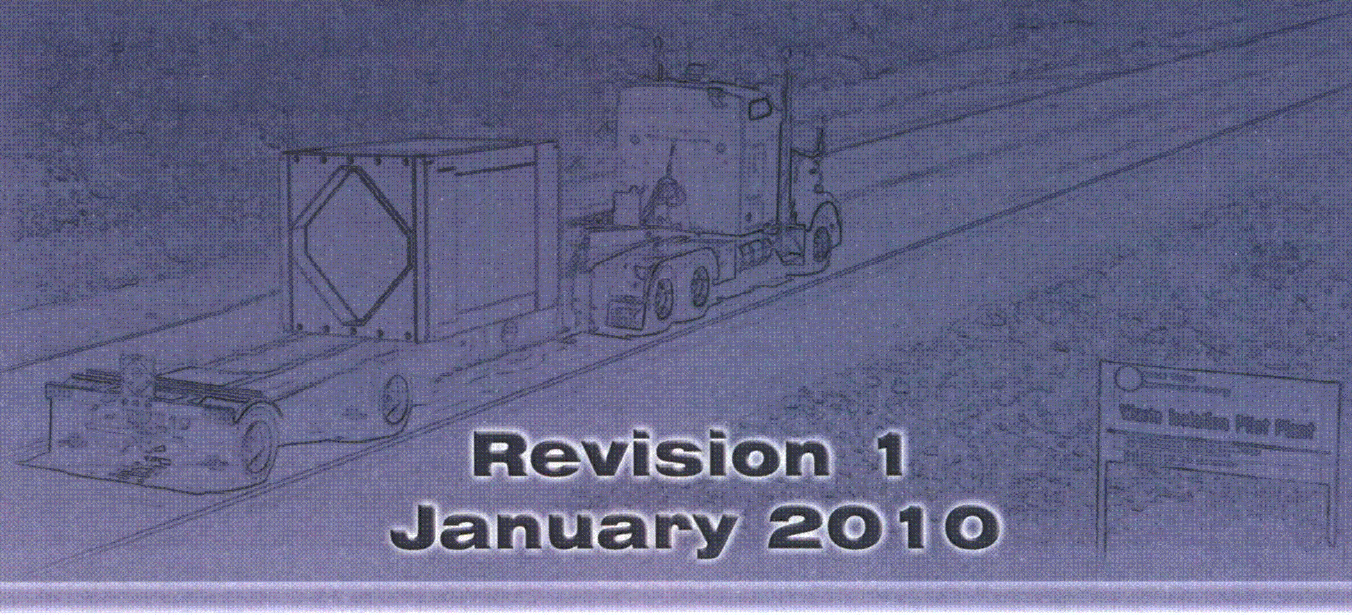
TRUPACT-III

TRAMPAC



Revision 1
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LIST OF ABBREVIATIONS AND ACRONYMS

ALARA	as-low-as-reasonably-achievable
ANS	American Nuclear Society
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
CBFO	Carlsbad Field Office
CFR	Code of Federal Regulations
CH	contact-handled
CM	concentration multiplier
CTU-2	certification test unit #2
DAC	drum age criteria
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
eV	electron volts
FGE	Pu-239 fissile gram equivalent
FGGR	flammable gas generation rate
GCF	group contribution factor
ID	Identification
MLEL	mixture lower explosive limit
mrem/hour	millirem per hour
MS	mass spectrometry
NCT	normal conditions of transport
NDE	nondestructive examination
NRC	U.S. Nuclear Regulatory Commission
PF	prediction factor
ppm	parts per million
psia	pounds per square inch absolute
psig	pounds per square inch gauge
PTCD	Payload Transportation Certification Document
QA	quality assurance
SLB2	Standard Large Box 2
STP	standard temperature and pressure
TCO	Transportation Certification Official
TRAMPAC	TRU Waste Authorized Methods for Payload Control
TRU	transuranic
TRUCON-III	TRUPACT-III Content Codes
TRUPACT-III TRAMPAC	TRUPACT-III TRU Waste Authorized Methods for Payload Control
VOC	volatile organic compound
WIPP	Waste Isolation Pilot Plant

1.0 INTRODUCTION

The TRUPACT-III TRU Waste Authorized Methods for Payload Control (TRUPACT-III TRAMPAC) is the governing document for shipments in the TRUPACT-III packaging. All users of the TRUPACT-III shall comply with all payload requirements outlined in this document, using one or more of the methods described.

1.1 Background

Several U.S. Department of Energy (DOE) sites have contact-handled (CH) transuranic (TRU) waste inventories that were packaged in large boxes. These boxes, which are too large to be accommodated by the packagings currently licensed for CH-TRU waste shipment (i.e., TRUPACT-II and HalfPACT), are considered "oversized." The largest rectangular box that potentially could be transported in a TRUPACT-II is approximately 4- x 4- x 5.5-feet. The oversized inventory in storage at the DOE sites is in boxes that are nominally 4- x 4- x 7-feet or larger. The TRUPACT-III packaging has been designed and developed primarily for the transportation of these large boxes. In addition to existing large boxes, it is anticipated that ongoing or planned site activities will result in the generation of new large boxes (e.g., decontamination and decommissioning of site facilities). The TRUPACT-III packaging is considered a cost-effective and safe alternative to designing, building, and operating repackaging and size-reduction facilities at each of the sites to repackage the oversized waste inventory into smaller containers for transportation in the TRUPACT-II packaging. The use of the TRUPACT-III for the shipment of oversized boxes that meet the requirements of this document is consistent with *as-low-as-reasonably-achievable* (ALARA) considerations associated with waste packaging and transportation plans that will decrease worker exposure by reducing the amount of waste that must be repackaged or size reduced.

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1.2 Scope

The TRUPACT-III TRAMPAC defines the authorized contents for the TRUPACT-III packaging.

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1.3 Purpose

The purposes of the TRUPACT-III TRAMPAC are to:

- Define the requirements for a payload to be transported in the TRUPACT-III packaging
- Describe the compliance methodology that shall be used to evaluate and prepare the payload for transport in a TRUPACT-III packaging
- Identify the quality assurance (QA) program that shall be applied to these methods.

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1.4 Requirements

Requirements are established to ensure compliance of the payload with the transportation parameters of the TRUPACT-III packaging. The TRUPACT-III TRAMPAC defines payload requirements under the following categories:

- Container and Physical Properties (Chapter 2.0)
- Nuclear Properties (Chapter 3.0)
- Chemical Properties (Chapter 4.0)
- Gas Generation Properties (Chapter 5.0)
- Payload Assembly Criteria (Chapter 6.0)
- Quality Assurance (Chapter 7.0).

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1.5 Methods of Compliance

This document describes allowable methods to be used for determining compliance with each payload requirement and the controls imposed on the use of each method. Each generator or storage site shall select and implement a single method, or a combination of methods, to ensure that the payload is compliant with each requirement and is qualified for shipment. These methods shall be delineated in a programmatic or waste-specific data TRU Waste Authorized Methods for Payload Control (TRAMPAC).

Each shipper shall document and demonstrate compliance with the TRUPACT-III TRAMPAC by one of the following methods:

- A programmatic TRAMPAC, which defines the process in which payload compliance is met, will be prepared by the shipper and approved by the DOE Carlsbad Field Office (CBFO). Implementing procedures of the TRAMPAC will be reviewed by the DOE-CBFO for completeness and compliance as part of the audit process.
- A waste-specific data TRAMPAC will be prepared by the shipper and approved by the DOE-CBFO. The waste data are evaluated against the requirements in this document.

A summary of the methods of compliance that shall be used for TRUPACT-III payload control is provided in the following sections.

1.5.1 Visual Examination

Visual examination at the time of waste generation and/or packaging may be used to qualify waste for transport. For example, site/equipment-specific procedures at a waste generating area may require visual examination of the physical form of the waste by the operator and the removal of all prohibited waste forms prior to placement in the payload container.

1.5.2 Visual Inspection

Visual inspection may be used to evaluate compliance with specific requirements (e.g., visual inspection of payload container marking). Visual inspection is typically used to verify external characteristics of the payload container.

1.5.3 Nondestructive Examination

Nondestructive examination (NDE) techniques, such as radiography, may be used to qualify waste for transport after the payload container is closed (e.g., to nondestructively examine the physical form of the waste and to verify the absence of prohibited waste forms). Site/equipment-specific quality assurance and quality control procedures shall ensure that NDE system operator(s) are properly trained and qualified.

