.

METHODS FOR DETERMINATION OF ISOTOPIC CHARACTERIZATION: The required isotopic information to demonstrate compliance with the limits on fissile content, decay heat, and curie content will be determined based on acceptable knowledge, the radioassay of samples, and on total drum activity measurements taken on the product material during the processing at the site.

FREE LIQUIDS: Liquid waste, except for residual amounts in well-drained containers, is prohibited in the drums. The total volume of residual liquid in a payload container shall be less than 1 volume percent of the payload container. Site procedures for liquid absorption and solidification ensure that free liquids are less than 1 volume percent of the payload container.

EXPLOSIVES/COMPRESSED GASES: Explosives and compressed gases in the payload containers are prohibited by waste packaging procedures. If present, pressurized cans shall be punctured and emptied prior to packaging.

PYROPHORICS: Nonradioactive pyrophorics in the payload containers are prohibited by waste packaging procedures. Process knowledge indicates that no non-radioactive pyrophoric material was generated in association with waste. Waste packaging procedures shall ensure that all radioactive pyrophoric materials are present only in small residual amounts (less than 1 weight percent) in payload containers.

CORROSIVES: Corrosives are prohibited in the payload container. Acids and bases that are potentially corrosive shall be neutralized or rendered noncorrosive prior to being a part of the waste. The physical form of the waste and the waste generating procedures ensure that the waste is in a nonreactive form.

CHEMICAL COMPATIBILITY: A chemical compatibility study has been performed on this content code, and all waste is chemically compatible for materials in greater than trace (>1% by weight) quantities.

ADDITIONAL CRITERIA: Each drum is fitted with a minimum of one filter vent. Drum filters have a minimum hydrogen diffusivity of 3.7E-06 mole/second/mole fraction. Inner containers greater than 4 liters in volume are punctured or vented to allow free gas release. If present, rigid liners in 55-gallon drums shall be punctured with a minimum 0.3-inch diameter hole for gas release.

MAXIMUM ALLOWABLE HYDROGEN GENERATION RATES - OPTION 1: The maximum allowable hydrogen generation rate limit is 4.659E-08 moles per second per drum and 4.659E-07 moles per second per CNS 10-160B cask.

MAXIMUM ALLOWABLE DECAY HEAT LIMIT - OPTION 2: The maximum allowable decay heat limit is 0.239 watts per drum and 2.39 watts per CNS 10-160B cask if dose $\leq$ 0.012 watt*yr and 0.591 watts per drum and 5.91 watts per CNS 10-160B cask if dose > 0.012 watt*yr.

ENERGY TECHNOLOGY ENGINEERING CENTER (ETEC) CONTENT CODE ET 326A SOLIDIFIED ORGANIC PROCESS WASTE

MATERIALS AND CHEMICALS >1%

ABSORBENTS (diatomaceous earth, vermiculite, fly ash, cement, concrete)
CONCRETE AND CONCRETE DUST/PARTICULATE
DIRT
GLASS
GRINDING MATERIALS (carborundum, other carbides)
IRON OXIDES
METALS (including carbon steel [containers, weir boxes, grindings and shavings], aluminum, chromium, titanium, zinc, beryllium, iron, nickel, copper, mercury, tungsten, zirconium, cadmium, brass, stainless steel [primarily grindings and shavings], molybdenum, lead)
PAINT CHIPS
PLASTIC
SAND (silica and alumina based)

MATERIALS AND CHEMICALS <1%

ACETONE
ALCOHOL
ALCONOX
BIG ORANGE CLEANER
CALCIUM CARBONATE
CAUSTIC CLEANERS: Oakite, MX-12, Big K (potassium hydroxide)
DOWANOL
ELECTROPOLISH (phosphoric and sulfuric acid)
FOGPROOF
FREON
GRAPHITE
HYDROFLUORIC, NITRIC, HYDROCHLORIC, CITRIC, PERCHLORIC/OXALIC ACID
KEROSENE
OIL, MINERAL OIL, HYDRAULIC OIL, CUTTING OIL, SPRAY LUBRICANTS
PETROSET, AQUASET, EARTH-TITE
RADIAC WASH
SODIUM OXIDE
TRICHLOROETHYLENE
TURCO PRODUCTS (alkaline cleaners), DEFOAMING AGENTS
WINDEX
ZEP SPRAY
METAL-X

Appendix 4.10.2.4

Compliance Methodology for TRU Waste From
Lawrence Livermore National Laboratory (LLNL)
Livermore, CA

1.0 INTRODUCTION

This appendix presents how acceptable knowledge including records and database information (process knowledge) is used to qualify six drums of contact-handled transuranic (CH-TRU) waste, as payload for transport in the CNS 10-160B cask. The methods for determining each restricted parameter, the factors influencing the parameter values, and the methods used by LLNL for demonstrating compliance, are provided in the following sections.

This appendix also includes the following as attachments:

- Content code LL 116A (Attachment A)
- Chemical List for the above mentioned content code (Attachment A).

2.0 PURPOSE

The purpose of this appendix is to describe the methods and acceptable knowledge that shall be used to prepare and characterize the CH-TRU waste belonging to LLNL in order to demonstrate compliance with the TRU waste payload requirements prior to transport in the CNS 10-160B cask. This appendix is based on the format and requirements for TRU waste identified in Appendix 4.10.2 of the CNS 10-160B cask Safety Analysis Report (SAR). It incorporates acceptable methods applicable to the content codes LL 116A and LL 116B of this appendix.

Section 3.0 describes the TRU waste payload. Sections 4.0 through 11.0 discuss each payload parameter and the acceptable knowledge, process knowledge, and methods employed to demonstrate compliance with the CNS 10-160B cask payload requirements.

3.0 TRU WASTE PAYLOAD FOR CNS 10-160B CASK

The six drums of CH-TRU waste from LLNL are currently classified into a single content code, LL 116, that describes CH-TRU waste material in terms of processes generating the waste, the packaging methods used in the waste container(s), and the generating site. Content code LL 116A represents the current packaging configuration of the six drums. The waste described in LL 116A may be repackaged to the packaging configuration described in content code LL 116B. The LL 116A and LL 116B content codes for the CH-TRU waste from LLNL are provided in Attachment A.

Several payload assembly/container filter options and associated requirements are presented for the LL 116A and LL 116B content codes. LL 116A represents the current packaging configuration of the six drums of LLNL waste to be shipped in the CNS 10-160B cask. This configuration has three layers of plastic bagging (2 inner bags, 1 inner bag). The waste may require repackaging to meet the hydrogen gas generation rate or decay heat limits calculated for LL 116A. A second packaging configuration LL 116B (no plastic bag layers) is presented to represent repackaging the LLNL waste. LL 116B packaging configuration requires all inner and liner bags be breached. Methods of complying with the CNS 10-160B requirements are presented for both packaging configurations. For LL 116B, repackaged waste, the outer waste containers (55-gallon drums) may be fitted with either a standard drum filter or a high diffusivity drum filter. Additionally, the payload may be shipped as a single shipment of 6 55-gallon waste drums with 4 open dunnage drums or may be shipped as multiple shipments of up to 3 55-gallon waste drums with 7 open dunnage drums in order to meet the hydrogen gas generation limits. The hydrogen gas generation rates and decay heat limits associated with these configurations are discussed in Section 10.0.

Complete documentation packages, along with quality assurance/quality control records, shall be generated for all payload containers. TRU waste generated from the LLNL will comply with all transportation requirements using the following methods:

- Formally documented acceptable knowledge (AK)/process knowledge of the processes generating the waste
- Data packages generated for all payload containers that document the contents and properties of the waste in the container including the absence of prohibited item and compliance with packaging requirements
- Measurement of required parameters to ensure compliance with limits.

4.0 PHYSICAL FORM

4.1 Requirements

The physical form of waste comprising the CNS 10-160B cask payload is restricted to solid or solidified materials in secondary containers. The total volume of residual liquid in a secondary container is restricted to less than 1% by volume. Secondary containers must be shored to prevent movement during accident conditions. Sharp or heavy objects in the waste shall be blocked, braced, or suitably packaged as necessary to provide puncture protection for the payload containers packaging these objects. Sealed containers greater than four liters in size are prohibited.

4.2 Methods of Compliance and Verification

Compliance with the physical form requirements is determined by records and database information. The waste consists mostly of dry solid laboratory waste such as tissues, paper, assorted plastics, glassware, ceramics and metals. Portland cement or Aquaset was used to solidify water-based liquids; Envirostone or Petroset was used to solidify small amounts of solvents and oil-based liquids. LLNL has certified that the waste contains less than 1% by volume of free liquids.

LLNL personnel shall ensure compliance with the requirement associated with sharp or heavy objects through visual examination at the time of packaging and process knowledge (records and database information). Items with the potential to puncture the liner and drum are blocked, braced, or suitably packaged to ensure container integrity.

LLNL personnel shall ensure compliance with the requirement associated with sealed containers through visual examination at the time of packaging and process knowledge (records and database information).

Compliance with each of the restrictions on physical form shall be recorded in the payload container data package.

5.0 CHEMICAL FORM AND CHEMICAL PROPERTIES

5.1 Requirements

The chemical properties of the waste are determined by the chemical constituents allowed in a given content code. Specific requirements regarding the chemical form of the waste are as follows:

- Explosives, nonradioactive pyrophorics, compressed gases, and corrosives are prohibited.
- Pyrophoric radionuclides may be present only in residual amounts less than 1 weight percent.
- The total amount of potentially flammable volatile organic compounds (VOCs) present in the headspace of a secondary container is restricted to 500 parts per million (ppm).

5.2 Methods of Compliance and Verification

Compliance with chemical form and chemical property restrictions is demonstrated through process knowledge or sampling programs, if required.

5.2.1 Pyrophoric Materials

LLNL has certified that the waste does not contain any pyrophorics.

5.2.2 Explosives, Corrosives, and Compressed Gases

LLNL has certified that the waste does not contain any explosives or compressed gases. LLNL procedures call for all aerosol cans to be punctured before placement in a TRU waste drum. LLNL has certified that the waste does not contain any corrosive materials. Any corrosive materials used during the production of the waste was neutralized prior to being emplaced in the waste containers.

5.2.3 Flammable VOCs

All TRU waste from the LLNL is from research and development and will be packaged with the generation of complete data packages. The LLNL will ensure that the total amount of potentially flammable VOCs present in the headspace of a secondary container is restricted to 500 ppm.

6.0 CHEMICAL COMPATIBILITY

6.1 Requirements

Each content code has an associated chemical list (Attachment A) based on AK information. Chemical constituents in a payload container assigned to a given content code shall conform to these approved chemical lists. Chemicals/materials that are not listed are allowed in trace amounts (quantities less than 1 weight percent) in a payload container provided that the total quantity of trace chemicals/materials is restricted to less than 5 weight percent.

Chemical compatibility of a waste with its packaging ensures that chemical reactions will not occur that might pose a threat to the safe transport of a payload in the CNS 10-160B cask.

6.2 Methods of Compliance and Verification

Attachment B of Appendix 4.10.2 presents the methodology and results for the chemical compatibility analyses performed for the list of allowable chemicals/materials associated with the TRU waste content codes expected to be shipped in the CNS 10-160B cask. The results of these chemical compatibility analyses show that these content codes can be transported without any incompatibilities.

The chemicals present in the LLNL content codes conform to the list of allowable materials in Attachment B of Appendix 4.10.2. Therefore the waste meets the chemical compatibility requirements.

7.0 GAS DISTRIBUTION AND PRESSURE BUILDUP

7.1 Requirements

Gas distribution and pressure buildup during transport of TRU waste in the CNS 10-160B cask payload are restricted to the following limits:

- The gases generated in the payload must be controlled to prevent the occurrence of potentially flammable concentrations of gases within the payload confinement layers and the void volume of the inner vessel (IV) cavity. Specifically, hydrogen concentrations within the payload confinement layers are limited to 5 percent by volume during a maximum 60-day shipping period (see Attachment C of Appendix 4.10.2).

- The gases generated in the payload and released into the IV cavity must be controlled to maintain the pressure within the IV cavity below the acceptable packaging design limit of 31.2 pounds per square inch gauge (psig).

7.2 Methods of Compliance and Verification

Compliance with the CNS 10-160B cask design pressure limit for the LLNL content codes and each payload assembly configuration is analyzed by assuming that all gases generated are released into the IV cavity and by including the contributions from thermal expansion of gases and vapor pressure of atmospheric water.

Table 7-1 shows that the pressure increase during a period of 365 days is below the design pressure limit of 31.2 psig for all waste shipment options of LLNL TRU waste.

Table 7-1. Maximum Pressure Increase Over 365-Day Shipping Period						
Content Code and Configuration	**G_{eff} (RT)[a]**	**Void Volume (Liters)**	**Activation Energy (kcal/mole)**	**Decay Heat Limit (Watts/cask)**	**G_{eff}[b]**	**P_{max}[c] (psig)**
LL 116A	8.1	1938	2.1	0.354	14.19	11.89
LL 116B standard drum filter (3.7E-6 mole/sec/mole fraction) (6 waste drums per cask)	8.1	1938	2.1	2.26	14.19	31.13
LL 116B high diffusivity drum filter (1.85E-5 mole/sec/mole fraction) (6 waste drums per cask)	8.1	1938	2.1	2.26	14.19	31.13
LL 116B standard drum filter (3.7E-6 mole/sec/mole fraction) (3 waste drums per cask)	8.1	1938	2.1	2.26	14.19	31.13
LL 116B high diffusivity drum filter (1.85E-5 mole/sec/mole fraction) (3 waste drums per cask)	8.1	1938	2.1	2.26	14.19	31.13

[a]G value for net gas (molecules per 100 eV) at room temperature (70°F) (dose > 0.012 watt*year).
[b]Effective G value (molecules per 100 eV) at maximum operating temperature of 168°F calculated using the Arrhenius equation for which activation energy is an input.
[c]Maximum pressure.

Compliance with the restrictions on flammable gas concentration is discussed in Section 10.0.

8.0 PAYLOAD CONTAINER AND CONTENTS CONFIGURATION

8.1 Requirements

Fifty-five-gallon drums are authorized payload containers in a CNS 10-160B cask. Up to ten 55-gallon drums of TRU waste may be packaged in the cask. Each 55-gallon drum to be packaged in the CNS cask must have a minimum of one filter vent. The minimum filter vent specifications for the 55-gallon drums of LLNL waste are provided in Table 8-1.

Filter vents shall be legibly marked to ensure both (1) identification of the supplier and (2) date of manufacture, lot number, or unique serial number.

The rigid polyethylene liner, if present, in a payload container shall be punctured with a 0.3-inch diameter hole for content code LL 116A or with a 1-inch diameter hole for content code LL 116B before the container is transported in the CNS 10-160B.