1.5.4 Records and Database Information (Knowledge of Process)

Information obtained from existing site records and/or databases or knowledge of process may be used to qualify waste for transport.

1.5.5 Administrative and Procurement Controls

Site-specific administrative and procurement controls may be used to show that the payload container specifications are met and/or that payload container contents are monitored and controlled (e.g., to show that filters procured from vendors meet the requirements of this document or that prohibited waste forms were excluded from the generating facility).

1.5.6 Measurement

Direct measurement or evaluation based on analysis using the direct measurement shall be used, as needed, to qualify waste (e.g., direct measurement of the weight, analysis of assay data to determine decay heat, or survey measurements to determine surface dose rate).

1.5.7 Sampling Programs

Sampling programs comprised of the statistical application of other methods identified in Section 1.5.1, *Visual Examination*, through Section 1.5.6, *Measurement*, may be used to qualify waste for transport.

1.6 TRUPACT-III Content Codes Document

The TRUPACT-III Content Codes (TRUCON-III) document[1] is a catalog of TRUPACT-III authorized contents and a description of the methods used to demonstrate compliance with the TRUPACT-III TRAMPAC.

1.6.1 Required Elements

Each content code within the TRUCON-III document must contain the following elements:

CONTENT CODE: Identifies the two-letter site abbreviation that designates the generator or physical location of the waste, the three-digit code that designates the physical and chemical form of the waste, and alpha or numeric differentiators (e.g., to designate differences in packaging configurations). Content code identifiers are defined in the TRUCON-III document[1].

CONTENT DESCRIPTION: Identifies the physical form of the waste (e.g., describing whether it is inorganic or organic, solidified or solid). This is similar to the waste material type titles in Section 5.1, *Payload Shipping Category*.

GENERATING SITE: Provides the location of waste generation.

WASTE DESCRIPTION: Provides basic information regarding the nature and/or main components of the waste.

GENERATING SOURCE(S): Lists processes and/or buildings at each site that generate the waste in each content code.

WASTE FORM: Provides more detailed information on the waste contents, how the waste is processed, and/or specific information about the chemistry of constituents.

WASTE PACKAGING: Describes, in detail, techniques necessary for waste packaging in a given content code. This includes a description of the waste confinement layers; the number of layers of confinement used in packaging waste; and the mechanism for bag, can, or container closure.

METHODS FOR ISOTOPIC DETERMINATION: Describes the types of radioactive measurement techniques or other methods used to obtain fissile material content and decay heat values for a particular content code.

RESIDUAL LIQUIDS: Describes the procedures used to ensure that the limit imposed on residual liquids (<1% by volume) is met for each content code.

EXPLOSIVES/COMPRESSED GASES: Identifies the methods used to preclude the presence of explosives and compressed gases.

PYROPHORICS: Describes the controls in place to ensure that nonradioactive pyrophoric materials in the waste are excluded, reacted to render nonreactive, or are immobilized prior to placement in waste. Describes the controls in place to ensure that the ≤1% (weight) limit on radioactive pyrophoric materials in the waste is met.

[1] U.S. Department of Energy (DOE), *TRUPACT-III Content Codes*, current revision, U.S. Department of Energy, Carlsbad Field Office, Carlsbad, New Mexico.

CORROSIVES: Describes the controls in place to ensure that corrosive materials in the waste either are not present or are neutralized or immobilized prior to placement in a container.

CHEMICAL COMPATIBILITY: Describes the controls in place to ensure chemical compatibility for the waste contents and the TRUPACT-III packaging. All chemicals/materials in the waste for a specific content code are restricted to the lists of allowable chemicals/materials (Table 4.3-1 through Table 4.3-7) and the 5% limit on total materials not listed as specified in Section 4.3, *Chemical Composition*.

CONTAINER VENTING AND ASPIRATION: Details how containers that have been stored in an unvented condition will be aspirated to ensure equilibration of any gases that may have accumulated in the closed container. This is required only for unvented containers.

ADDITIONAL CRITERIA: Provides details on how the waste qualifies for shipment by meeting additional transport requirements (e.g., venting containers).

SHIPPING CATEGORY: Shipping categories based on the above parameters for each TRUPACT-III content code are summarized in the TRUCON-III document[1].

MAXIMUM ALLOWABLE WATTAGE: The maximum allowable wattage limit for each shipping category is determined in accordance with Section 5.2.3, *Flammable Gas Generation Rate Limits and Decay Heat Limits*.

1.6.2 Use and Approval

All containers must have a content code approved by the Waste Isolation Pilot Plant (WIPP) CH-TRU Payload Engineer to be eligible for shipment. Any site requiring the transportation of CH-TRU waste in the TRUPACT-III that is not described in an approved content code must request the revision or addition of a content code by submitting a request in writing to the WIPP CH-TRU Payload Engineer.

The WIPP CH-TRU Payload Engineer has the authority to approve a content code request only if compliance with the transportation requirements of the TRUPACT-III TRAMPAC can be demonstrated. Any submittal not meeting the requirements of the TRUPACT-III TRAMPAC shall not be approved for inclusion in the TRUCON-III document[1] or be used as the basis for a shipment in the TRUPACT-III. The WIPP CH-TRU Payload Engineer does not have the authority to change the transportation requirements for the TRUPACT-III as specified in the TRUPACT-III TRAMPAC without approval from the U.S. Nuclear Regulatory Commission (NRC).

The process for requesting a content code addition or revision is as follows:

1. The site prepares in writing a request containing sufficient information to satisfy all of the necessary elements identified in Section 1.6.1, *Required Elements*. If the request is for a content code revision, only the revised elements require preparation and documentation. The site shall ensure that the information submitted in the form of a content code addition or revision accurately describes the waste and waste generating processes based on site knowledge.
2. The site submits the request (e.g., draft content code or revised content code elements) in writing to the WIPP CH-TRU Payload Engineer for review.

3. The WIPP CH-TRU Payload Engineer shall review the submittal for completeness and satisfactory demonstration of compliance with all transportation requirements of the TRUPACT-III TRAMPAC. As part of this review, the WIPP CH-TRU Payload Engineer's responsibilities may include a review to ensure that each of the previously identified elements (Section 1.6.1, *Required Elements*) is complete, the calculation or verification of new payload shipping categories to accommodate changes in packaging configurations using the Numeric Payload Shipping Category Worksheet (Table 8.1.6-3 in Appendix 8.1.6, *Procedure for Determining TRUPACT-III Payload Shipping Categories*), and the evaluation of compliance with the list of allowable chemicals/materials pursuant to Section 4.3, *Chemical Composition*. The WIPP CH-TRU Payload Engineer shall not approve any submittal that does not demonstrate compliance with every transportation requirement for the TRUPACT-III.
4. Upon completion of the review, the WIPP CH-TRU Payload Engineer shall send formal written notification to the site indicating the status of the request. If the request is denied, the WIPP CH-TRU Payload Engineer shall indicate in the notification the reason why the request was not accepted and shall identify which elements of the submittal are incomplete or out of compliance.
5. If the request is approved, a site may begin using the new or revised content code once official notification is received from the WIPP CH-TRU Payload Engineer. Sites may not use proposed content code additions or revisions to make shipments in the TRUPACT-III prior to receipt of notification from the WIPP CH-TRU Payload Engineer.
6. The WIPP CH-TRU Payload Engineer shall record all approved content code additions or revisions in the TRUCON-III document[1]. The current revision of the TRUCON-III document[1] shall be available to sites.

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1.7 Compliance Responsibilities

1.7.1 Transportation Certification Official

The site Transportation Certification Official (TCO) is responsible for administratively verifying the compliance of payloads with all TRUPACT-III TRAMPAC requirements. The site TCO shall approve every payload for transport by signature on the transportation certification documents.

1.7.2 DOE-CBFO

The DOE-CBFO is responsible for the performance of compliance verification audits, which are conducted prior to the first shipment and periodically thereafter to evaluate TRUPACT-III payload compliance. Audit activities include document reviews and interviews of site operators on a job-function basis relative to meeting the applicable criteria. Where specific technical ability is required (e.g., for isotopic inventory and assay data), technical experts are included on the audit team. The DOE-CBFO will grant or deny waste transportation authorization based on objective evidence of the audit and the recommendation of the audit team's report. Compliance verification audits are not required at sites that document compliance by preparing waste-specific data TRAMPAC documents that are reviewed and approved by the DOE-CBFO.

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1.8 Quality Assurance

The QA requirements applicable to the use of the TRUPACT-III packaging are defined by Title 10, Code of Federal Regulations (CFR), Part 71 (10 CFR 71), Subpart H. The use and maintenance of the TRUPACT-III by the user are conducted under a QA program approved by the appropriate DOE field office. The compliance of a payload to be transported in the TRUPACT-III is determined by the user under a QA program approved by the DOE-CBFO (see Chapter 7.0, *Quality Assurance*).

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2.0 CONTAINER AND PHYSICAL PROPERTIES REQUIREMENTS

2.1 Authorized Payload Container

2.1.1 Requirements

The only authorized payload container for the TRUPACT-III is the Standard Large Box 2 (SLB2). The TRUPACT-III will accommodate one SLB2. The SLB2 is a specialized payload container with a top-loading and a bottom-loading option for use within the TRUPACT-III packaging. The SLB2 and any ancillary handling equipment transported within the TRUPACT-III (i.e., payload loading system components) shall comply with the specifications in Section 2.8, *Specification for Authorized Payloads*.

2.1.2 Methods of Compliance and Verification

Compliance shall be by one, or a combination, of the following methods:

- Visual inspection to the specifications of Section 2.8, *Specification for Authorized Payloads*
- Administrative and procurement controls demonstrating that payload containers have been procured to the specifications of Section 2.8, *Specification for Authorized Payloads*.

In addition to meeting the specifications of Section 2.8, *Specification for Authorized Payloads*, at the time of procurement, the integrity of the payload container shall be visually inspected prior to transport to ensure that the payload container is in good and unimpaired condition (e.g., no significant rusting and is of sound structural integrity). Compliance shall be documented in accordance with site-specific procedures prior to shipment.

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2.2 Container/Assembly Weight

2.2.1 Requirements

Each payload container, payload assembly, and loaded TRUPACT-III shall comply with the maximum weight limits summarized in Table 2.2-1 and Table 2.2-2.

Table 2.2-1 – Payload Container Maximum Gross Weight Limit

Authorized Payload Container	Maximum Gross Weight per Payload Container (pounds)
SLB2	10,500

Table 2.2-2 – Payload Assembly and Loaded TRUPACT-III Maximum Gross Weight Limits

Authorized Payload Configuration	Maximum Weight per Payload Assembly (Contents) (pounds)	Maximum Gross Weight per Loaded TRUPACT-III (Package) (pounds)
One SLB2	11,486	55,116

The maximum gross weight limit for the payload assembly includes the weight of the loaded payload container and any removable ancillary handling equipment (i.e., payload loading system as specified in Section 2.8.2, *Specification for Payload Loading System*). Actual payload assembly weights may be further limited by the "as-built" TRUPACT-III weights and U.S. Department of Transportation requirements for a loaded transport vehicle.

Payload containers, payload assemblies, and loaded TRUPACT-III packages shall be acceptable for transport only if the weights plus the measurement errors are less than or equal to the maximum gross weights specified in Table 2.2-1 and Table 2.2-2.

2.2.2 Methods of Compliance and Verification

Compliance shall be by measurement. Weights of well-defined components such as those making up the payload loading system may be analytically established. The weight of each payload container shall be determined using a calibrated scale. The scale calibrations shall be in accordance with the National Institute of Standards and Technology Handbook 44[1], or an equivalent standard. The weight of the payload loading system shall be added to the weight of the individual payload container for the evaluation of compliance with the maximum weight per

[1] National Institute of Standards and Technology, *Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices*, NIST Handbook 44, National Institute of Standards and Technology, Office of Weights and Measures, Washington, D.C.

payload assembly of 11,486 pounds. The measured weight and measurement error of the payload container shall be recorded in the Payload Transportation Certification Document (PTCD) (see Section 6.2.1, *Procedure for Certification of Individual Payload Containers*). The measurement error is determined from the scale calibration tolerance. If multiple scales are used, a bounding value based on the highest scale calibration tolerance may be used to determine the measurement error.

2.3 Container Marking

2.3.1 Requirements

Each payload container shall be labeled with a unique identification number.

2.3.2 Methods of Compliance and Verification

Compliance shall be through visual inspection of each payload container, and the unique container identification number/label shall be recorded on the PTCD (see Section 6.2.1, *Procedure for Certification of Individual Payload Containers*).

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2.4 Filter Vents

2.4.1 Requirements

Each payload container to be transported in the TRUPACT-III shall have one or more filter vents meeting the minimum specifications of Table 2.4-1 and this section. Specifications for filter vents in plastic bags and other inner layers used as confinement layers within the payload container are also included in Table 2.4-1.

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

The filter vent housing and element for the payload container shall have an operating temperature range from –40°C to +70°C (-40°F to +158°F). The filter vent threads shall be compatible with the bung in the container.

2.4.2 Methods of Compliance and Verification

Compliance shall be by one, or a combination, of the following methods:

- Administrative and procurement controls demonstrating that filter vents have been procured to the specifications of Section 2.4.1, *Requirements*
- Visual inspection to the specifications of Section 2.4.1, *Requirements*
- Sampling by measurement of filter characteristics to the specifications of Section 2.4.1, *Requirements*.

If sampling by measurement is selected as the compliance method, the test methods used to determine the compliance of filter vents with the minimum performance-based requirements specified in Table 2.4-1 and this section shall be directed by procedures under a QA program.

Table 2.4-1 – Minimum Filter Vent Specifications

Container Type	Minimum Filter Vent Specification: Total Flow Rate (ml/min of air, STP, at 1 inch of water)①	Efficiency (percent)	Total Hydrogen Diffusivity (mol/s/mol fraction at 25°C)②,③
SLB2	35	>99.9	6.60E-4
Filtered Confinement Layer (e.g., Metal Can) ④	35	NA⑤	3.70E-6
Filtered Bag⑥	35	NA⑤	1.075E-5
High-Diffusivity Filters (HDF)			
HDF (2X)	35	NA⑤	7.40E-6
HDF (5X)	35	NA⑤	1.85E-5
HDF (25X)	35	NA⑤	9.25E-5
HDF (100X)	35	NA⑤	3.70E-4
High-Diffusivity Bag Filters (HDBF)			
HDBF (2X)	35	NA⑤	2.150E-5
HDBF (5X)	35	NA⑤	5.375E-5
HDBF (25X)	35	NA⑤	2.688E-4
HDBF (100X)	35	NA⑤	1.075E-3

① Filters tested at a different pressure gradient shall have a proportional flow rate (e.g., 35 ml/min at 1 inch of water = 1,000 ml/min at 1 psi).

② Total hydrogen diffusivity may be achieved through the use of multiple filter vents.

③ Filters exceeding these specifications may be used to decrease the resistance to hydrogen release in accordance with the logic outlined in Appendix 8.1.6, *Procedure for Determining TRUPACT-III Payload Shipping Categories*.

④ Filtered confinement layer specification is not applicable to Waste Material Type II.2 (packaged in a metal can) due to zero gas generation potential.

⑤ Filters installed in inner confinement layers are exempt from the efficiency requirement as the SLB2 must exhibit a >99.9 percent efficiency.

⑥ The use of a heat-sealed filtered bag as the innermost layer of confinement to package CH-TRU waste is limited to Waste Material Types I.3, II.1, III.1, and III.3 provided that there is no potential for contact of the filters with water. Waste Material Types II.3 and III.2, which by definition include a metal can as the innermost layer of confinement, may use heat-sealed filtered bags as confinement layers outside of the innermost metal can. Because Waste Material Type II.2 (inorganic solids packaged in metal cans) does not generate flammable gas, heat-sealed filtered or unfiltered bags may be used as confinement layers outside of the innermost metal can. For other waste material types, heat-sealed filtered bags are not allowed as the innermost layer of confinement. The use of filtered bags in waste packaging configurations must be specified in approved content codes. Appendix 3.11 of the CH-TRU Payload Appendices[1] describes the use of filtered bags as confinement layers.

ml/min = Milliliter(s) per minute
mol/s/mol fraction = Moles per second per mole fraction
NA = Not applicable
STP = Standard temperature and pressure

[1] U.S. Department of Energy (DOE), *CH-TRU Payload Appendices*, current revision, U.S. Department of Energy, Carlsbad Field Office, Carlsbad, New Mexico.

2.5 Residual Liquids

2.5.1 Requirements

Liquid waste is prohibited in payload containers, except for residual amounts in well-drained containers. The total volume of residual liquid in a payload container shall be less than 1 percent (volume) of the payload container.