ATTACHMENT 2
CHAPTER 4

For conservatism, the test will be conducted for 15 minutes.

4.5 Periodic Verification Leak Rate Determination Using R-12 Test Gas

This section contains calculations to determine the periodic verification test measurement that is equivalent to the maximum permissible leak rate as determined using ANSI N14.5-1997 (Reference 4).

The purpose of this calculation is to determine the allowable leak rate using the R-12 halogen gas that may be used to perform the annual verification leak tests on the CNS 10-160B cask.

4.5.1 Introduction

The text of this document is prepared using Mathcad, Version 6.0, software. Most conventions used in the text are the same as normal practice. A benefit of the Mathcad code is that is automatically carries all units with the variables used in the calculations. The code also allows output of variables in any form of the fundamental units (length, mass, time, etc.), allowing for automatic conversions between unit systems without the need for conversion factors. All Mathcad calculations in this Section 4.5 have been verified by hand calculations.

This calculation uses formulas presented in ANSI N14.5 - 1997.

4.5.2 Detector Sensitivity Calculation – Test Conditions

This section determines the sensitivity necessary for a leak test performed with R-12 halogen gas. This test is performed using a halogen leak detector. A leak standard, traceable to NIST, is used to calibrate the leak detector to detect the maximum allowable test leak rates specified in Figure 4.3. The test is performed as follows: The annulus between the o-ring seals of the 10-160B primary and secondary lids will be evacuated to a minimum vacuum of 20"Hg, and then be pressurized to a minimum pressure of 25 psig with R-12 halogen gas. In section 4.2.1, it was determined that the maximum possible diameter hole in the cask O-ring (D_{max}) that would permit the standard leak rate ($L_{std} = 3.25 \times 10^{-6}$) is:

The maximum possible diameter of hole in the O-ring is:

$D_{max} := 3.74 \cdot 10^{-4} \cdot c$ From Section 4.2.1

$$L_{std}(D) = (F_c(D) + F_m(D) \bullet (P_u - P_d) \bullet \frac{P_a}{P_d}$$ Eqn. B5 – ANSI N14.5 - 1997

Determine the equivalent air/R12 mixture (L_{mix}) that would leak from D_{max} during a leak test. Assume the O-ring void is first evacuated to 20"Hg vacuum (9.92"Hg abs) and then pressurized to 25 psig (2.7 atm) with an air/R12 mixture:

$P_{mix} := 2.7 \cdot atm$

$P_{air} := 9.92 \cdot in\_Hg$

$P_{air} = 0.33 atm$

$P_{R12} := P_{mix} - P_{air}$

$P_{R12} = 2.37 atm$ $P_d := 1.0 \cdot atm$

$P_a := \frac{P_{mix} + P_{air}}{2} \Rightarrow P_a = 1.85 atm$

$M_{R12} := 121 \cdot \frac{gm}{mole}$ ANSI N14.5 – 1997

$\mu_{R12} := 0.0124 \cdot cP$ ANSI N14.5 – 1997

$M_{mix} := \frac{M_{R12} \cdot P_{R12} + M_{air} \cdot P_{air}}{P_{mix}}$ Eqn. B7 - ANSI N14.5

$\Rightarrow M_{mix} = 109.7 \frac{gm}{mole}$

$\mu_{mix} := \frac{\mu_{air} \cdot P_{air} + \mu_{R12} \cdot P_{R12}}{P_{mix}}$ Eqn. B8 – ANSI N14.5 - 1997

$\Rightarrow \mu_{mix} = 0.0131 cP$

Determine L_{mix} as a function of temperature. Assume the viscosities of air and R12 do not change significantly over the range of temperatures evaluated:

$T := 273 \cdot K, 278 \cdot K .. 318 \cdot K$ Temperature range for test: 32°F to 113°F

$$F_c := \frac{2.49\,10^6 \cdot D_{max}^{\ 4} \cdot cP \cdot std}{a \cdot \mu_{mix} \, sec \cdot atm}$$

then,

$$F_c = 6.175\times\ 10^{-6}\,\frac{cm^3}{sec \cdot atm}$$

$$F_m(T) := \frac{3.81 \cdot 10^3 \cdot D_{max}^{\ 3} \cdot \sqrt{\frac{T}{M_{mix}}} \cdot cm \cdot gm^{0.5}}{a \cdot P_a \cdot K^{0.5} \cdot mole^{0.5} \cdot sec}$$

$$L_{mix}(T) := \left(F_c + F_m(T)\right)\cdot\left(P_{mix} - P_{air}\right)\cdot\frac{P_a}{P_{mix}}$$

$$T_F(T) := \left[(T \cdot F - 273 K)\cdot\frac{9}{5 \cdot K} + 32\right]$$

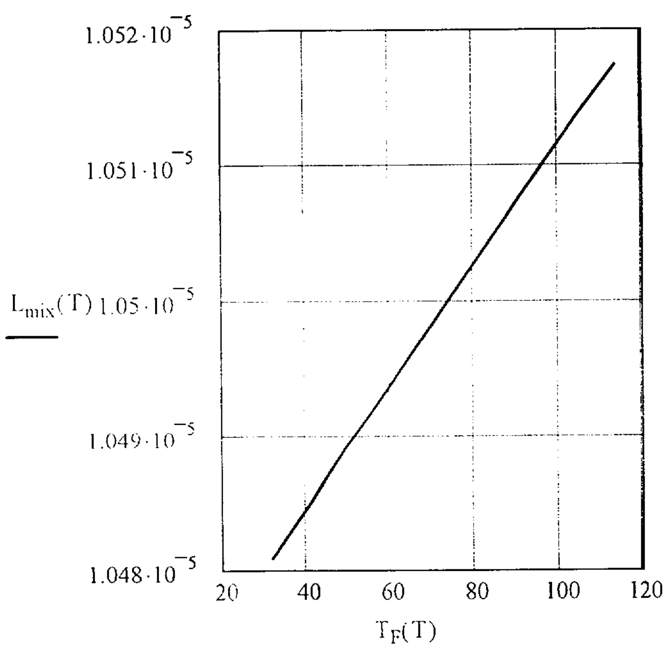


Fig.4.1 - Allowable R-12 Gas/Air Mixture Test Leakage, cm^3/sec, versus test temperature, deg.F

The R-12 component of this leak rate can be determined by multiplying the leak rate of the mixture by the ratio of the R-12 partial pressure to the total pressure of the mix, as follows.

$$L_{R12}(T) := L_{mix}(T)\cdot\frac{P_{R12}}{P_{mix}}$$

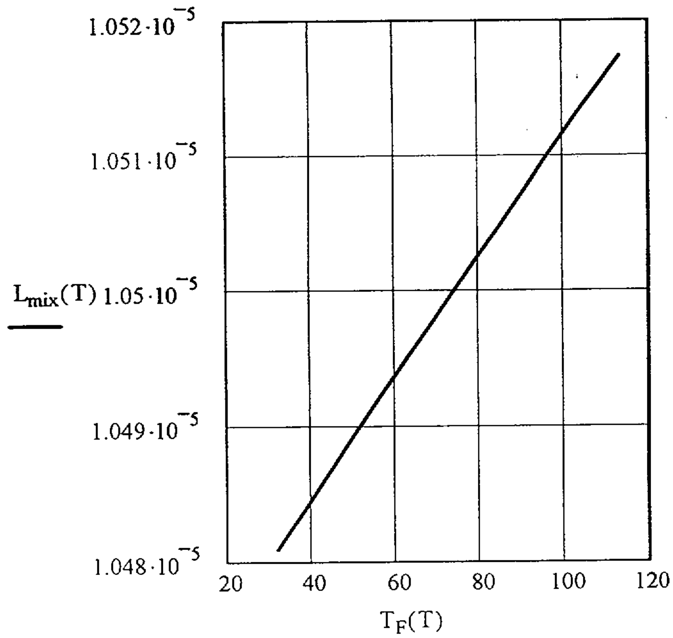


Fig.4.2 - Allowable R-12 test leakage, cm^3/sec versus test temperature, deg.F

Determine the equivalent mass flow rate for L_{R12} in oz/yr:

$$N(T) := \frac{P_{R12} \cdot}{R_o \cdot T}$$ Ideal Gas Law

where,

$$R_o := \frac{82.05\,cm^3 \cdot atm}{mole \cdot K}$$

This data can then be used to convert the volumetric leak rate for R-12 calculated above to a mass leak rate. By dividing N by V, the number of moles per unit volume can be multiplied by the molecular weight of the gas and the maximum allowable volumetric leak rate to determine the maximum allowable mass leak rate, as a function of test temperature as shown in the graph below. The conversion from grams per second to ounces per year is also shown below.

$$L(T) := L_{R12}(T) \cdot \frac{N(T)}{V} \cdot M_{R12} \cdot \frac{yr}{oz}$$

$$\frac{gm}{sec} = 1.113 \times 10^{6} \frac{oz}{yr}$$ Conversion of gm/sec to oz/yr

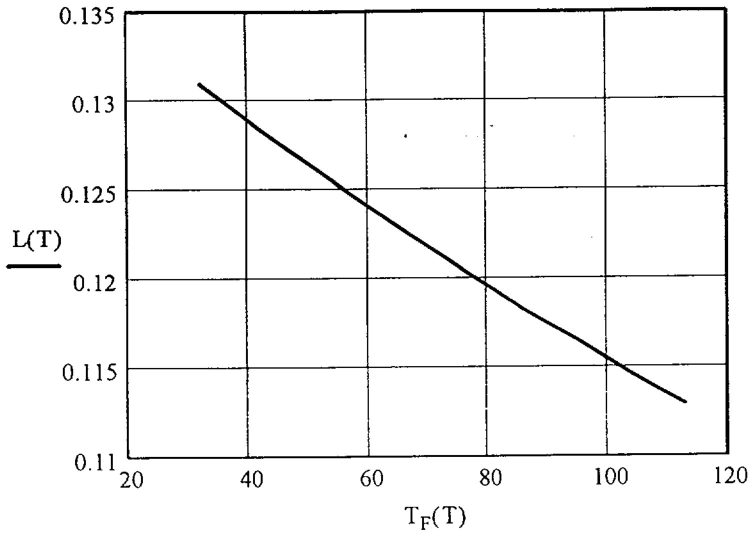


Fig.4.3 - Allowable R-12 test leakage, oz/yr, versus test temperature, deg.F

The graph above can be used to determine the allowable leak rate based on the temperature at the time of the test. According to ANSI N14.5 methodology, the maximum allowable leak rate must be divided by 2 to determine the minimum sensitivity for the test. A graph of the required sensitivity in oz/yr is presented below:

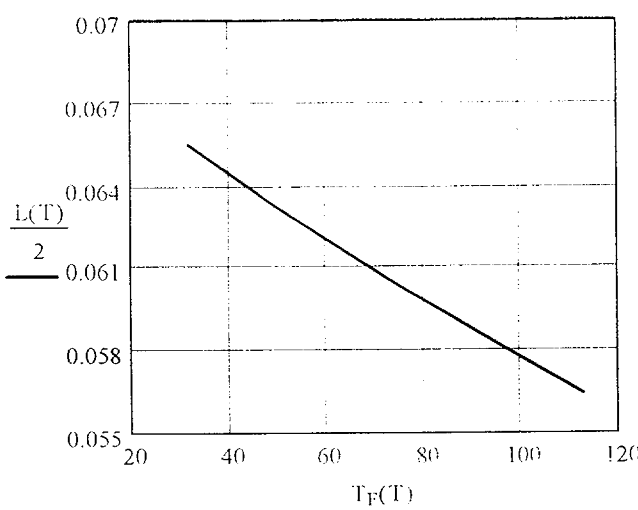


Fig.4.4 - Allowable R-12 test leakage sensitivity, oz/yr, versus test temperature, deg.F

The values presented in Figure 4.4 should be used to determine the sensitivity to calibrate the leak detector prior to the test.

4.6 Periodic Verification Leak Rate Determination Using Helium Test Gas

This section contains calculations to determine the periodic verification test measurement that is equivalent to the maximum permissible leak rate as determined using ANSI N14.5-1997 (Reference 4).

4.6.1 Introduction

The purpose of this calculation is to determine the allowable leak rate using the Helium gas that may be used to perform the annual verification leak tests on the CNS 10-160B cask.

The text of this document is prepared using Mathcad, Version 6.0, software. Most conventions used in the text are the same as normal practice. A benefit of the Mathcad code is that it automatically carries all units with the variables used in the calculations. The code also allows output of variables in any form of the fundamental units (length, mass, time, etc.), allowing for automatic conversions between unit systems without the need for conversion factors. All Mathcad calculations in this Section 4.6 have been verified by hand calculations.

4.6.2 Detector Sensitivity – Test Conditions

In Section 4.2.1, it was determined that the maximum possible diameter hole in the cask O-ring (D_{max}) that would permit the standard leak rate ($L_{std} = 3.25\times10^{-6}$ ref- cm^3/sec) is:

$D_{max} = 3.74 \cdot 10^{-4} \cdot cm$

Next, determine the equivalent air/He mixture (L_{mix}) that would leak from D_{max} during a leak test. Assume the O-ring void is pressurized to 25 psig (2.7 atm) with an air/He mixture.

$P_{mix} = 2.7 \cdot atm$

$P_{air} = 1.0 \cdot atm$

$P_{He} = 1.7 \cdot atm$

$$P_a = \frac{P_{mix} + P_{air}}{2}$$

$P_a = 1.85 \cdot atm$

$M_{He} = 4.0 \cdot \frac{gm}{mole}$ ANSI N14.5 - 1997

$\mu_{He} = 0.0198 \cdot cP$ ANSI N14.5 - 1997

$$M_{mix} := \frac{M_{He} \cdot P_{He} + M_{air} \cdot P_{air}}{P_{mix}}$$ Eqn. B7 - ANSI N14.5

$\Rightarrow$ $$M_{mix} = 13.26 \cdot \frac{gm}{mole}$$

$$\mu_{mix} := \frac{\mu_{air} \cdot P_{air} + \mu_{He} \cdot P_{He}}{P_{mix}}$$ Eqn. B8 - ANSI N14.5

$\Rightarrow$ $$\mu_{mix} = 0.019 \cdot cP$$

Determine L_{mix} as a function of temperature. Assume the viscosities of air and Helium do not change significantly over the range of temperatures evaluated:

$:= 273 \cdot K, 278 \cdot K .. 318 \cdot K$ Temperature range for test: $32^{o}F$ to approx. $113^{o}F$

$$F_c := \frac{2.49 \cdot 10^{6} \cdot D_{max}^{4} \cdot cP \cdot std}{a \cdot \mu_{mix} \cdot sec \cdot atm}$$

$\Rightarrow$ $$F_c = 4.203 \cdot 10^{-6} \cdot \frac{cm^3}{sec \cdot atm}$$

$$F_m(T) := \frac{3.81 \cdot 10^{3} \cdot D_{max}^{3} \cdot \sqrt{\frac{T}{M_{mix}}} \cdot cm \cdot gm^{0.5}}{a \cdot P_a \cdot K^{0.5} \cdot mole^{0.5} \cdot sec}$$

$$L_{mix}(T) := \left(F_c + F_m(T)\right) \cdot \left(P_{mix} - P_{air}\right) \cdot \frac{P_a}{P_{mi}}$$

$$T_F(T) := (T \cdot F - 273 \cdot K) \cdot \frac{9}{5 \cdot K} + 32$$

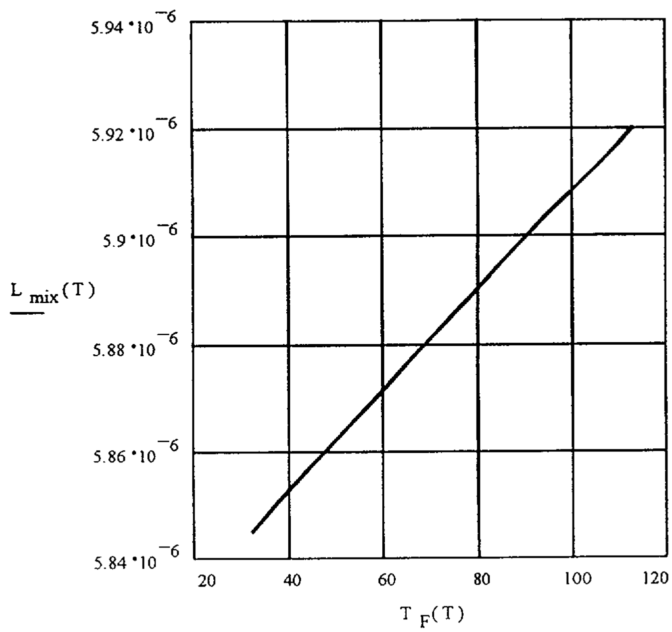


Fig.4.5 - Allowable He/Air Mixture Test Leakage, cm^3/sec, versus test temperature, deg.F

The Helium component of this leak rate can be determined by multiplying the leak rate of the mixture by the ratio of the Helium partial pressure to the total pressure of the mix, as follows.

$$L_{He}(T) = L_{mi}(T) \cdot \frac{P_{He}}{P_{mi}}$$

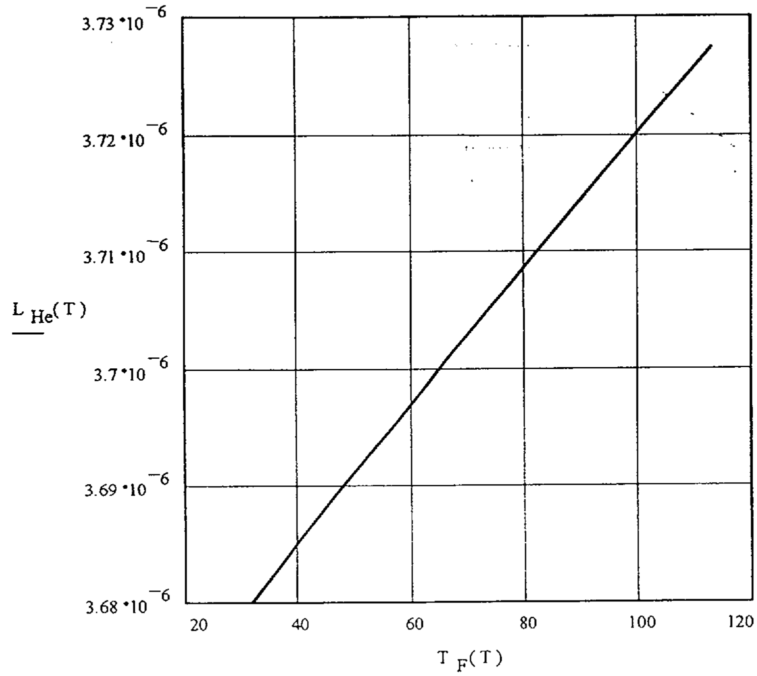


Fig.4.6 - Allowable Helium test leakage, cm^3/sec versus test temperature, deg.F

Determine the equivalent mass flow rate for L_{He} in oz/yr:

$$N(T) := \frac{P_{He} \cdot V}{R_o \cdot T}$$ Ideal Gas Law

where,

$$R_o := \frac{82.05\ cm^3 \cdot atm}{mole K}$$

This data can then be used to convert the volumetric leak rate for Helium calculated above to a mass leak rate. By dividing N by V, the number of moles per unit volume can be multiplied by the molecular weight of the gas and the maximum allowable volumetric leak rate to determine the maximum allowable mass leak rate, as a function of test temperature as shown in the graph below. The conversion from grams per second to ounces per year is also shown below.

$$L(T) := L_{He}(T) \cdot \frac{N(T)}{V} \cdot M_{He} \cdot \frac{yr}{oz}$$

$$\frac{gm}{sec} = 1.113 \cdot 10^6 \cdot \frac{oz}{yr}$$ Conversion of gm/sec to oz/yr

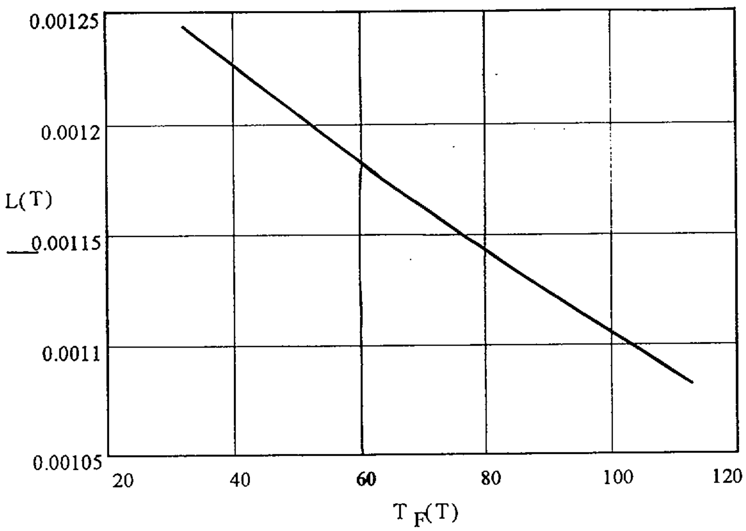


Fig.4.7 - Allowable helium test leakage, oz/yr, versus test temperature, deg.F

The graph above can be used to determine the allowable leak rate based on the temperature at the time of the test. According to ANSI N14.5 methodology, the maximum allowable leak rate must be divided by 2 to determine the minimum sensitivity for the test. A graph of the required sensitivity in oz/yr is presented below:

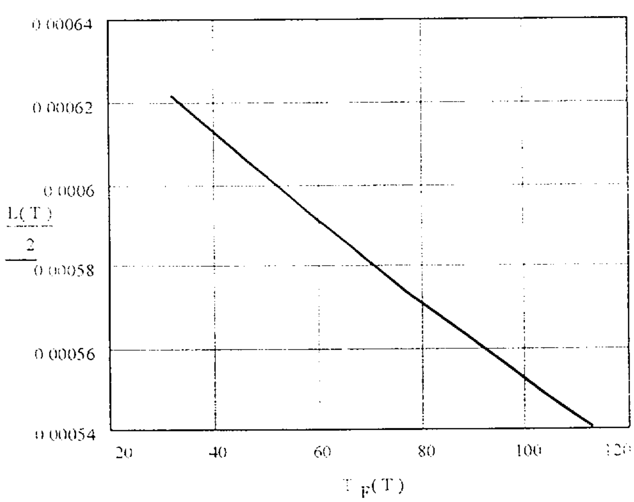


Fig.4.8 - Allowable helium test leakage sensitivity, oz/yr, versus test temperature, deg.F

The values presented in Figure 4.8 should be used to determine the sensitivity to calibrate the leak detector prior to the test.

4.7 Periodic Verification Leak Rate Determination Using R-134A Test Gas

This section contains calculations to determine the periodic verification test measurement that is equivalent to the maximum permissible leak rate as determined using ANSI N14.5-1997 (Reference 8).

4.7.1 Introduction

The purpose of this calculation is to determine the allowable leak rate using the R-134a halogen gas that will be used as an alternative to perform the annual verification leak tests on the CNS 10-160B cask. This halogen gas is now in widespread use as a replacement gas for R-12 in many industrial applications. Properties for R134a are included in Appendix 4.1.

The text of this document is prepared using Mathcad, Version 6.0, software. Most conventions used in the text are the same as normal practice. A benefit of the Mathcad code is that it automatically carries all units with the variables used in the calculations. The code also allows output of variables in any form of the fundamental units (length, mass, time, etc.), allowing for automatic conversions between unit systems without the need for conversion factors. All Mathcad calculations in this Section 4.7 have been verified by hand calculations.

4.7.2 Detector Sensitivity Calculation - Test Conditions

This section determines the sensitivity necessary for a leak test performed with R-134a halogen gas. This test is performed using a halogen leak detector. A leak standard, traceable to NIST, is used to calibrate the leak detector to detect the maximum allowable test leak rates specified in Figure 4.11. The test is performed as follows: The annulus between the o-ring seals of the 10-160B primary and secondary lids will be evacuated to a minimum vacuum of 20"Hg, and then be pressurized to a minimum pressure of 25 psig with R-134a halogen gas. In section 4.2.1, it was determined that the maximum possible diameter hole in the cask O-ring (D_{max}) that would permit the standard leak rate ($L_{std} = 3.25 \times 10^{-6}$) is:

$$D_{max} = 3.74 \cdot 10^{-4} \cdot cm$$

Next, determine the equivalent air/R134a mixture (L_{mix}) that would leak from D_{max} during a leak test. Assume the O-ring void is first evacuated to 20"Hg vacuum (9.92"Hg absolute) and then pressurized to 25 psig (2.7 atm) with an air/R134a mixture.

$$P_{mix} := 2.7 \cdot atm$$

$$P_{air} := 9.92 \, in\_H$$

$$P_{air} = 0.33at$$

$P_{R134a} := P_{mix} - P_{ai}$

$P_{R134a} = 2.37\text{atm}$ $\quad$ $P_d := 1.0\cdot\text{atm}$

$$P_a := \frac{P_{mix} + P_{air}}{2}$$

$P_a = 1.85\text{atm}$

The properties of R134a are given in the attached literature:

$$M_{R134a} := 102\cdot\frac{gm}{mole}$$

$\mu_{R134a} := 0.012c$

$$M_{mix} := \frac{M_{R134a}\cdot P_{R134a} + M_{air}\cdot P_{air}}{P_{mix}}$$ Eqn. B7 - ANSI N14.5

$$\Rightarrow \quad M_{mix} = 93.04\frac{gm}{mole}$$

$$\mu_{mix} := \frac{\mu_{air}\cdot P_{air} + \mu_{R134a}\cdot P_{R134a}}{P_{mix}}$$ Eqn. B8 - ANSI N14.5

$$\Rightarrow \quad \mu_{mix} = 0.013c$$

Determine L_{mix} as a function of temperature. Assume the viscosities of air and R134a do not change significantly over the range of temperatures evaluated:

$T := 273\cdot K, 278K..318$ $\quad$ Temperature range for test: 32°F to 113°F

$$F_c := \frac{2.49\cdot 10^6\cdot D_{max}^{\ 4}\cdot cP\cdot ref}{a\cdot \mu_{mix}\cdot sec\cdot atm}$$

$$\Rightarrow \quad F_c = 6.344\times 10^{-6}\frac{cm^3}{sec\cdot atm}$$

$$F_m(T) := \frac{3.81\cdot 10^3 \cdot D_{max}{}^3 \cdot \sqrt{\frac{T}{M_{mix}}} \cdot cm \cdot gm^{0.5}}{a \cdot P_a \cdot K^{0.5} \cdot mole^{0.5} \cdot sec}$$

$$L_{mix}(T) := (F_c + F_m(T)) \cdot (P_{mix} - P_{air}) \cdot \frac{P_a}{P_{mix}}$$

$$T_F(T) := \left[(T \cdot F - 273K) \cdot \frac{9}{5 \cdot K} + 32 \right]$$

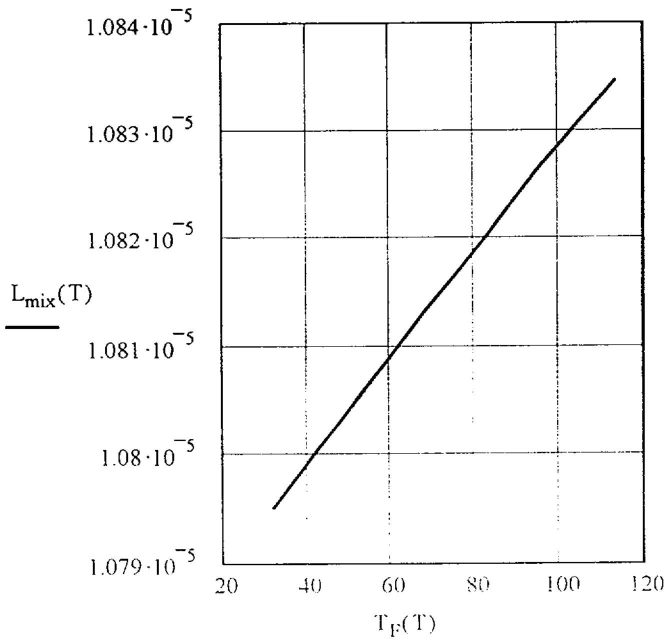


Fig.4.9 - Allowable R134a/Air Mixture Test Leakage, cm^3/sec, versus test temperature, deg.F

The R-134a component of this leak rate can be determined by multiplying the leak rate of the mixture by the ratio of the R-134a partial pressure to the total pressure of the mix, as follows.