2.5.2 Methods of Compliance and Verification

Compliance shall be by one, or a combination, of the following methods:

- Review of records and database information, which may include knowledge of process
- Radiography
- Visual examination
- Sampling program.

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2.6 Sharp or Heavy Objects

2.6.1 Requirements

Sharp or heavy objects in the payload container shall be blocked, braced, or suitably packaged as necessary to provide puncture protection for the payload container packaging these items.

2.6.2 Methods of Compliance and Verification

Compliance shall be by one, or a combination, of the following methods:

- Review of records and database information, which may include knowledge of process
- Radiography
- Visual examination
- Sampling program.

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2.7 Sealed Containers

2.7.1 Requirements

Sealed containers that are greater than 4 liters (nominal) are prohibited except for Waste Material Type II.2. Waste Material Type II.2 (solid inorganic waste in metal cans) does not generate any flammable gas (see Appendix 3.2 of the CH-TRU Payload Appendices[1]).

2.7.2 Methods of Compliance and Verification

Compliance shall be by one, or a combination, of the following methods:

- Review of records and database information, which may include knowledge of process
- Radiography
- Visual examination
- Sampling program.

[1] U.S. Department of Energy (DOE), *CH-TRU Payload Appendices*, current revision, U.S. Department of Energy, Carlsbad Field Office, Carlsbad, New Mexico.

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2.8 Specification for Authorized Payloads

2.8.1 Specification for Authorized Payload Container

The SLB2 is authorized for transport in the TRUPACT-III (Figure 2.8-1). The TRUPACT-III will accommodate one SLB2. The SLB2 is a specialized payload container with a top-loading and a bottom-loading option for use within the TRUPACT-III packaging. The SLB2 has been specifically designed for efficient loading of the TRUPACT-III. The SLB2 is sized to accommodate the packaging of existing 4- x 4- x 7- and 5- x 5- x 8-foot boxes as well as other containers of smaller sizes. Table 2.8-1 presents the nominal external dimensions for the SLB2. The SLB2 shall employ the use of square tubing as external bumpers located to align, where applicable, with the TRUPACT-III payload cavity guide bars. The minimum overall length of the SLB2 over the external bumpers shall be 107⅜ inches.

Table 2.8-1 – Payload Container Dimensions

Authorized Payload Container	Nominal External Dimensions (inches)		
	Width	Height	Length
SLB2	69	73	108

Table 2.8-2 presents the payload container construction materials. Table 2.8-3 specifies the weights associated with the SLB2 that are applicable to shipment within the TRUPACT-III. Each SLB2 must be filtered to meet the specifications of Section 2.4, *Filter Vents*.

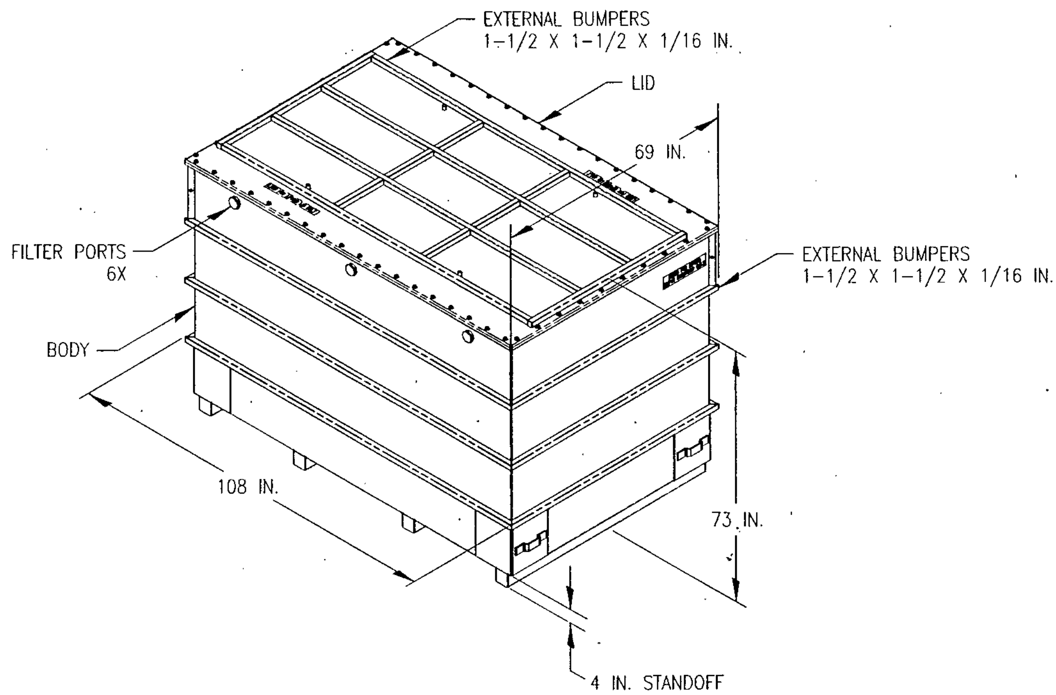
Table 2.8-2 – Payload Container Materials of Construction

SLB2 Component	Material
Body and lid	Steel
Gasket	Elastomeric

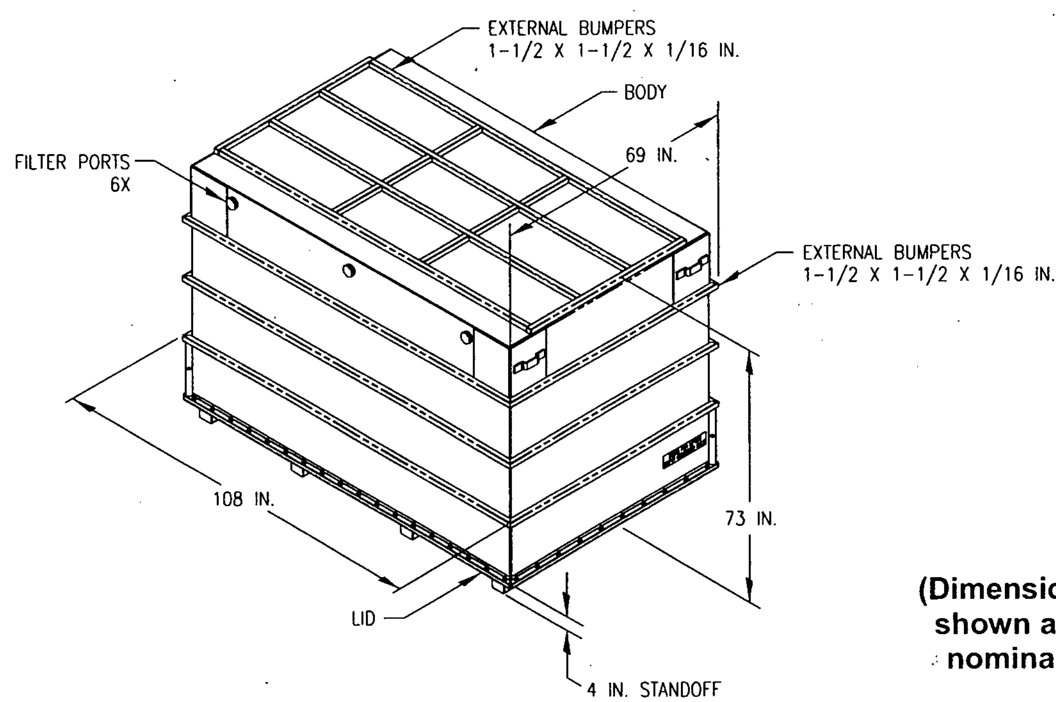
Table 2.8-3 – Payload Container Weights

Authorized Payload Container	Weight (pounds)	
	Approximate Empty	Maximum Gross
SLB2	2,700	10,500

The SLB2 may be directly loaded with waste or used to package various individual containers. Table 2.8-4 identifies the material content forms authorized for transport within this payload container.



Top-Loading Configuration



(Dimensions shown are nominal)

Bottom-Loading Configuration

Figure 2.8-1 – Schematic of SLB2

Table 2.8-4 – Payload Container Material Content Forms Authorized for Transport

Form Number	Description
1	Direct Load: Solids, any particle size (e.g., fine powder or inorganic particulates)
2	Direct Load: Solids, large particle size (e.g., sand, concrete, or debris)
3	Direct Load: Solids, large objects (e.g., metal cans, such as drums, containing waste)
4	Direct Load: Large, bulky dense objects with sharp and obtrusive members or components with dispersible Form 1 and 2 (e.g., steel or concrete boxes, steel plate, electric motors, steel pipe, or concrete blocks) ①

① Blocked, braced, or suitably packaged as necessary to provide puncture protection for the payload container.

2.8.2 Specification for Payload Loading System

The only ancillary handling equipment transported within the TRUPACT-III is the payload loading system used to allow loading of the SLB2 into the payload cavity and to support the SLB2 during transportation. The loading system can take various forms, but must satisfy the following dimensional, material and weight criteria. These criteria have been established from a consideration of the roller floor and pallet configuration used during testing of the second certification test unit (CTU-2). However, other payload loading system configurations or operational features are acceptable as long as the following criteria are satisfied.

Dimensionally, the most important aspect of any loading system is to vertically align the SLB2 bumpers with the TRUPACT-III payload cavity guide bars. When supported within the TRUPACT-III payload cavity, the bottom edge of each SLB2 bumper shall nominally align with the bottom edge of the adjacent payload cavity guide bar. In addition, the displaced volume associated with all loading system components must be no more than 280 liters as established in Appendix 8.1.5, *Determination of Void Volumes for TRUPACT-III Payload.* A representative set of payload loading system components, corresponding to those used during testing of CTU-2, is presented in Figure 2.8-2 and Figure 2.8-3.

Table 2.8-5 presents the payload loading system construction materials. Table 2.8-6 specifies the weights associated with the payload loading system.

Table 2.8-5 – Payload Loading System Primary Materials of Construction

Component	Material
Any	Steel and/or aluminum

Table 2.8-6 – Payload Loading System Weights

Component	Nominal Gross Weight (pounds)
Full set of payload loading system components supporting an SLB2	986