$$L_{R134a}(T) := L_{mix}(T) \cdot \frac{P_{R134a}}{P_{mix}}$$

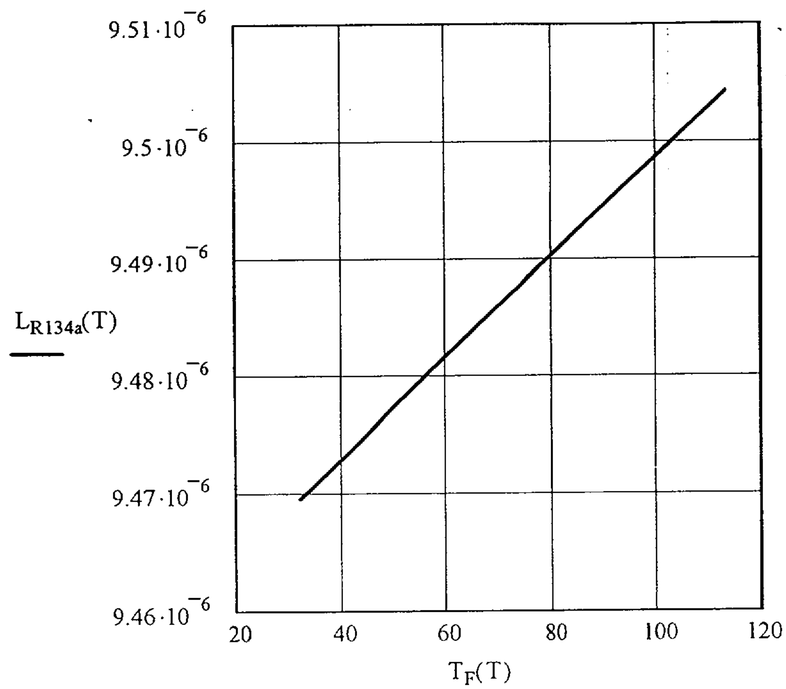


Fig.4.10 - Allowable R-134a test leakage, cm^3/sec versus test temperature, deg.F

Determine the equivalent mass flow rate for L_{R134a} in oz/yr, the measurement used by the detector:

$$N(T) := \frac{P_{R134a} \cdot}{R_o \cdot T}$$ Ideal Gas Law

where,

$$R_o := \frac{82.05\,cm^3 \cdot atm}{mole \cdot K}$$ Universal Gas Constant

This data can then be used to convert the volumetric leak rate for R-134a calculated above to a mass leak rate. By dividing N by V, the number of moles per unit volume can be multiplied by the molecular weight of the gas and the maximum allowable volumetric leak rate to determine the maximum allowable mass leak rate, as a function of test temperature as shown in the graph below. The conversion from grams per second to ounces per year is also shown below.

$$L(T) := L_{R134a}(T) \cdot \frac{N(T)}{V} \cdot M_{R134a} \cdot \frac{yr}{oz}$$

$$\frac{gm}{sec} = 1.113 \times 10^6 \frac{oz}{yr}$$ Conversion of gm/sec to oz/yr

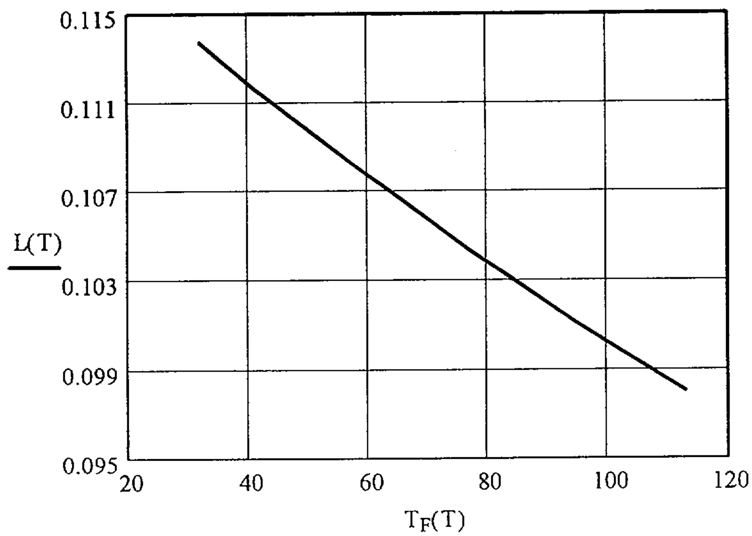


Fig.4.11 - Allowable R134a test leakage, oz/yr, versus test temperature, deg.F

The graph above can be used to determine the allowable leak rate based on the temperature at the time of the test. According to ANSI N14.5 methodology, the maximum allowable leak rate must be divided by 2 to determine the minimum sensitivity for the test. A graph of the required sensitivity in oz/yr is presented below:

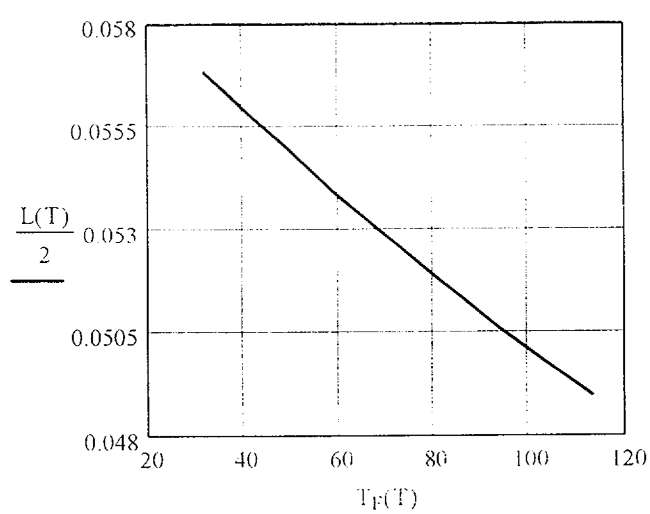


Fig.4.12 - Allowable R134a test leakage sensitivity, oz/yr, versus test temperature, deg.F

The values presented in Figure 4.12 should be used to determine the sensitivity to calibrate the leak detector prior to the test.

ATTACHMENT 3
CHAPTER 8

8.0 ACCEPTANCE TESTS AND MAINTENANCE

8.1 Acceptance Test

Prior to the first use of the CNS 10-160B package, the following tests and evaluations will be performed:

8.1.1 Visual Examination

The package will be examined visually for any adverse conditions in materials or fabrication.

8.1.2 Structural Tests

Containment welds identified on Dwg. C-110-D-29003-010 are inspected per ASME Code, Section III, Div. I, Subsection ND, Article ND-5000.

All ferromagnetic material welds are inspected per ASME Code, Section III, Div. I, Subsection NF, NF-5230 for Class 3 support attachments, and Section V Article 7 for magnetic particle (MT) examinations, and Section V Article 6 for liquid penetrant (PT) examinations. Acceptance standards are per ASME Section III, Div. I, Subsection NF, NF-5340 and NF-5350, as appropriate.

All non-ferromagnetic material welds are liquid penetrant (PT) inspected per ASME Code, Section V, Article 6 with acceptance criteria per ASME Code, Section III, Div. I, Subsection NF, NF-5350.

Welds on lifting and tiedown lugs are inspected before and after 150% load test in accordance with the ASME Code requirements for MT examination as specified above.

8.1.3 Leak Tests

This test shall be performed, prior to acceptance and operation of a newly fabricated package, in accordance with ASTM E-427 using a halogen leak detector (or a helium leak detector if helium is the test gas used); capable of meeting the sensitivity requirements specified in Figures 4.4 and 4.12 (Figure 4.8 for helium) in Chapter 4. Calibration of the leak detector shall be performed using a leak rate standard traceable to NIST. The leak standard's setting shall correspond to the approved leak test rate (see Chapter 4). The annulus between the o-ring seals of the 10-160B primary and secondary lids will be evacuated to a minimum vacuum of 20"Hg, and then be pressurized to a minimum pressure of 25 psig with pure dichlorodifluoromethane (R-12) or 1,1,1,2 – tetrafluoroethane (R-134a). Helium testing does not require evacuation of the annulus prior to pressurization. The detector probe shall be moved along the interior surface of the inner seal according to the specifications of ASTM E-427.

If installed, the vent and drain lines will be tested as above by evacuating and pressurizing the inlet (cavity) side of the lines and checking for leaks at the outlet side of the cap screw.

The maximum allowable leak rate (which is temperature dependent) is specified in Section 4.5, 4.6, or 4.7 (depending on the test gas used). Any condition, which results in leakage in excess of this value, shall be corrected.

8.1.4 Component Tests

Gasket and seals will be procured and examined in accordance with the Duratek Quality Assurance Program.

8.1.5 Test for Shielding Integrity

Shielding integrity of the package will be verified by gamma scan or gamma probe methods to assure package is free of significant voids in the poured shield annulus. All gamma scanning will be performed on a 4-inch square or less grid system. The acceptance criteria will be that voids resulting in shield loss in excess of 10% of the normal lead thickness in the direction measured shall not be acceptable.

8.1.6 Thermal Acceptance Tests

No thermal acceptance testing will be performed on the CNS 10-160B package. Refer to the Thermal Evaluation, Section 3.0 of this report.

8.1.7 Impact Limiter Foam

Acceptance testing of the impact limiter foam will be performed as required by ES-M-172, which is included in Appendix 8.3.1.

8.1.8 Pressure Test

A pressure test of the containment system will be performed as required by 10CFR71.85. As determined in Section 3.4.4, the maximum normal operating pressure for the cask cavity is 8.4 psig, therefore the minimum test pressure will be 1.5 x 8.4 = 12.6 psig.

8.2 Maintenance Program

Duratek is committed to an ongoing preventative maintenance program for all shipping packages. The 10-160B package will be subjected to routine and periodic inspection and tests as outlined in this section and Duratek approved procedure.

8.2.1 Routine Maintenance

Unless noted otherwise, for loaded packages containing large quantity LSA materials or greater than Type A quantities of non-LSA materials, each of the following safety related items and functional features shall be visually examined for defects or replacement. Corrective action for defects shall be as noted.

8.2.1.1 Fasteners

The primary and secondary lid bolts shall be visually inspected for defects whenever it is necessary to remove the corresponding lid. Obtain replacement parts as specified on Drawing C-110-D-29003-010 (current revision) for any components that show cracking or other visual signs of distress.

The cap screws for the vent port, test ports and drain shall be visually inspected for defects whenever it is necessary to remove them. Obtain replacement cap screws as specified on Drawing C-110-D-29003-010 (current revision) for any cap screws that show cracking or other visual signs of distress.

8.2.1.2 Gaskets and Seals

a. Primary Lid Seals

The primary lid O-ring seals shall be visually inspected for serviceability, ensuring that they are in the proper position and free of cracks, tears, cuts or discontinuities that may prevent them from sealing properly. The seal seating surfaces shall be visually inspected to ensure that they are free of damage, dirt, gravel or any foreign matter, which might damage the seals. If any defects are detected, the seals shall be replaced and/or the seal seating surfaces shall be reworked as necessary to ensure that the lid will seal properly.

New O-rings shall be lightly coated with a lightweight lubricant such as Parker Super O-Lube or equivalent prior to installation. The lubricant will minimize deterioration or cracking of the elastomer during usage and tearing if removal from the dovetail groove is necessary for inspection. If new O-rings have not been installed, coat the exposed surfaces of the O-rings with the lightweight lubricant immediately prior to closing the lid. Excess lubricant shall be wiped off before closing the lid.

b. Secondary Lid Seals

The secondary lid O-ring seals and seating surfaces shall be inspected as specified in Section 8.2.1.2 (a) at any time it is necessary to remove the secondary lid. Seal replacement and/or seating surface repair shall be as specified in Section 8.2.1.2 (a).

c. Test/Vent Ports and Drain Seals

The above seals and seating surfaces shall be inspected as specified in Section 8.2.1.2 (a) at any time it is necessary to remove them. Seal replacement and/or seating surface repair shall be as specified in Section 8.2.1.2 (a).

8.2.1.3 Painted Surfaces Identification Markings and Match Marks Used for Closure Orientation

The above items shall be visually inspected to ensure that painted surfaces are in good condition, identification markings are legible and that match marks used for closure orientation remain legible and are easy to identify.

8.2.2 Periodic Maintenance

The following inspections and/or tests shall be performed as specified.

8.2.2.1 Periodic Leak Tests

The package shall be leak tested as described in Section 8.1.3 after its third use. In addition, the containment system, before actual use for shipment, shall have been leak tested according to Section 8.1.3 within the preceding 12-month period.

Also, before actual use for shipment, all seals shall have been replaced within the preceding 12-month period.

8.2.2.2 Assembly Verification Leak Test

This test is required before each shipment of Type B material quantities. The test will verify that the containment system has been assembled properly.

The test will be performed by pressurizing the annulus between the O-ring seals of either the primary or the secondary lid or the inlet to the vent and drain lines (if applicable) with dry air or nitrogen.

NOTE: PRESHIPMENT LEAKAGE RATE TESTING IS REQUIRED ONLY FOR THE CONTAINMENT BOUNDARY AREAS THAT HAVE BEEN OPENED DURING THE UNLOAD-LOADING CYCLE.

NOTE: IF AIR IS USED FOR THE TEST, THE AIR SUPPLY SHOULD BE CLEAN AND DRY. IF IT IS NOT, OR IF THE QUALITY OF THE AIR SUPPLY IS UNCERTAIN, THE TEST SHOULD BE PERFORMED WITH NITROGEN TO ENSURE RELIABLE RESULTS.

The test shall be performed using a pressure gauge, accurate within 1%, or less, of full scale.

The test pressure shall be applied for at least 15 minutes (10 minutes for vent or drain ports). A drop in pressure of greater than the minimum detectable amount shall be cause for test failure. The maximum sensitivity of the gauge shall be 0.1 psig.

Sensitivity at the test conditions is equivalent to the prescribed procedure sensitivity of 10^{-3} ref-cm^3/sec based on dry air at standard conditions as defined in ANSI N14.5-1997 (See Section 4.4 for the determination of the test conditions).

8.2.2.3 Ratchet Binders

Ratchet binders are designed for long use with minimal maintenance. Inspection for operation is conducted prior to each use of the cask. The ratchet binder mechanism as well as the threads on the joining bolt are checked for dryness and ease of operation. If required, these parts are lubricated with standard chassis lubricant.

Ratchet binders which show excessive wear or have received impact or suspected overloading in an accident must be completely disassembled and inspected or replaced. Cause for rejection during an inspection shall include:

a. Cracks in the jaws or joining bolt.

b. Deformation of the jaws or joining bolt.

c. Excessive rust or corrosion pitting in the threads of the jaw or joining bolts.

8.2.3 Subsystem Maintenance

The CNS 10-160B package contains no subsystem assemblies.

8.2.4 Valves Rupture Discs and Gaskets on Containment Vessel

As a minimum, all gasket seals will be replaced prior to the annual leak test specified in 8.2.2.1.

8.2.5 Shielding

No shielding tests will be performed after acceptance testing unless there has been a repair to a damaged area, which will affect shield integrity. Any shield testing which might be required would be in accordance with the original criteria specified in Section 8.1.5.

Appendix 8.3.1
Polyurethane Foam Specification
ES-M-172

ATTACHMENT 4
CHAPTER 7

between the secondary container and the cask, the cask will also be inerted.

7.4.1.3 Inerting of the secondary container and / or the cask cavity, to achieve an oxygen concentration of less than 5%, can be performed per the following:

- Connect a nitrogen supply.
- Pressurize with nitrogen to 15 ±1 psig. for fifteen minutes.
- Depressurize to ~ 0 psig.
- Repeat this pressurization / depressurization cycle two more times

7.4.2 Combustible Gas Suppression

7.4.2.1 Dewater the secondary container. See paragraph 7.4.1.1.

7.4.2.2 Install the previously qualified* combustible gas suppression system (e.g., a vapor pressure catalytic recombiner).

*Previous qualification means that the catalytic recombiner design to be used has been tested for a period of twice the expected shipping time under conditions expected in transport and has proven satisfactory.

7.4.2.3 Sample the gas in the secondary container and measure static pressure. This will assure that the combustible gas control method is working properly and that the combustible gas criteria specified in Section 4.4 will be met.

7.4.2.4 Load the secondary container.

ATTACHMENT 5
DRAWINGS

Table 8-1. Minimum Filter Vent Specifications				
	Filter Specification			
Container Filter Type	**Number of Vents Required per Container**	**Flow Rate (ml/min of air, STP, at 1 inch of water)[a]**	**Efficiency (percent)**	**Hydrogen Diffusivity (mol/s/mol fraction at 25°C)**
Standard drum filter	1	35	99.5	3.70E-6
High diffusivity drum filter	1	35	99.5	1.85E-5

[a] Filters tested at a different pressure gradient shall have a proportional flow rate (e.g., 35 ml/min at 1 inch of water = 1 L/min at 1 psi).

8.2 Methods of Compliance and Verification

Compliance with the payload container and contents configuration requirements is determined by visual examination, process knowledge, and through procurement records.

Procured filter vents at LLNL shall be inspected to verify compliance with the applicable filter vent specifications specified in the purchase requisition (i.e., visual inspection of certificate of conformance, serial numbers to actual filter vents, and inspection of filters for physical damage). Nonconforming filter vents shall be segregated.

Prior to transport, payload container filter vents shall be visually inspected for damage or defect. If a defect is identified, a nonconformance report shall be issued, and the payload container shall be returned for repackaging or overpacking prior to certification.

The requirements for the rigid liner shall be met by procurement controls and site QA procedures. Venting of the lid of a liner (along with the minimum diameter of the hole in the liner) may be controlled administratively (i.e., buying only punctured liners) or by visual examination of the liner prior to closure. Alternatively, radiography or sampling programs and existing records may be used to verify that the liner meets the requirements.

9.0 ISOTOPIC CHARACTERIZATION AND FISSILE CONTENT

9.1 Requirements

The CNS 10-160B cask payload allows fissile materials, provided the mass limits of Title 10, Code of Federal Regulations, Section 71.53 are not exceeded. Plutonium content cannot exceed 0.74 TBq (20 curies) per cask.

9.2 Methods of Compliance and Verification

LLNL assays drums in Building 332 using an SGS, or a combination of calorimetry and gamma counting. In Building 251, individual waste parcels are assayed using gamma spectrometry. Assay results are used to calculate plutonium content and decay heat (plus error). Some drums having a low level of activity are assayed with LLNL's High Sensitivity Neutron Instrument, located in Building 331. LLNL may use other instruments, such as active and passive neutron detectors, gamma spectrometers, or an active and passive computed tomography gamma scanner to meet the isotopic characterization and fissile content requirements. The site transportation certification official (TCO) shall evaluate the compliance of the fissile material mass and plutonium curies of payload containers with the maximum limits.

10.0 DECAY HEAT AND HYDROGEN GAS GENERATION RATES

This section describes the logic and methodology used in evaluating payload characteristics that meet the hydrogen gas concentration requirement for the LL 116A and LL 116B content codes for the LLNL CH-TRU wastes described in this section.

10.1 Requirements

The hydrogen gas concentration shall not exceed 5% by volume in all void volumes within the CNS 10-160B cask payload during a 60-day shipping period. A CNS 10-160B Cask payload must be assembled of payload containers belonging to the same content code. Payload containers of different content codes with different bounding G values and resistances may be assembled together as a payload, provided the decay heat limit and hydrogen gas generation rate limit for all payload containers within the payload is conservatively assumed to be the same as that of the payload container with the lowest decay heat limit and hydrogen gas generation rate limit.

10.2 Methodology of Ensuring Compliance with Flammable Gas Concentration Limits

As stated in Section 7.2, chemical, biological, and thermal gas generation mechanisms are insignificant in the CNS 10-160B cask. In addition, as shown in Section 5.1, potentially flammable VOCs are restricted to 500 ppm in the headspace of the CNS 10-160B cask secondary containers. Therefore, the only flammable gas of concern for transportation purposes is hydrogen. The concentration of hydrogen within any void volume in a layer of confinement of the payload or in the cask IV has been evaluated during a 60-day shipping period (see Attachment C of Appendix 4.10.2).

Attachment A provides the TRU waste content code for the LLNL TRU wastes that are included in the authorized payload for the CNS 10-160B cask. This content code has a unique and completely defined packaging configuration. Modeling the movement of hydrogen from the waste material to the payload voids, using the release rates of hydrogen through the various confinement layers, defines the relationship between generation rate and void concentration. This modeling allows determination of the maximum allowable hydrogen generation rate for the LL 116A and LL 116B content codes to meet the 5% concentration limit, as detailed in Section 10.3. Based on hydrogen gas generation potential, quantified by hydrogen gas generation G values, the gas concentration limit can be converted to a decay heat limit, as detailed in Section 10.4. The maximum allowable hydrogen generation rates and decay heat limits for the LLNL content code for different payload assembly configurations are listed in Table 10-1 (see Attachment A of Appendix 4.10.2 for a description of the Matrix Depletion Program and dose-dependent G values).

10.3 Determination of Maximum Allowable Hydrogen Generation Rates for Content Codes

The maximum allowable hydrogen generation rates were determined using the modeling methodology described in Appendix 4.10.2 and the following input parameters.

Table 10-1. Maximum Allowable Hydrogen Gas Generation Rates and Decay Heat Limits						
Content Code/ Payload Configuration	**Maximum Allowable Hydrogen Gas Generation Rate, mole/second /drum**	**Maximum Allowable Hydrogen Gas Generation Rate, moles/second/ cask**	**Maximum Allowable Decay Heat Limit, Watts/Drum (Dose <= 0.012 watt*year)**	**Maximum Allowable Decay Heat Limit, Watts/Cask (Dose <= 0.012 watt*yr)**	**Maximum Allowable Decay Heat Limit, Watts/Drum (Dose > 0.012 watt*year)**	**Maximum Allowable Decay Heat Limit, Watts/Cask (Dose > 0.012 watt*year)**
LL 116A	8.268×10^{-9}	4.961×10^{-8}	0.020	0.120	0.059	0.354
LL 116B Standard drum filter (3.7×10^{-6} mole/sec/mole fraction) (6 waste drums per cask)	7.360×10^{-8}	4.416×10^{-7}	0.182	1.092	0.533	2.26
LL 116B High diffusivity drum filter (1.85×10^{-5} mole/sec/mole fraction) (6 waste drums per cask)	1.412×10^{-7}	8.472×10^{-7}	0.275	1.650	0.807	2.26
LL 116B Standard drum filter (3.7×10^{-6} mole/sec/mole fraction) (3 waste drums per cask)	9.635×10^{-8}	2.890×10^{-7}	0.275	0.825	0.807	2.26
LL 116B High diffusivity drum filter (1.85×10^{-5} mole/sec/mole fraction) (3 waste drums per cask)	2.581×10^{-7}	7.742×10^{-7}	0.564	1.692	1.656	2.26

[a] Other limits applicable to the cask (not related to gas generation) shall also be met.

Waste Packaging Configuration and Release Rates: LL 116A: The waste described by LL 116A is packaged in 2 inner bags and 1 liner bag. The waste is then placed into a 55-gallon drum that may be lined with a polyethylene liner with a minimum 0.3-inch diameter hole. Six drums of waste will comprise the payload for the CNS 10-160B cask with the remainder being comprised of 55-gallon dunnage drums that allow free release of gas across the hole in the drum lid. Release rates of hydrogen through the drum filter, the drum polyethylene liner, the inner plastic bags, and the liner bags are summarized in Table 10-2.

LL 116B: The waste described by LL 116B assumes that the waste described in LL 116A has either been repackaged or that all inner plastic bag layers have been breached. The waste is placed into a 55-gallon drum that may be lined with a polyethylene liner with a minimum 1-inch diameter hole. Either three or six drums of waste will comprise the payload for the CNS 10-160B cask with the remainder being comprised of 55-gallon dunnage drums that allow free release of gas across the hole in the drum lid. Release rates of hydrogen through the drum filters and drum polyethylene liner are summarized in Table 10-2.

The release rates in Table 10-2 are shown for two different temperatures (minimum and maximum operating temperature of the CNS 10-160B) and are based on release rate values for various TRU waste packaging confinement layers documented in Appendices 3.6.9 and 3.6.12 of the TRUPACT-II SAR (Reference 12.1). The temperature dependence of these release rates is discussed later in this section.

Void Volume in the 10-160B Cask IV: The cask will have a payload of 10 drums and a drum carriage. The interior volume of the cask, V_{cask}, is 4438 liters. The volume occupied by the drum carriage, $V_{carriage}$, is 143.2 liters. The external volume of a single drum, V_{drum}, is 235.7 liters. The void volume within the cask is calculated as:

$$V_{V,cask} = V_{cask} - V_{carriage} - 10\ V_{drum} + n_{dunnage}\ (208\ liters)$$

$$V_{V,cask} = 4438\ liters - 143.2\ liters - 10\ (235.7\ liters) + n_{dunnage}\ (208\ liters)$$

$$V_{V,cask}\ 1938\ liters + n_{dunnage}\ (208\ liters)$$

where,

$n_{dunnage}$ = number of 55-gallon dunnage drums

Pressure: The pressure is assumed to be isobaric and equal to one atmosphere. The mole fraction of hydrogen in each void volume would be smaller if pressurization is considered and would result in a greater maximum allowable hydrogen gas generation rate. Furthermore, the amount of hydrogen gas generated during a 60-day shipping period would be negligible compared to the quantity of air initially present at the time of sealing the CNS 10-160B cask.

Temperature: The input parameter affected by temperature is the release rate through the different confinement layers in the payload containers and the G values for hydrogen. For the LL 116A waste content code, these are the release rates across plastic bags, the filter on the drum and the release rate across the 0.3-inch-diameter hole on the rigid polyethylene drum liner. For the LL 116B waste content code, these are the filters on the drums and the release rate across the 1-inch diameter hole on the rigid polyethylene drum liner. These release rates increase with increasing temperature as documented in Appendix 3.6.12 of the TRUPACT-II SAR (Reference 12.1). Therefore, the minimum release rates

Table 10-2. Release Rates of Hydrogen

Content Code Payload Configuration	Confinement Layer	Release Rate (mol/sec/mol fraction) T = 233K	Release Rate (mol/sec/mol fraction) T = 348.6K
LL 116A	Drum filter	2.46×10^{-6}	4.98×10^{-6}
	Inner bag	3.895×10^{-7}	5.58×10^{-7} [a]
	Liner bag	4.67×10^{-6}	4.67×10^{-6} [b]
	Polyethylene Liner (0.3-inch hole)	4.695×10^{-5}	5.09×10^{-5}
LL 116B (3.7×10^{-6} mole/sec/mf drum filter)	Polyethylene Liner (1.0-inch hole)	5.20×10^{-4}	5.66×10^{-4}
	Standard Drum Filter	2.46×10^{-6}	4.98×10^{-6}
LL 116B (1.85×10^{-5} mole/sec/mf drum filter)	Polyethylene Liner (1.0-inch hole)	5.20×10^{-4}	5.66×10^{-4}
	High Diffusivity Drum Filter	1.23×10^{-5}	2.49×10^{-5}

(a) The value at 70°F is conservatively used.
(b) This is the minimum measured value and is applicable to all temperatures.

would be those at the lowest operating temperature. These are the release rates indicated in Table 10-2 for 233K. The minimum decay heat limits are determined by the ratio of the release rates and the G values. In other words, the higher the release rates, the higher the decay heat limit; the higher the G value, the lower the decay heat limit. The dependence of G values on temperature is documented in Section 10.4. For determining the decay heat limit, the temperature that yielded the minimum decay heat limit was used as the input parameter.

In summary, the temperature dependence of the input parameters was accounted for in the calculation so that, in each case, the minimum possible limit (hydrogen generation rate or decay heat limit) was obtained. This provides an additional margin of safety in the analysis for the LL 116A and LL 116B content codes.

10.4 Determination of Maximum Allowable Decay Limits

The maximum allowable decay heat limits for the CH-TRU waste content codes, LL 116A and LL 116B, were calculated using the methodology described in Appendix 4.10.2 and the content-code specific G value described below.

G values are determined based on the bounding materials present in the payload. The maximum operating temperature yields the lowest decay heat limits for the operating temperature range of the CNS 10-160B cask. Content codes LL 116A and LL 116B represent solid organic debris consisting of various combustible and non-combustible items. The material present in this waste with the highest G value at the maximum operating temperature of the CNS 10-160B cask (168°F) is cellulosics and is therefore considered as the bounding material. The G value for hydrogen associated with cellulosics is 3.2 molecules/100eV (at 70°F) if the attained dose is less than or equal to 0.012 watt*year. The dose dependent G value for cellulosics is 1.09 molecules/100 eV if the dose attained in the drum is greater than 0.012 watt*yr. The methodology associated with the determination of dose-dependent G values pursuant to the Matrix Depletion Program is further discussed in Attachment A of Appendix 4.10.2. The G values at 70°F are adjusted to the maximum operating temperature of the CNS 10-160B cask (168°F) using the Arrhenius equation. The activation energy of the G value for cellulosics is 2.1 kcal/mole. Thus, at the maximum operating temperature of the CNS 10-160B cask (168°F), the bounding hydrogen G values for the LLNL content codes are 5.61 molecules/100 eV (dose $\leq$ 0.012 watt*year) and 1.91 molecules/100 eV (dose > 0.012 watt*year).

10.5 Methodology for Compliance with Payload Assembly Requirements

LLNL assays drums in Building 332 using an SGS, or a combination of calorimetry and gamma counting. In Building 251, individual waste parcels are assayed using gamma spectrometry. Assay results are used to calculate the decay heat (plus error). Some drums having a low level of activity are assayed with LLNL's High Sensitivity Neutron Instrument, located in Building 331. LLNL may use other instruments, such as active and passive neutron detectors, gamma spectrometers, or an active and passive computed tomography gamma scanner to establish the decay heat of the drum. The TCO shall evaluate the compliance of individual drums and the total of all drums with the maximum limits per drum and per cask.