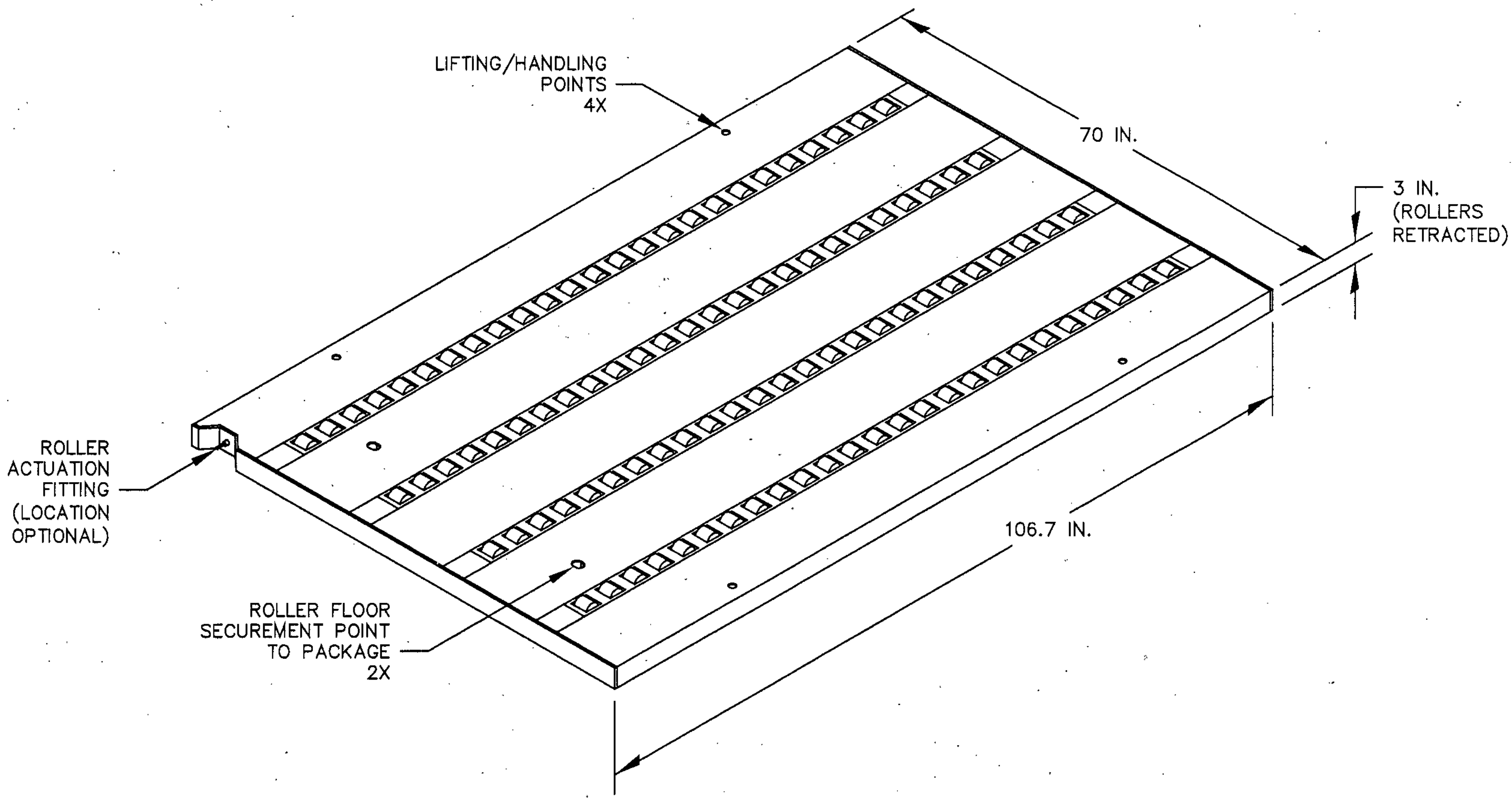


Figure 2.8-2 – Representative TRUPACT-III Roller Floor

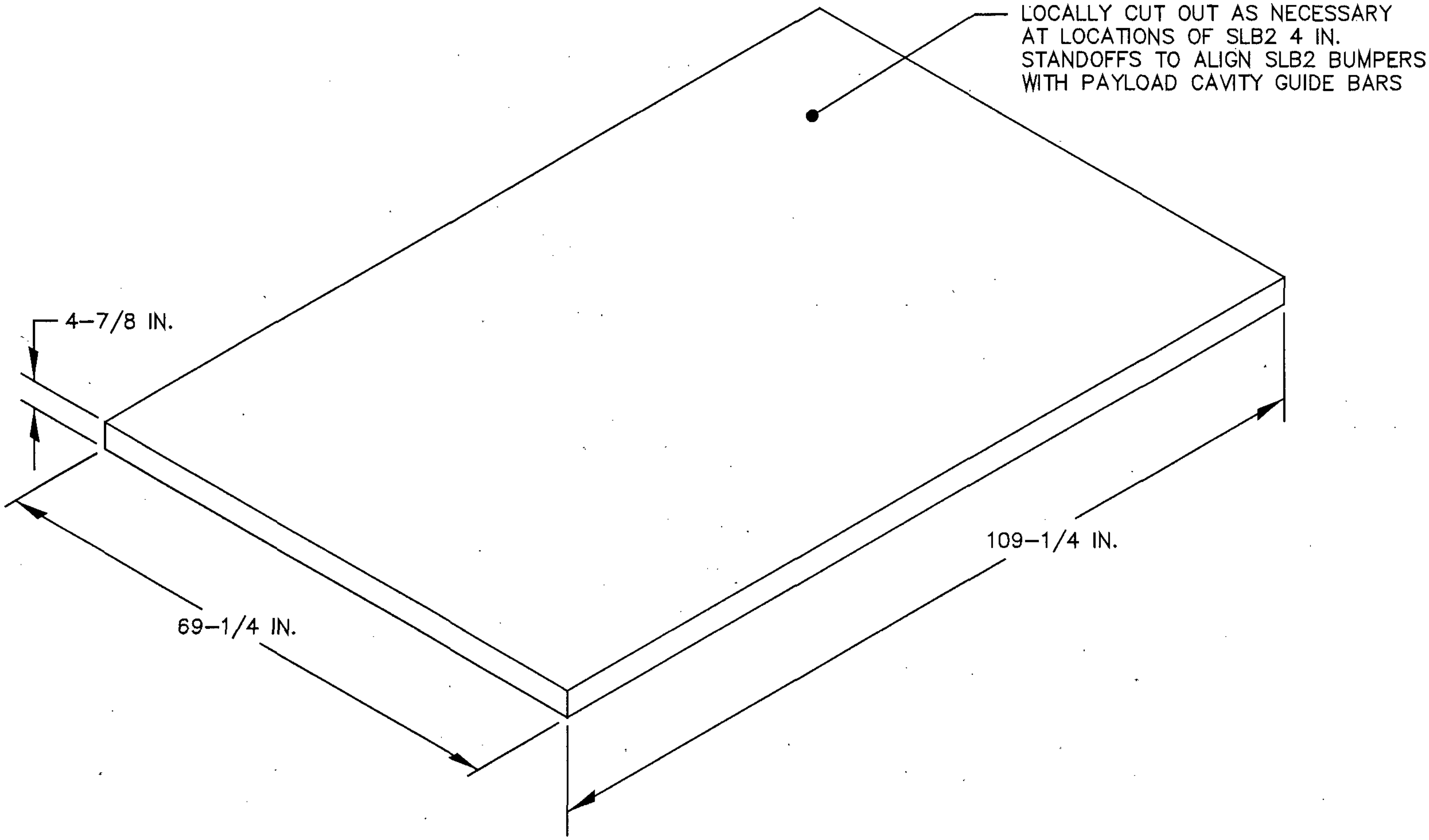


Figure 2.8-3 – Representative TRUPACT-III Loading Pallet

3.0 NUCLEAR PROPERTIES REQUIREMENTS

The nuclear properties requirements outlined in this section require a knowledge of isotopic composition and quantity of fissile material. The four major product material isotopic compositions are:

1. Weapons-grade plutonium (primarily Pu-239)
2. Fuel-grade plutonium (primarily Pu-239)
3. Heat-source plutonium (primarily Pu-238)
4. Other TRU isotopes.

Site process areas usually only handle product materials of specific isotopic composition (e.g., weapons-grade plutonium has the following composition: 93.83% Pu-239, 5.82% Pu-240, 0.34% Pu-241, 0.02% Pu-242, 0.01% Pu-238). Therefore, the isotopic composition in the waste from specific process areas remains constant since product isotopic composition is closely controlled to meet production isotopic specification requirements.

3.1 Nuclear Criticality

3.1.1 Requirements

A TRUPACT-III payload shall not contain greater than 1 percent by weight beryllium and/or beryllium oxide.

A TRUPACT-III payload shall not contain machine-compacted waste.

A payload shall be acceptable for transport only if the Pu-239 fissile gram equivalent (FGE) plus two times the error (i.e., two standard deviations) is less than or equal to 325 grams per TRUPACT-III package.

The fissile material limit per TRUPACT-III package may be increased if the payload is documented to contain Pu-240 as specified in Table 3.1-1. The minimum Pu-240 content for the payload shall be determined after the subtraction of two times the error (i.e., two standard deviations).

Table 3.1-1 – Fissile Material Limits per TRUPACT-III Package with Credit for Pu-240 Poisoning

Minimum Pu-240 Content in TRUPACT-III Payload (grams)	Fissile Material Limit per TRUPACT-III Package (Pu-239 FGE)
0	325
5	340
15	360
25	380

3.1.2 Methods of Compliance and Verification

Compliance with the FGE requirements involves the following steps:

- Determination of the isotopic composition
- Determination of the quantity of radionuclides
- Calculation of the FGE and compliance evaluation.

Each of these steps is discussed in detail below.

Isotopic Composition

The isotopic composition of the waste may be determined from direct measurements taken on the product material during the processing or post-process certification at each site, from analysis of the waste, or from existing records. The isotopic composition of the waste need not be determined by direct analysis or measurement of the waste unless process information is not available.

Pu-239 FGE for other fissile or fissionable isotopes, including special actinide elements, shall be obtained using the American National Standards Institute (ANSI) / American Nuclear Society (ANS) method ANSI/ANS-8.15[1], or an equivalent method. Table 3.1-2 lists the Pu-239 FGE, as well as the decay heat and specific activity, of many radionuclides.

The following are two examples of analytical methods for determining isotopic composition:

- Mass spectrometry (MS)
- Gamma ray pulse height analysis.

Depending on the mixture of radionuclides present in the waste, one or both of the methods may be required. These assay methods are described in Appendix 5.2 of the CH-TRU Payload Appendices.[2]

MS is a primary method for determining the radioisotopic composition in product material (e.g., plutonium isotopic composition). The isotopic analyses shall be performed in accordance with the following American Society for Testing and Materials (ASTM) MS methods: ASTM C 696[3], ASTM C 697[4], and ASTM C 759[5], or equivalent methods.

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[1] American National Standards Institute/American Nuclear Society (ANSI/ANS), Nuclear Criticality Control of Special Actinide Elements, ANSI/ANS-8.15, American National Standards Institute/American Nuclear Society, Washington, D.C.

[2] U.S. Department of Energy (DOE), *CH-TRU Payload Appendices*, current revision, U.S. Department of Energy, Carlsbad Field Office, Carlsbad, New Mexico.

[3] American Society for Testing and Materials (ASTM), *Standard Test Methods for Chemical, Mass Spectrometric, and Spectrochemical Analysis of Nuclear-Grade Uranium Dioxide Powders and Pellets*, ASTM C 696, American Society for Testing and Materials, West Conshohocken, Pennsylvania.

[4] American Society for Testing and Materials (ASTM), *Standard Test Methods for Chemical, Mass Spectrometric, and Spectrochemical Analysis of Nuclear-Grade Plutonium Dioxide Powders and Pellets,* ASTM C 697, American Society for Testing and Materials, West Conshohocken, Pennsylvania.

[5] American Society for Testing and Materials (ASTM), *Standard Test Methods for Chemical, Mass Spectrometric, Spectrochemical, Nuclear, and Radiochemical Analysis of Nuclear-Grade Plutonium Nitrate Solutions*, ASTM C 759, American Society for Testing and Materials, West Conshohocken, Pennsylvania.

Gamma ray pulse height analysis or MS may be used to determine the isotopic composition for gamma-emitting radionuclides. Gamma ray pulse height analysis shall be performed in accordance with ASTM C 1030[6], or an equivalent method.

Quantity of Radionuclides

The quantity of the radionuclides in each payload container shall be estimated by either a direct measurement or records of the individual payload container, a summation of assay results from individual packages in a payload container, or a direct measurement on a representative sample of a waste stream (such as solidified inorganics). An assay refers to one of several radiation measurement techniques that determine the quantity of nuclear material in TRU wastes. Assay instruments detect and quantify the primary radiation (alpha, gamma, and/or neutron) emanating from specific radionuclides, or a secondary radiation emitted from neutron interrogation techniques. The measured quantity of radiation is then used to calculate the quantity of other radionuclides and the total quantity of Pu-239 FGE. That calculation requires knowledge of the isotopic composition of the waste. Combinations of gamma spectroscopy and neutron measurements are often needed to calculate the quantity of nonfissile radionuclides.

The following are five examples of assay methods for quantifying radionuclides in TRU waste:

- Passive gamma (hyper-pure germanium, germanium, lithium-drifted germanium, sodium iodide, lanthinum bromide: transmission-corrected and noncorrected)
- Radiochemical assay (alpha, beta, and gamma analysis)
- Passive neutron coincidence counting assay
- Passive-active neutron assay
- Calorimetry.

These assay methods are described in Appendix 5.2 of the CH-TRU Payload Appendices.[2]

General assay requirements that apply to all sites are as follows:

- Each site shall select and use the assay method(s) of its choice, provided the method(s) is/are approved by the DOE-CBFO under the programmatic or waste-specific data TRAMPAC (see Section 1.5, *Methods of Compliance*) and the prescribed controls are implemented.
- The site's waste content code descriptions shall list the specific assay method(s) and its/their application(s).
- Site/equipment-specific operating and QA procedures or the waste-specific data package shall describe the assay method(s) and the controls imposed on the assay operations. The controls include performing calibration and background measurements. The calibration and background measurements shall fall within the stated acceptable ranges before assays are performed.

[6] American Society for Testing and Materials (ASTM), *Standard Test Method for Determination of Plutonium Isotopic Composition by Gamma-Ray Spectrometry*, ASTM C 1030, American Society for Testing and Materials, West Conshohocken, Pennsylvania.

- Site/equipment-specific QA plans and procedures or the QA associated with the waste-specific data package shall include oversight of assay methods and controls.
- Each site shall provide a specialized training program for assay operators.