If compliance with the decay heat limit cannot be demonstrated, the hydrogen generation rate of the container shall be determined and compared to the hydrogen gas generation rate limit specified for the LL 116A content code. If the container meets the limit, it is eligible for shipment if all other transportation requirements are met. If the container does not meet the limit, it cannot be shipped and shall be segregated for repackaging or other mitigation measures.

Compliance with the hydrogen gas generation rate shall be demonstrated by testing. Compliance with the requirements of the test plan described below must be documented in procedures under a quality assurance program.

10.5.1 Gas Generation Test Methodology

The following describes how compliance with the limit on the hydrogen gas generation rate will be implemented for LLNL content codes.

Demonstration of Compliance With Hydrogen Gas Generation Limit

During the course of the testing, the headspace gas of the selected waste containers will be sampled and analyzed to determine the concentrations of hydrogen and other gases that are produced by radiolysis or present when the waste was packaged. Sampling lines that communicate with the headspace of the waste containers will be installed. Samples of the headspace gas will be withdrawn periodically and analyzed using a gas chromatograph and/or a mass spectrometer. The analytical results will be used to calculate the hydrogen gas generation rate. The measured hydrogen gas generation rate will be compared to the appropriate hydrogen gas generation limits to evaluate compliance with transportation requirements.

Because all layers of confinement in all the containers have been vented since the time of packaging and the containers have been in a vented condition for a period of time, steady-state hydrogen concentrations exist within all void volumes inside a container. At steady-state conditions, the rate of gas generation by radiolysis equals the release rate of gas across each layer of confinement. The measured hydrogen gas concentration in the headspace gas will be used to calculate the hydrogen gas generation rate.

The hydrogen gas generation rate of the waste container is calculated from the measured hydrogen gas concentration using the following relationship:

$$C_g = X_H \times L_{CF}$$

where,

C_g = the hydrogen gas generation rate (mole/sec)
X_H = the measured concentration of hydrogen gas in the waste container headspace (mole fraction)
L_{CF} = diffusion characteristic of the waste container filter.

The actual drum hydrogen gas generation rate will be compared to the maximum allowable hydrogen generation rate limit in Table 10-1 of this appendix. The container shall be qualified for shipment only if the limit is met.

The TCO shall ensure that the CNS 10-160B cask payload consists of payload containers belonging to the same content code. In the event that payload containers of different content codes with different bounding G values and resistances are assembled together in the CNS 10-160B cask, the TCO shall ensure that the decay heat and hydrogen gas generation rate for all payload containers within the payload are less than or equal to the limits associated with the payload container with the lowest decay heat limit and hydrogen gas generation rate limit.

11.0 WEIGHT

11.1 Requirements

The weight limit for the contents of the loaded cask is 14,500 pounds.

11.2 Methods of Compliance and Verification

The LLNL shall weigh each payload container and contents on a calibrated scale to determine the total weight of the payload container. Based on the total measured weight of the individual payload containers and the payload carriage, LLNL shall calculate total assembly weight and evaluate compliance with the maximum contents weight limit.

12.0 REFERENCES

12.1 U.S. Department of Energy (DOE), "Safety Analysis Report for the TRUPACT-II Shipping Package," and associated TRUPACT-II Authorized Methods for Payload Control (TRAMPAC) Current Revision, U.S. Department of Energy Carlsbad Field Office, Carlsbad, New Mexico.

Attachment A

Transuranic Content Code and Chemical List
for Lawrence Livermore National Laboratory (LLNL)

CONTENT CODE: LL 116

CONTENT DESCRIPTION: TRU Combustible Waste

GENERATING SITE: Lawrence Livermore National Laboratory (LLNL)

STORAGE SITE: LLNL.

WASTE DESCRIPTION: The waste consists of glovebox bagout waste, non-glovebox-line generated laboratory trash, some contaminated equipment and some sealed sources. The waste may occasionally include small quantities of solidified liquids, especially if it is mixed waste, but this is usually segregated.

GENERATING SOURCE: The waste originates from LLNL Building 251.

WASTE FORM: The waste consists mostly of dry solids such as tissues, paper, assorted plastics, glassware, ceramics, and metals. Portland cement or Aquaset is used to solidify water-based liquids; Envirostone or Petroset is used to solidify small amounts of solvents and oil-based liquids.

WASTE PACKAGING: Details of the waste packaging for each content code are presented in the following table:

WASTE PACKAGING DESCRIPTION TABLE

Code	Description*
LL 116A	The waste is placed in two plastic bags, then placed in a 55-gallon drum fitted with a vented high density polyethylene rigid liner, itself lined inside with a third large plastic bag. Bags and liners are either polyvinyl chloride or polyethylene. All bag closures are by twist-and-tape or fold-and-tape method.
LL 116B	The waste is placed directly in a 55-gallon drum fitted with a vented high density polyethylene rigid liner. Any inner plastic bag layers are either open or breached

METHODS FOR DETERMINATION OF ISOTOPIC CHARACTERIZATION: LLNL assays drums in Building 332 using an SGS, or a combination of calorimetry and gamma counting. In Building 251, individual waste parcels are assayed using gamma spectrometry. Assay results are used to calculate the decay heat (plus error). Some drums having a low level of activity are assayed with LLNL's High Sensitivity Neutron Instrument, located in Building 331. LLNL may use other instruments, such as active and passive neutron detectors, gamma spectrometers. or an active and passive computed tomography gamma scanner to establish the decay heat of the drum. The TCO shall evaluate the compliance of individual drums and the total of all drums with the maximum limits per drum and per cask.

FREE LIQUIDS: Liquids are solidified according to procedure and allowed to cure before final sealing of the drum. LLNL has certified that the waste contains less than 1% by volume of free liquids.

EXPLOSIVES/COMPRESSED GASES: LLNL has certified that the waste does not contain any explosives or compressed gases. LLNL procedures call for all aerosol cans to be punctured before placement in a TRU waste drum.

PYROPHORICS: LLNL has certified that the waste does not contain any pyrophorics.

CORROSIVES: LLNL has certified that the waste does not contain any corrosive materials.

CHEMICAL COMPATIBILITY: A chemical compatibility study has been performed on this content code, and all waste is chemically compatible for materials in greater than trace (>1% weight) quantities.

ADDITIONAL CRITERIA: Each drum is fitted with a minimum of one filter vent.

MAXIMUM ALLOWABLE HYDROGEN GENERATION RATES — OPTION 1: The maximum allowable hydrogen generation rates are listed in the table below for the various payload configurations.

MAXIMUM ALLOWABLE WATTAGE — OPTION 2: The maximum allowable decay heat limits are listed in the table below for the various payload configurations.

Maximum Allowable Hydrogen Generation Rates and Decay Heat Limits for LL 116A						
Content Code/ Payload Configuration	**Maximum Allowable Hydrogen Gas Generation Rate, mole/second/ drum**	**Maximum Allowable Hydrogen Gas Generation Rate, moles/second/ cask**	**Maximum Allowable Decay Heat Limit, Watts/Drum (Dose <= 0.012 watt*year)**	**Maximum Allowable Decay Heat Limit, Watts/Cask (Dose <= 0.012 watt*yr)**	**Maximum Allowable Decay Heat Limit, Watts/Drum (Dose > 0.012 watt*year)**	**Maximum Allowable Decay Heat Limit, Watts/Cask (Dose > 0.012 watt*year)**
LL 116A $3.7x10^{-6}$ mole/sec/mole fraction drum filter (6 waste drums per cask)	$8.268x10^{-9}$	$4.961x10^{-8}$	0.020	0.120	0.059	0.354
LL 116B $3.7x10^{-6}$ mole/sec/mole fraction drum filter (6 waste drums per cask)	$7.360x10^{-8}$	$4.416x10^{-7}$	0.182	1.092	0.533	2.26
LL 116B $1.85x10^{-5}$ mole/sec/mole fraction drum filter (6 waste drums per cask)	$1.412x10^{-7}$	$8.472x10^{-7}$	0.275	1.650	0.807	2.26
LL 116B $3.7x10^{-6}$ mole/sec/mole fraction drum filter (3 waste drums per cask)	$9.635x10^{-8}$	$2.890x10^{-7}$	0.275	0.825	0.807	2.26
LL 116B $1.85x10^{-5}$ mole/sec/mole fraction drum filter (3 waste drums per cask)	$2.581x10^{-7}$	$7.742x10^{-7}$	0.564	1.692	1.656	2.26

LAWRENCE LIVERMORE NATIONAL LABORATORY
CONTENT CODE LL 116A and LL 116B
TRU COMBUSTIBLE WASTE
MATERIALS AND CHEMICALS >1%

CLOTH
GLASS, LABWARE
GRAPHITE (Molds and Crucibles)
METALS (including mercury, brass, lead shielding, lead shot, silver, stainless steel, aluminum, iron, copper beryllium, and zirconium)
PAPER
POLYETHYLENE
RUBBER
RUBBER GLOVES
SOLIDIFICATION AGENTS/ABSORBANTS (Portland Cement, Aquaset, Petroset, Envirostone)
STAINLESS STEEL

FIGURE WITHHELD UNDER 10 CFR 2.390

PROPRIETARY	PROJECT No. 003-10091 FILE ID. 11050112		CHEM–NUCLEAR SYSTEMS
☒ NON–PROPRIETARY	REVIEWERS OF ORIGINAL (REV. 0)		
FSCM No. 54643	DRAWN BY CHRIS SMOAK	4/8/88	CASK ASSEMBLY GENERAL NOTES/PARTS LIST 10–160B
DIMENSIONS ARE IN INCHES UNLESS NOTED DO NOT SCALE PRINT	CHECKED BY MIKE AHEARN	4/8/88	
	ENGINEER CARL McGOVERN	4/8/88	
	QUALITY ASSURANCE Wm H PETER	4/11/88	SIZE D	DRAWING NUMBER C–110–D–29003–010	REV. 12
	APPROVAL R.T. ANDERSON	4/11/88	SCALE 1:5	WT. N/A	SHEET 1 OF 5

FABRICATION GENERAL NOTES

1. THESE CONTAINMENT WELDS SHALL BE INSPECTED PER ASME CODE, SECTION III, DIV. I, SUBSECTION ND, ARTICLE ND-5000.

2. ALL FERROMAGNETIC MATERIAL WELDS SHALL BE INSPECTED PER ASME CODE, SECTION III, DIV. I, SUBSECTION NF, NF-5230 FOR CLASS 3 SUPPORT ATTACHMENTS AND SECTION V, ARTICLE 7 FOR MAGNETIC PARTICLE (MT) EXAMINATIONS AND SECTION V, ARTICLE 6 FOR LIQUID PENETRANT (PT) EXAMINATIONS. ACCEPTANCE STANDARDS SHALL BE PER ASME SECTION III, DIV. I, SUBSECTION NF-5340 AND NF-5350, AS APPROPRIATE.

ALL NON-FERROMAGNETIC MATERIAL WELDS SHALL BE LIQUID PENETRANT (PT) INSPECTED PER ASME CODE SECTION V, ARTICLE 6 WITH ACCEPTANCE CRITERIA PER ASME CODE, SECTION III, DIV. I, SUBSECTION NF, NF-5350

WELDS ON LIFTING AND TIEDOWN LUGS SHALL BE INSPECTED BEFORE AND AFTER 150% LOAD TEST IN ACCORDANCE WITH THE ASME CODE REQUIREMENTS FOR MT EXAMINATION AS SPECIFIED ABOVE.

3. WELDING SHALL BE IN ACCORDANCE WITH ASME CODE SECTION IX. ALL WELDS TO BE FULL PENETRATION UNLESS OTHERWISE SPECIFIED.

4. LEAD INTEGRITY AND SHIELDING EFFECTIVENESS. ALL LEAD POURING SHALL BE DONE CONTINUOUSLY TO AVOID GAPS OR RADIATION STREAMING PATHS. GAMMA SCAN OR GAMMA PROBE WILL BE REQUIRED TO ENSURE SHIELDING INTEGRITY. LOSS OF SHIELDING AT ANY POINT IN EXCESS OF 10% WILL REQUIRE REMEDY BY THE FABRICATOR. THE PROCEDURES AND EQUIPMENT TO BE USED FOR THE GAMMA SCAN SHALL BE APPROVED BY CHEM-NUCLEAR PRIOR TO PERFORMANCE OF THE TEST.

5. PAINT SHALL BE IN ACCORDANCE WITH CNS APPROVED PROCEDURES.

6. LOCKWIRE IMPACT LIMITER AS SHOWN FOR EACH SHIPMENT. SEE ITEM 39 AND 40.

7. TORQUE PRIMARY LID AND SECONDARY LID BOLTS TO 300 ±30 FT/LBS. OPTIONAL VENT AND DRAIN PLUGS, ITEM 13 TO 20 ±2 FT-LBS.

8. ALIGNMENT STRIPES ARE PROVIDED ON LIDS, IMPACT LIMITERS AND CASK BODY FOR PROPER COMPONENT ORIENTATION AT ASSEMBLY.

9. MAXIMUM CASK PAYLOAD WEIGHT 14,500 LBS
MAXIMUM LICENSED (NRC) GROSSWEIGHT 72,000 LBS

10. ALL SEALING SURFACES 32 rms OR BETTER

11. THE NIL DUCTILITY TRANSITION TEMPERATURE OF FRACTURE CRITICAL COMPONENTS AND WELDING SHALL BE DETERMINED USING METHODS OF ASTM E208-81. ITEMS 1, 3, 4, 5, 24 AND 25 SHALL HAVE NIL DUCTILITY TRANSITION TEMPERATURES (TNDT) NO GREATER THAN THE TNDT LISTED BELOW:

PLATE THICKNESS	MAXIMUM TNDT °F
1 1/8 INCH	0
2 INCH	-3
2 1/2 INCH	-14
3 INCH	-20

WELDS JOINING BOTTOM END PLATES AND THE UPPER RING TO THE SHELLS SHALL BE MADE USING A WELD PROCEDURE QUALIFIED TO A MAXIMUM TNDT OF -3°F PER QW-172 OF THE ASME CODE SECTION IX.

12. ALL DIMENSIONS / VALUES SHOWN ARE NOMINAL UNLESS OTHERWISE SPECIFIED.

13. MT INSPECT THE ROOT PASS AND COVER PASS OF THE WELD PER THE REQUIREMENTS OF GENERAL NOTE 2.

14. MT INSPECT THE ROOT PASS, EACH SUCCESSIVE PASS AND THE COVER PASS OF THIS WELD. ACCEPTANCE STANDARDS SHALL BE PER ASME CODE SECTION III, DIV. I, SUBSECTION ND-5340.

15. A BACKING RING SHALL BE USED TO PREVENT LEAD CONTAMINATION OF THESE WELDS. APPROVAL BY CNS OF THE BACKING RING DESIGN IS REQUIRED.

16. FABRICATION TOLERANCES
BODY: O.D., I.D.,= +0 -1/2"
HEIGHT= +0 -1"
MACHINED ITEMS AND LOCATION DIMENSIONS = ±1/8"
BOLT HOLE LOCATIONS MATCH DRILLED WITH LID
LIDS: O.D±1/4" RELATIVE TO BODY DIAMETER
STEPPED DIAMETERS SHALL HAVE A 1/8" GAP +1/8 -0" BETWEEN PRIMARY LID AND BODY, SECONDARY LID AND PRIMARY LID
MACHINED PARTS AND LOCATION DIMENSIONS ±1/8"
IMPACT LIMITERS: O.D., I.D. = +0 -1/2" RELATIVE TO CASK BODY SIZE
I.D SHALL HAVE A 1/2" GAP +1/8 -0" BETWEEN IMPACT LIMITER AND BODY
MACHINED ITEMS AND LOCATION DIMENSIONS ±1/8"
SEALS: PER STANDARD DOVETAIL GROOVE DESIGN FOR O-RINGS 1/4" NOM. CROSS SECTION

17. ITEM 17 USED ON PRIMARY LID (3 PLACES) WHEN SECONDARY LID IS IN PLACE.
ITEM 57 USED ON PRIMARY LID (3 PLACES) TO LIFT PRIMARY LID ONLY, WHEN SECONDARY LID IS NOT BOLTED IN PLACE TO PRIMARY LID

MATERIAL SPECIFICATIONS

LTR	DESCRIPTION
A	ASME-SA516 GR 70
B	ASTM-B29 CHEMICAL GR LEAD
C	ASTM-A517 GR F
D	ASTM-A240, TYPE 304
E	ASTM-313, TYPE 304 OR ASTM-478, TYPE 304
F	SCH 40 S
G	ASTM-A240, TYPE 304L
H	ASTM-A108
J	304 SST
K	ASTM-A570
L	TEFLON COATED, 450°F TEMPERATURE RANGE
M	ASTM-A516 GR 70
N	ASTM-A36
P	18-8 SST
Q	ASTM-A354-BD
R	ASTM-F436
S	SILICONE, 50-70 DUROMETER, TEMPERATURE RANGE -65°F TO 450°F
T	ASTM-A563, GRADE DH
U	ES-M-172
V	SCH 5S
W	WEATHERPROOF RUBBER NON-SKID OR EQUIVALENT
X	CLOSED CELL SPONGE RUBBER TUBING, ADHERED WITH RTV
Y	GR 3 OR BETTER
Z	MOLDED RUBBER/METAL SEAL C/S BOLT MATERIAL -65° F - TEMP. RANGE
AA	10,000 LB W.L.L
BB	45,000 LB ULTIMATE STRENGTH-JAWS AND RATCHET EYEBOLT 7/8" DIA. 17.4 PH MATERIAL
CC	ASME-SA537, CLASS 2, MIN. UTS=82,000 PSI
DD	ASTM-A540-B21, CLASS 1

BILL OF MATERIALS

ITEM	QTY	DESCRIPTION		MATERIAL SPEC. REFERENCE
57	3	(OPTION) SWIVEL HOIST RING 1 1/4 - 7 UNC		AA
56	A/R	(OPTION) DEBRIS SEAL 1" DIA NOM		X
55	A/R	RATCHET BINDER STOPS, 11 GA.		D
54	8	RATCHET BINDER WITH EYEBOLS		BB
53	A/R	NON SKID MAT		W
52	3	LIFT EAR 1/4" THICK		M
51	16	#10 SHEETMETAL SCREW		P
50	1	HANDLE 1/4" DIA (1 1/2" X 6")		K
49	1	RAIN COVER 50 1/2" DIA, 12 GA.		K
48	24	BOLT COVER, 4 1/2" DIA, 11 GA.		K
47	24	BOLT COVER, 4" PIPE X 2 1/2" LG		V
46	16	RATCHET BINDER LUG 1/2" PLATE		N
45	A/R	1/2" PLATE		M
44	A/R	12 GA. SHEET, 1 1/2"		K
43	A/R	ANGLE 1/8" X 1 1/2" X 1 1/2"		N
42	A/R	FOAM		U
41	A/R	IMPACT LIMITER SKIN 11 GA.		K
40	A/R	WASHER 3/4" O.D. CUT IN HALF		P
39	A/R	TAMPERPROOF SEAL		COMMERCIAL
38	2	1/2" NPT HEX SOCKET PLUG		L
37	36	NUT (OPTION) 1 3/4"-8 UNC		T
36	36	STUD/LID (OPTION) 1 3/4"-8 UNC X 7 1/2" LG +0-1/8		Q
35	2	TUBE 1/4" O.D. X 1/16" WALL		J
34	4	LID ALIGNMENT PIN 3/4" DIAMETER		H
33	36	FLAT WASHER, REGULAR 1 3/4"		R
32	36	HEX HD CAP SCREW, 1 3/4"-8UNC X 5 3/8" LG +0-1/8		Q or DD
31	1	O'RING INNER SECONDARY LID	.285 NOM. CROSS SECTION	S
30	1	O'RING OUTER SECONDARY LID		
29	1	O'RING INNER PRIMARY LID		
28	1	O'RING OUTER PRIMARY LID		
27	2	SEAL RING PLATE 5/8" THICK		G
26	3	LID LIFT LUGS 1" THICK		A
25	1	SECONDARY LID 5 1/2" THICK		A
24	1	PRIMARY LID 5 1/2" THICK		A
23	16	FLAT WASHER REGULAR, 1 1/4"		R
22	16	HEX HD CAP SCREW 1 1/4"-7UNC X 3" LG +0-1/8		Q
21	2	REDUNDANT LIFT LUG 2 1/4" THICK		M
20	2	LIFT LUG 1" THICK		M
19	4	LIFT LUG 1" THICK		M
18	2	LIFT LUG 2 1/4" THICK		M
17	3	SET SCREW, 1 1/4-7 UNC x 2 1/2" LG., S.S.		COMMERCIAL
16	1	PIPE 1" SCH 40 S		F
15	2	1/2" STAT-O-SEAL		Z
14	2	HEX HD CAP SCREW, 1/2-20 UNF X 1" LG.		Y
13	2	1" NPT HEX SOCKET PLUG		L
12	24	PLUG 1/4" THICK		M
11	A/R	INNER LINING 11 GA.		D
10	4	LIFT LUG PADS 2" THICK		M
9	1	THERMAL BARRIER 12 GA.		K
8	A/R	WIRE SPACER 5/32" DIAMETER		E
7	1	SEAL SURFACE 1/4" THICK		D
6	4	TIE-DOWN LUG 2 1/2" THICK		C
5	1	BASE 5 1/2" THICK		A
4	1	BOLT RING 3" THICK		A or CC
3	1	INNER SHELL 1 1/8" THICK		A or CC
2	A/R	LEAD 1 7/8" THICK		B
1	1	OUTERSHELL 2" THICK		A

PROPRIETARY
☒ NON-PROPRIETARY
FSCM No. 54643
DIMENSIONS ARE IN INCHES UNLESS NOTED
DO NOT SCALE PRINT

PROJECT No.893-10091 FILE ID. 11050212
REVIEWERS OF ORIGINAL (REV. 0)
DRAWN BY CHRIS SMOAK 4/8/88
CHECKED BY MIKE AHEARN 4/8/88
ENGINEER CARL McGOVERN 4/8/88
QUALITY ASSURANCE Wm H PETER 4/11/88
APPROVAL R.T. ANDERSON 4/11/88

CHEM-NUCLEAR SYSTEMS

CASK ASSEMBLY
GENERAL NOTES/PARTS LIST
10-160B

SIZE D DRAWING NUMBER C-110-D-29003-010 REV. 12
SCALE 1:4 WT. N/A SHEET 2 OF 3

FIGURE WITHHELD UNDER 10 CFR 2.390

PROPRIETARY	PROJECT No. 663-10091 FILE ID. 11050312		CHEM–NUCLEAR SYSTEMS
☒ NON–PROPRIETARY	REVIEWERS OF ORIGINAL (REV. 0)		
FSCM No. 54643	DRAWN BY CHRIS SMOAK	4/8/88	CASK ASSEMBLY GENERAL NOTES/PARTS LIST 10–1603
DIMENSIONS ARE IN INCHES UNLESS NOTED DO NOT SCALE PRINT	CHECKED BY MIKE AHEARN	4/8/88	
	ENGINEER CARL McGOVERN	4/8/88	
	QUALITY ASSURANCE Wm H PETER	4/11/88	SIZE D DRAWING NUMBER C–110–D–29003–010 REV. 12
	APPROVAL R.T. ANDERSON	4/11/88	SCALE 1:4 WT. N/A SHEET 3 OF 5

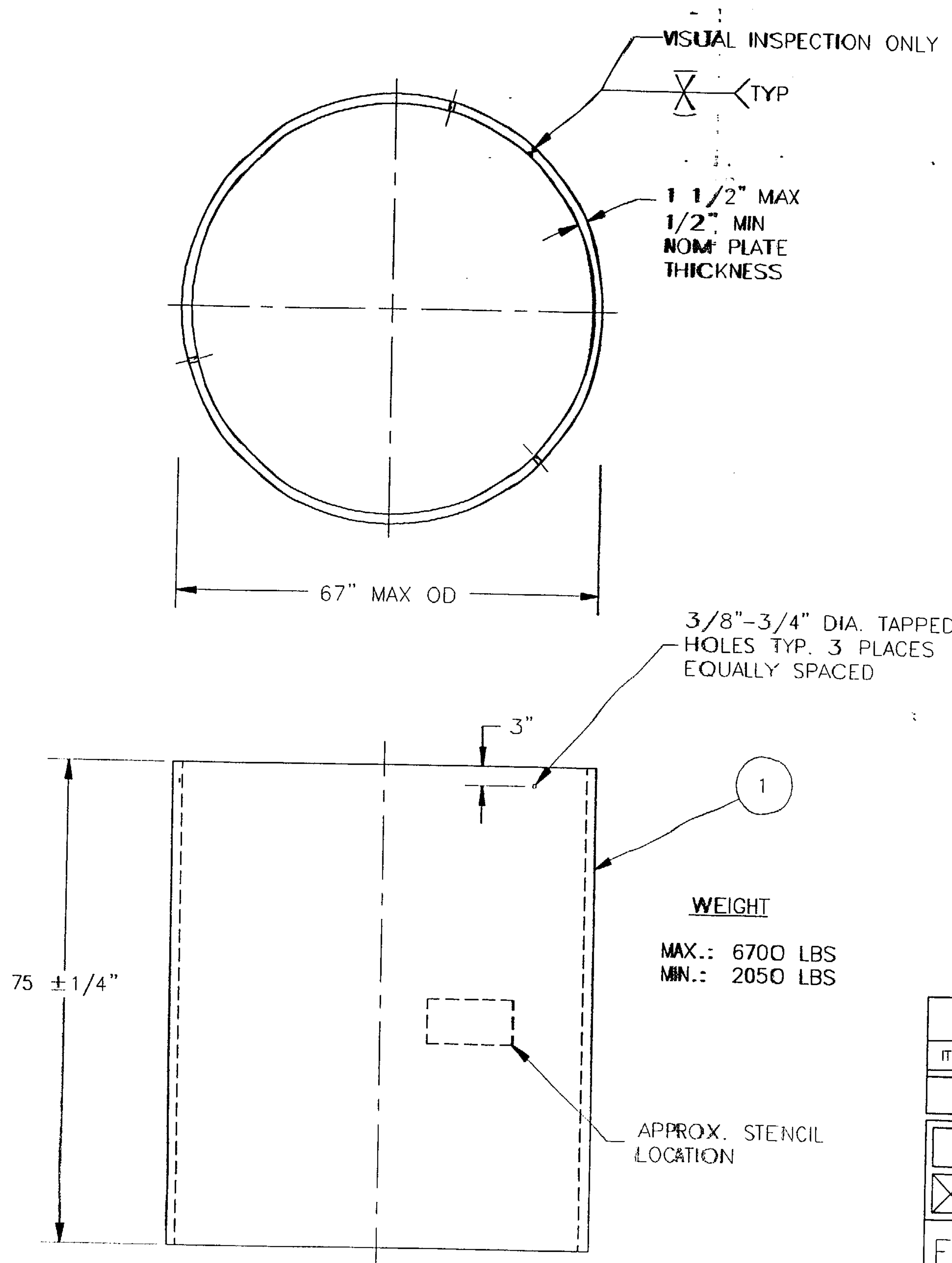
FIGURE WITHHELD UNDER 10 CFR 2.390

PROPRIETARY	PROJECT No. 093-10091	FILE ID. 11050412	CHEM–NUCLEAR SYSTEMS	
☒ NON–PROPRIETARY	REVIEWERS OF ORIGINAL (REV. 0)			
FSCM No. 54643	DRAWN BY CHRIS SMOAK	4/8/88	CASK ASSEMBLY GENERAL NOTES/PARTS LIST 10–160B	
DIMENSIONS ARE IN INCHES UNLESS NOTED DO NOT SCALE PRINT	CHECKED BY MIKE AHEARN	4/8/88		
	ENGINEER CARL McGOVERN	4/8/88		
	QUALITY ASSURANCE Wm H PETER	4/11/88	SIZE D DRAWING NUMBER C–110–D–29003–010	REV. 12
	APPROVAL R.T. ANDERSON	4/11/88	SCALE 1 : 4 WT. N / A	SHEET 4 OF 5

A

FIGURE WITHHELD UNDER 10 CFR 2.390

☐ PROPRIETARY	PROJECT No. 003-10091	FILE ID. 11050512	CHEM-NUCLEAR SYSTEMS	A
☒ NON-PROPRIETARY	REVIEWERS OF ORIGINAL (REV. 0)			
FSCM No. 54643	DRAWN BY CHRIS SMOAK	4/8/88	CASK ASSEMBLY GENERAL NOTES/PARTS LIST 10-160B	
DIMENSIONS ARE IN INCHES UNLESS NOTED DO NOT SCALE PRINT	CHECKED BY MIKE AHEARN	4/8/88		
	ENGINEER CARL McGOVERN	4/8/88		
	QUALITY ASSURANCE Wm H PETER	4/11/88	SIZE D DRAWING NUMBER C-110-D-29003-010	REV. 12
	APPROVAL R.T. ANDERSON	4/11/88	SCALE 1:4 WT. N/A	SHEET 5 OF 5



NOTE:
1. FABRICATION DIMENSIONS SHALL BE WITHIN THESE RANGES, AND SHALL BE SPECIFIED WITH PROCUREMENT DOCUMENTATION.