Calculation of the Pu-239 FGE and Compliance Evaluation

The ANSI/ANS (ANSI/ANS-8.1[7]) establishes U-233, U-235, and Pu-239 subcritical mass limits for aqueous mixtures that might not be uniform and are independent of compound. Subcritical mass limits for other actinide isotopes are given in ANSI/ANS-8.15[1]. The bases for these limits are similar, and the same mass limit for Pu-239 is given in both standards. The ratio of these mass limits provides the basis for the Pu-239 FGE conversion factors given in Table 3.1-2.

The FGE of the SLB2 shall be calculated by summing the product of the quantity (in grams) of each radionuclide and its respective FGE conversion factor provided in Table 3.1-2. The FGE value plus two times the error (i.e., two standard deviations) shall be less than or equal to the applicable limit for the SLB2. The FGE of the SLB2 shall be recorded in the PTCD (see Section 6.2.1, *Procedure for Certification of Individual Payload Containers*).

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[7] American National Standards Institute/American Nuclear Society (ANSI/ANS), 1998, *Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors*, ANSI/ANS-8.1, American National Standards Institute/American Nuclear Society, Washington, D.C.

Table 3.1-2 – Pu-239 Fissile Gram Equivalent, Decay Heat, and Specific Activity of Selected Radionuclides

NUCLIDE		SPECIFIC ATOMIC NUMBER	Pu-239 FGE①②	DECAY HEAT③ (W/g)	SPECIFIC ACTIVITY④ (Ci/g)
H	3	1	0.00E+00	3.28E-01	9.76E+03
Be	10	4	0.00E+00	2.68E-05	2.24E-02
C	14	6	0.00E+00	1.32E-03	4.51E+00
Na	22	11	0.00E+00	8.94E+01	6.32E+03
P	32	15	0.00E+00	1.19E+03	2.89E+05
P	33	15	0.00E+00	2.33E+02	1.58E+05
S	35	16	0.00E+00	1.23E+01	4.26E+04
Ca	45	20	0.00E+00	8.12E+00	1.78E+04
Sc	46	21	0.00E+00	4.25E+02	3.38E+04
V	49	23	0.00E+00	2.06E-01	8.08E+03
Cr	51	24	0.00E+00	1.95E+01	9.24E+04
Mn	54	25	0.00E+00	3.88E+01	7.82E+03
Fe	55	26	0.00E+00	8.49E-02	2.44E+03
Fe	59	26	0.00E+00	3.80E+02	4.92E+04
Co	57	27	0.00E+00	7.29E+00	8.55E+03
Co	58	27	0.00E+00	1.91E+02	3.18E+04
Co	60	27	0.00E+00	1.76E+01	1.14E+03
Ni	59	28	0.00E+00	3.22E-06	8.08E-02
Ni	63	28	0.00E+00	6.05E-03	5.98E+01
Cu	64	29	0.00E+00	7.21E+03	3.89E+06
Zn	65	30	0.00E+00	2.89E+01	8.24E+03
As	73	33	0.00E+00	1.02E+01	2.25E+04
Se	79	34	0.00E+00	2.18E-05	6.97E-02
Kr	85	36	0.00E+00	5.94E-01	3.97E+02
Rb	86	37	0.00E+00	3.71E+02	8.22E+04
Rb	87	37	0.00E+00	7.32E-11	8.75E-08
Sr	89	38	0.00E+00	1.01E+02	2.94E+04
Sr	90	38	0.00E+00	1.60E-01	1.38E+02
Y	88	39	0.00E+00	2.24E+02	1.41E+04
Y	90	39	0.00E+00	3.01E+03	5.44E+05
Y	90m	39	0.00E+00	4.40E+04	1.09E+07
Y	91	39	0.00E+00	8.83E+01	2.45E+04
Zr	88	40	0.00E+00	4.46E+01	1.80E+04
Zr	90	40	0.00E+00	N/A⑤	N/A⑤
Zr	90m	40	0.00E+00	2.13E+09	1.55E+11

NUCLIDE		SPECIFIC ATOMIC NUMBER	Pu-239 FGE①②	DECAY HEAT③ (W/g)	SPECIFIC ACTIVITY④ (Ci/g)
Zr	93	40	0.00E+00	7.29E-07	2.51E-03
Zr	95	40	0.00E+00	1.10E+02	2.17E+04
Nb	93m	41	0.00E+00	5.01E-02	2.83E+02
Nb	94	41	0.00E+00	1.91E-03	1.87E-01
Nb	95	41	0.00E+00	1.87E+02	3.91E+04
Nb	95m	41	0.00E+00	6.11E+02	3.81E+05
Tc	99	43	0.00E+00	8.49E-06	1.70E-02
Tc	99m	43	0.00E+00	4.31E+03	5.27E+06
Ru	103	44	0.00E+00	1.05E+02	3.26E+04
Ru	106	44	0.00E+00	2.00E-01	3.38E+03
Rh	103m	45	0.00E+00	7.55E+03	3.25E+07
Rh	106	45	0.00E+00	6.74E+07	3.56E+09
Pd	107	46	0.00E+00	2.83E-08	5.14E-04
Ag	108	47	0.00E+00	2.74E+06	7.35E+08
Ag	108m	47	0.00E+00	2.53E-01	2.61E+01
Ag	109m	47	0.00E+00	1.32E+06	2.61E+09
Ag	110	47	0.00E+00	3.01E+07	4.17E+09
Ag	110m	47	0.00E+00	7.99E+01	4.80E+03
Cd	109	48	0.00E+00	1.68E+00	2.61E+03
Cd	113m	48	0.00E+00	2.34E-01	2.17E+02
Cd	115m	48	0.00E+00	9.59E+01	2.55E+04
In	114	49	0.00E+00	6.32E+06	1.38E+09
In	114m	49	0.00E+00	3.23E+01	2.31E+04
In	115m	49	0.00E+00	1.26E+04	6.34E+06
Sn	119m	50	0.00E+00	2.38E+00	4.48E+03
Sn	121m	50	0.00E+00	1.44E-02	5.91E+01
Sn	123	50	0.00E+00	2.58E+01	8.22E+03
Sn	126	50	0.00E+00	3.06E-05	2.84E-02
Sb	124	51	0.00E+00	2.32E+02	1.75E+04
Sb	125	51	0.00E+00	3.27E+00	1.04E+03
Sb	126	51	0.00E+00	1.54E+03	8.36E+04
Sb	126m	51	0.00E+00	1.01E+06	7.85E+07
Te	123	52	0.00E+00	6.50E-17	4.85E-12
Te	123m	52	0.00E+00	1.31E+01	8.87E+03
Te	125m	52	0.00E+00	1.57E+01	1.80E+04
Te	127	52	0.00E+00	3.59E+03	2.64E+06
Te	127m	52	0.00E+00	5.21E+00	9.43E+03
Te	129	52	0.00E+00	7.48E+04	2.09E+07

NUCLIDE		SPECIFIC ATOMIC NUMBER	Pu-239 FGE①②	DECAY HEAT③ (W/g)	SPECIFIC ACTIVITY④ (Ci/g)
Te	129m	52	0.00E+00	5.42E+01	3.01E+04
I	125	53	0.00E+00	6.38E+00	1.76E+04
I	129	53	0.00E+00	9.34E-08	1.79E-04
I	131	53	0.00E+00	4.23E+02	1.25E+05
Cs	134	55	0.00E+00	1.33E+01	1.31E+03
Cs	135	55	0.00E+00	3.82E-07	1.15E-03
Cs	137	55	0.00E+00	9.74E-02	8.80E+01
Ba	133	56	0.00E+00	6.82E-01	2.53E+02
Ba	137	56	0.00E+00	N/A⑤	N/A⑤
Ba	137m	56	0.00E+00	2.12E+06	5.38E+08
Ce	141	58	0.00E+00	4.19E+01	2.88E+04
Ce	142	58	0.00E+00	0.00E+00	2.40E-08
Ce	144	58	0.00E+00	2.14E+00	3.22E+03
Pr	143	59	0.00E+00	1.26E+02	6.73E+04
Pr	144	59	0.00E+00	5.54E+05	7.56E+07
Pr	144m	59	0.00E+00	6.22E+04	1.81E+08
Pm	146	61	0.00E+00	2.22E+00	4.43E+02
Pm	147	61	0.00E+00	3.44E-01	9.38E+02
Pm	148	61	0.00E+00	1.26E+03	1.64E+05
Pm	148m	61	0.00E+00	2.73E+02	2.14E+04
Sm	146	62	0.00E+00	3.47E-07	2.38E-05
Sm	147	62	0.00E+00	3.04E-10	2.30E-08
Sm	151	62	0.00E+00	3.10E-03	2.66E+01
Eu	150	63	0.00E+00	5.95E-01	6.46E+01
Eu	152	63	0.00E+00	1.35E+00	1.78E+02
Eu	154	63	0.00E+00	2.39E+00	2.67E+02
Eu	155	63	0.00E+00	3.42E-01	4.70E+02
Gd	152	64	0.00E+00	2.77E-13	2.18E-11
Gd	153	64	0.00E+00	2.96E+00	3.53E+03
Tb	160	65	0.00E+00	9.24E+01	1.13E+04
Ho	166m	67	0.00E+00	1.99E-02	1.80E+00
Tm	168	69	0.00E+00	8.39E+01	8.44E+03
Ta	182	73	0.00E+00	5.60E+01	6.31E+03
Au	198	79	0.00E+00	1.51E+03	2.45E+05
Tl	207	81	0.00E+00	5.58E+05	1.90E+08
Tl	208	81	0.00E+00	6.93E+06	2.95E+08
Tl	209	81	0.00E+00	8.58E+06	4.16E+08
Pb	209	82	0.00E+00	5.32E+03	4.54E+06