2. PAINT, STENCIL AND LIFTING SYSTEM REQUIREMENTS TO BE SPECIFIED WITH PROCUREMENT DOCUMENTATION.

ITEM	QTY	DESCRIPTION	SPEC. AND / OR PART No.
1	A/R	PLATE 1/2", 1", 1 1/2" AS REQUIRED C/S	ASTM-A36

BILL OF MATERIALS

☐ PROPRIETARY
☒ NON-PROPRIETARY

FSCM No. 54643

DO NOT SCALE PRINT
DIMENSIONS ARE IN INCHES UNLESS NOTED

PROJECT No. 04600 FILE ID. 10910102

REVIEWERS OF ORIGINAL (REV. 0)

DRAWN BY	JEREMY MURPHY	8/7/98
CHECKED BY	MIKE AHEARN	8/7/98
ENGINEER	CHARLES WITT	8/7/98

CHEM-NUCLEAR SYSTEMS

10-160B
SHIELD INSERT

SIZE	DRAWING NUMBER	REV.
B	C-119-B-0018	2

SCALE 1 : 24 WT. N / A SHEET 1 OF 1

ATTACHMENT 6

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

ATTACHMENT 7
DISCUSSION OF CHANGES

ATTACHMENT 7

DISCUSSION OF CHANGES TO THE CNS 10-160B SAR

1. Changes Applicable to TRU Waste

Appendix 4.10.2:

This appendix contains the payload parameter requirements associated with the shipment of transuranic (TRU) waste, both remote handled (RH) and contact handled (CH), in the CNS 10-160B cask. The requirements were moved from the previously approved Appendix 4.10.2.1 "Compliance Methodology for RH-TRU Waste From Battelle Columbus Laboratories (BCL) West Jefferson, OH" dated November 2000. Changes to the previously approved requirements include:

- The removal of activated reactor components in Section 4.0, Physical Form Requirements.
- The generalization of the filter vent requirements in Section 8.0 Payload Container and Contents Configuration. The filter vent requirements are specified in detail in each of the site-specific payload compliance appendices.
- The simplification of the method used for calculating hydrogen gas generation rate limits and decay heat limits in Section 10.0, Decay Heat and Hydrogen Gas Generation Rates. The transient model methodology previously used for the BCL content codes has been replaced with the simpler and more conservative pseudo-steady state model. This change is described in more detail below.
- The individual payload container weight limit of 1000 pounds has been removed in Section 11.0, Weight.

Typical compliance methods used to meet the requirements are summarized in Section 2.0 of Appendix 4.10.2. These compliance methods were taken directly from Section 1.4 of Appendix 1.3.7 (RH-TRAMPAC) of the Safety Analysis Report for the RH-TRU 72-B Waste Shipping Package (72-B Cask SAR), Revision 3, currently under review by the U.S. Nuclear Regulatory Commission (NRC).

The pseudo-steady state method presented for calculating hydrogen gas generation rate limits in Section 10.3 of Appendix 4.10.2 has been used for determining the hydrogen gas generation rate for all CH-TRU waste to be shipped in the TRUPACT-II shipping package for many years. This methodology was taken from the TRUPACT-II Authorized Methods for Payload Control (TRAMPAC) approved by the NRC as part of Revision 19 of the Safety Analysis Report for the TRUPACT-II Shipping Package (TRUPACT-II SAR) and Appendix 3.6.9 of the TRUPACT-II SAR, Revision 19.

The methods for calculating the decay heat limits presented in Section 10.4 of Appendix 4.10.2 of the CNS 10-160B SAR are taken from the Appendix 5.5 of the TRAMPAC (part of Revision 19 of the TRUPACT-II SAR) for CH-TRU waste and from Appendix 3.6.9 of the 72-B Cask SAR, Revision 3, currently under review by the NRC, for RH-TRU waste.

Attachment A to Appendix 4.10.2 – Use of Dose-Dependent G Values for TRU Waste

Attachment A describes the use of dose-dependent G values for TRU waste based on the results of the Matrix Depletion Program. This attachment is taken directly from Appendix 5.2 of the TRAMPAC (part of Revision 19 of the TRUPACT-II SAR) and Section 5.0 of Appendix 1.3.7 (RH-TRAMPAC) of the 72-B Cask SAR, Revision 3, currently under review by the NRC.

Attachment B to Appendix 4.10.2 – Chemical Compatibility of TRU Waste Content Codes

Attachment B presents the chemical compatibility analysis performed for TRU waste content codes. This attachment is taken directly from Appendix 2.10.12 of the 72-B Cask SAR, Revision

3, currently under review by the NRC, and Appendix 2.10.12 of the TRUPACT-II SAR, Revision 19.

Attachment C to Appendix 4.10.2 – Shipping Period for TRU Waste in the 10-160B Cask

Attachment C presents the basis for the 60-day shipping period for TRU waste in the CNS 10-160B cask. This attachment was previously Attachment D to Appendix 4.10.2.1 of the CNS 10-160B SAR, Revision 16, November 2000. Minor modifications have been made to the attachment so that it is applicable to all TRU waste shipment within the CNS 10-160B cask. The maximum shipping period has not been altered.

Appendix 4.10.2.1 – Compliance Methodology for TRU Waste From Battelle Columbus Laboratories (BCL), West Jefferson, OH

This appendix is based on the previously approved Appendix 4.10.2.1, Revision 16 of the CNS-10-160B SAR. Changes to this appendix include:

- Two CH-TRU waste content codes have been added to the appendix (BC 121A and BC 121B)
- The hydrogen gas generation rate limits and decay heat limits have been updated for all content codes using the pseudo-steady state modeling methodology.
- The hydrogen gas generation rate limit and decay heat limit modeling methodology has been moved from the site-specific appendix to payload requirement appendix, Appendix 4.10.2.

Appendix 4.10.2.2 – Compliance Methodology for TRU Waste From Missouri University Research Reactor, Columbia, MO

This appendix provides the payload compliance methodology to qualify 7 drums of CH-TRU waste for shipment in the CNS 10-160B cask. Compliance is based on records and data packages (process knowledge) for the individual drums. This site-specific payload compliance appendix is new.

Appendix 4.10.2.3 – Compliance Methodology for TRU Waste From Energy Technology Engineering Center (ETEC)

This appendix provides the payload compliance methodology to qualify 7 content codes of TRU waste for shipment in the CNS 10-160B cask (4 RH-TRU content codes and 3 CH-TRU content codes). This site-specific payload compliance appendix is new.

Appendix 4.10.2.4 – Compliance Methodology for TRU Waste From Lawrence Livermore National Laboratory, Livermore, CA

This appendix provides the payload compliance methodology to qualify 6 drums of CH-TRU waste for shipment in the CNS 10-160B cask. Compliance is based on records and data packages (process knowledge) for the individual drums. This site-specific payload compliance appendix is new.

2. Changes to Chapter 4 and Chapter 8

- Chapters 4 and 8 have been revised to require evacuation of the volume being tested, prior to performing a periodic leak test; when using R12 or R134a test gas. This evacuation alleviates concerns expressed in the R134a MSDS regarding the mixing of R134a with relatively large quantities of air. For consistency, evacuation is also performed when using R12. As this changes the concentration of halogen gas used to detect a leak, the leak rate calculations have been revised (Sections 4.5 through 4.7).

- Chapters 4 and 8 have been further amended to remove the make and model specification for the halogen leak detector and calibration standard. Selection of the detector and standard will be based on the performance requirements, i.e., ability to measure at the specified leak rate and sensitivity, specified in Chapters 4 and 8 of the SAR. This will allow the cask user flexibility in selection of detection units and standards. Further, the units currently specified are no longer commercially available.

- The third paragraph of Section 8.1.3 was changed to clarify the periodic leak test acceptance criteria.

- Sections 8.1.4 and 8.2 (1st paragraph) were revised to replace references to "CNSI" with "Duratek".

- Section 8.2.1.1 was revised to correct a typographical error with regard to a referenced drawing.

- Editorial changes were made to parts "b" and "c" of Section 8.2.1.2.

- The third paragraph in Section 8.2.2.2 was revised to reflect the language in Section A.5.2.4 (2nd paragraph) of ANSI 14.5-1997.

- Section 8.2.2.2 (last paragraph) was revised to reflect the latest revision of ANSI 14.5 (ANSI 14.5-1997).

3. Changes to Chapter 7

- Section 7.4.1.3 is revised to eliminate the sampling requirement following nitrogen inertion. Duratek has demonstrated by analysis that a void can be inerted by pressurizing with nitrogen to 15 psig, depressurizing to 0 psig, and repeating this process two more times. The essential steps of the inertion process (which assures that the oxygen level is reduced to less than 5%) were added to Section 7.4.1.3. Section 7.4.1.2 was changed to remove the parenthetical statement that cask inerting will be performed by a special procedure since the process specified in 7.4.1.3 is used for the cask as well as the secondary container.

4. Changes to Design Drawings

<u>Drawing C-110-D-29003-010</u>

SHEET 1 0F 5

- ZONE E6/E7: DELETED ITEMS 39 AND 40 (2 PLACES)
- ZONE C3/D3: DELETED ITEMS 39 AND 40 (5 PLACES)
  These change were made to remove redundant tamper seal locations. Seals remain on the rain cover, upper impact limiter to cask body, and lower impact limiter to cask body. The containment boundary can not be breached without breaking at least one of these three seals.
- ZONE C5: ADDED "OPTIONAL" TO ITEM 56
  This debris seal is not required for regulatory compliance; it is for convenience in maintaining the appearance of the cask.
- ZONE E5/D8/B7/A6: ADDED FLAG NOTE 16
  This note was inadvertently left off earlier revisions

SHEET 2 OF 5

- ZONE A7: DELETED "REV.0" FROM LETTER –U-
  Change to indicate the most current revision of the specification instead of a specific revision.

- ZONE E6: REVISED NOTE 6 TO "LOCKWIRE IMPACT LIMITER AS SHOWN FOR EACH SHIPMENT. SEE ITEMS 39 AND 40
  Revised to be consistent with the change to the seal locations noted above
- ZONE A4: ADDED (OPTION) TO ITEM 56
  This debris seal is not required for regulatory compliance; it is for convenience in maintaining the appearance of the cask.
- ZONE A4: REVISED QTY. OF ITEM 55 FROM 4 TO A/R
  These stops are not required for regulatory compliance; they are for convenience in operating the cask.
- ZONE A8: REVISED MATERIAL SPEC –W- TO: WEATHERPROOF RUBBER NON-SKID OR EQUIVALENT
  Removed the RTV adhesive to allow fabrication flexibility

SHEET 3 OF 5
- ZONE F7,C7, AND C6: ADDED FLAG NOTE 16 (FOUR PLACES)
  This note was inadvertently left off earlier revisions

SHEET 4 OF 5
- ZONE F8, C7, AND B7: ADDED FLAG NOTE 16 (FOUR PLACES)
  This note was inadvertently left off earlier revisions

Drawing C-119-B-0018
- ZONE A/3: FOLLOWING NOTE WAS REMOVED:

> "THIS DRAWING IS THE PROPERTY OF CHEM-NUCLEAR SYSTEMS. IT IS LOANED UPON CONDITION THAT IT IS NOT TO BE REPRODUCED, COPIED, OR LOANED TO OTHERS WITHOUT THE WRITTEN PERMISSION OF CHEM-NUCLEAR SYSTEMS AND IS TO BE RETURNED UPON REQUEST."

The note does not reflect current company policy.

5. Suggested Changes to the Certificate of Compliance

Page 1
5.(a)(2) Description
Overall package height, with impact limiters ~~30~~ 130 inches

This is apparently a typographical error.

Page 2
5.(a)(3) Drawings
Change the cask drawing revision level to 12 and the shield insert to revision 2 to reflect the revised drawings submitted.

Page 3
5.(b)(2) Maximum quantity of material per package
Remove the third sentence. The drum weights are not a critical constraint for transportation. The drum weight limit has been removed from the SAR TRU appendicies.

Page 4
11.(c)(1)
Remove "and weight" in line 3 and change to "in accordance with Appendix 4.10.2" in line 4. This reflects the change above and the change to the organization of Appendix 4.10.2.

11.(c)(2)
Revise to "Each waste container must not exceed the decay heat limits in Section 10 of the applicable site specific appendix to Appendix 4.10.2 or must satisfy the requirements of Attachment B, "Methodology for Determination of Decay Heats and Hydrogen Gas Generation Rates..." of the applicable site specific appendix; and"
Each site specific appendix includes an Attachment B for the waste for that site. The requirement should specify that Attachment B for the specific site.

11.(c)(3)
Revise to "One or more filter vents must be installed in the payload container and any sealed secondary containers overpacked in the payload container. Filter vents must meet the minimum specifications in Section 8, "Payload Container and Contents Configuration" of the applicable site specific appendix to Appendix 4.10.2; and"
Each site specific appendix includes a Section 8 which specifies the payload container and filter vents. The requirement should specify the Section 8 for the specific site.

ATTACHMENT 8
DOE LETTER

TRU Solutions
Westinghouse TRU Solutions LLC

P.O. Box 2078
Carlsbad, New Mexico 88221-2078
Phone: (505) 234-7200 Fax: (505) 234-7083

TP:02:04089
UFC:5822.00

June 6, 2002

Mr. D. H. Tiktinsky, Project Manager
NMSS/SFPO MS/06F18
U.S. Nuclear Regulatory Commission
One White Flint North
15555 Rockville Pike
Rockville, MD 20852-2738

Subject: PRIORITY REQUEST FOR REVISIONS TO THE CONTACT-HANDLED AND REMOTE-HANDLED PACKAGINGS

Dear Mr. Tiktinsky:

Westinghouse TRU Solutions LLC, on behalf of the U.S. Department of Energy (DOE), hereby requests that the revision to the CNS 10-160B shipping cask receive a higher priority than revision 3 to the Remote-Handled (RH) 72-B shipping cask. Once the CNS 10-160B amendment is completed, please continue with the priorities requested by our letter dated November 27, 2001.

The reprioritization does not alter the priority request for Revision 19a to the TRUPACT-II. Revision 19a remains the highest priority as requested by the DOE letter dated March 27, 2002.

If you have any questions regarding this request, please contact me at (505) 234-7463.

Sincerely,

M L Caviness

M. L. Caviness, Manager
Packaging Engineering

MLC:lmc

cc: T. A. Baillieul, DOE-OH
M. C. Gross, DOE-OAK
M. A. Italiano, CBFO
J. D. VandeKraats, CBFO
K. W. Watson, CBFO

UNIQUE #	DOE UFC	DATE REC'VD	ADDRESSEES
0209400	5822.00	JUN 10 2002	M. Italiano J. VandeKraats K. Watson