NUCLIDE		SPECIFIC ATOMIC NUMBER	Pu-239 FGE①②	DECAY HEAT③ (W/g)	SPECIFIC ACTIVITY④ (Ci/g)
Pb	210	82	0.00E+00	1.96E-02	7.72E+01
Pb	211	82	0.00E+00	7.61E+04	2.47E+07
Pb	212	82	0.00E+00	2.64E+03	1.39E+06
Pb	214	82	0.00E+00	1.49E+05	3.28E+07
Bi	207	83	0.00E+00	5.34E-01	5.48E+01
Bi	210	83	0.00E+00	2.86E+02	1.24E+05
Bi	211	83	0.00E+00	1.64E+07	4.18E+08
Bi	212	83	0.00E+00	2.42E+05	1.47E+07
Bi	213	83	0.00E+00	7.64E+04	1.93E+07
Bi	214	83	0.00E+00	7.25E+05	4.41E+07
Po	209	84	0.00E+00	4.94E+00	1.68E+01
Po	210	84	0.00E+00	1.45E+02	4.54E+03
Po	211	84	0.00E+00	4.58E+09	1.04E+11
Po	212	84	0.00E+00	9.24E+15	1.77E+17
Po	213	84	0.00E+00	6.26E+14	1.26E+16
Po	214	84	0.00E+00	1.46E+13	3.21E+14
Po	215	84	0.00E+00	1.29E+12	2.95E+13
Po	216	84	0.00E+00	1.40E+10	3.48E+11
Po	218	84	0.00E+00	9.90E+06	2.78E+08
At	211	85	0.00E+00	3.05E+04	2.06E+06
At	217	85	0.00E+00	6.74E+10	1.61E+12
Rn	219	86	0.00E+00	5.30E+08	1.30E+10
Rn	220	86	0.00E+00	3.44E+07	9.22E+08
Rn	222	86	0.00E+00	5.01E+03	1.54E+05
Fr	221	87	0.00E+00	6.71E+06	1.77E+08
Fr	223	87	0.00E+00	1.10E+05	3.87E+07
Ra	223	88	0.00E+00	1.83E+03	5.18E+04
Ra	224	88	0.00E+00	5.37E+03	1.59E+05
Ra	225	88	0.00E+00	2.78E+01	3.92E+04
Ra	226	88	0.00E+00	2.88E-02	1.00E+00
Ra	228	88	0.00E+00	2.76E-02	2.76E+02
Ac	225	89	0.00E+00	1.99E+03	5.80E+04
Ac	227	89	0.00E+00	3.68E-02	7.32E+01
Ac	228	89	0.00E+00	1.80E+04	2.24E+06
Th	227	90	0.00E+00	1.11E+03	3.07E+04
Th	228	90	0.00E+00	2.71E+01	8.29E+02
Th	229	90	0.00E+00	6.17E-03	2.13E-01
Th	230	90	0.00E+00	5.75E-04	2.04E-02

NUCLIDE		SPECIFIC ATOMIC NUMBER	Pu-239 FGE①②	DECAY HEAT③ (W/g)	SPECIFIC ACTIVITY④ (Ci/g)
Th	231	90	0.00E+00	6.43E+02	5.32E+05
Th	232	90	0.00E+00	2.68E-09	1.11E-07
Th	234	90	0.00E+00	3.45E+00	2.32E+04
Pa	231	91	0.00E+00	1.46E-03	4.78E-02
Pa	233	91	0.00E+00	4.90E+01	2.08E+04
Pa	234	91	0.00E+00	2.40E+04	2.00E+06
Pa	234m	91	0.00E+00	3.40E+06	6.87E+08
U	232	92	0.00E+00	6.93E-01	2.16E+01
U	233	92	9.00E-01	2.84E-04	9.76E-03
U	234	92	0.00E+00	1.82E-04	6.32E-03
U	235	92	6.43E-01	6.04E-08	2.19E-06
U	236	92	0.00E+00	1.78E-06	6.54E-05
U	237	92	0.00E+00	1.64E+02	8.25E+04
U	238	92	0.00E+00	8.62E-09	3.40E-07
U	239	92	0.00E+00	1.69E+05	3.35E+07
U	240	92	0.00E+00	1.17E+03	9.26E+05
Np	237	93	1.50E-02	2.09E-05	7.13E-04
Np	238	93	0.00E+00	1.49E+03	2.59E+05
Np	239	93	0.00E+00	5.87E+02	2.32E+05
Np	240	93	0.00E+00	8.52E+04	1.27E+07
Np	240m	93	0.00E+00	9.98E+05	1.08E+08
Pu	236	94	0.00E+00	1.87E+01	5.37E+02
Pu	238	94	1.13E-01	5.73E-01	1.73E+01
Pu	239	94	1.00E+00	1.95E-03	6.29E-02
Pu	240	94	2.25E-02	7.16E-03	2.30E-01
Pu	241	94	2.25E+00	3.31E-03	1.04E+02
Pu	242	94	7.50E-03	1.17E-04	3.97E-03
Pu	243	94	0.00E+00	5.38E+03	2.60E+06
Pu	244	94	0.00E+00	5.22E-07	1.79E-05
Am	241	95	1.87E-02	1.16E-01	3.47E+00
Am	242	95	0.00E+00	9.38E+02	8.08E+05
Am	242m	95	3.46E+01	4.32E-03	9.83E+00
Am	243	95	1.29E-02	6.49E-03	2.02E-01
Am	245	95	0.00E+00	2.12E+04	6.24E+06
Cm	240	96	0.00E+00	7.48E+02	2.01E+04
Cm	242	96	0.00E+00	1.23E+02	3.35E+03
Cm	243	96	5.00E+00	1.90E+00	5.22E+01
Cm	244	96	9.00E-02	2.86E+00	8.18E+01

NUCLIDE		SPECIFIC ATOMIC NUMBER	Pu-239 FGE①②	DECAY HEAT③ (W/g)	SPECIFIC ACTIVITY④ (Ci/g)
Cm	245	96	1.50E+01	5.77E-03	1.74E-01
Cm	246	96	0.00E+00	1.02E-02	3.11E-01
Cm	247	96	5.00E-01	2.98E-06	9.38E-05
Cm	248	96	0.00E+00	5.53E-04	4.30E-03
Cm	250	96	0.00E+00	1.59E-01	2.10E-01
Bk	247	97	0.00E+00	3.69E-02	1.06E+00
Bk	249	97	0.00E+00	3.24E-01	1.66E+03
Bk	250	97	0.00E+00	3.34E+04	3.90E+06
Cf	249	98	4.50E+01	1.54E-01	4.14E+00
Cf	250	98	0.00E+00	4.12E+00	1.11E+02
Cf	251	98	9.00E+01	5.89E-02	1.60E+00
Cf	252	98	0.00E+00	4.06E+01	5.44E+02
Cf	254	98	0.00E+00	9.10E-01	8.50E+03
Es	252	99	0.00E+00	4.37E+01	1.11E+03
Es	253	99	0.00E+00	9.91E+02	2.52E+04
Es	254	99	0.00E+00	7.35E+01	1.88E+03
Es	254m	99	0.00E+00	1.69E+03	3.14E+05

① American National Standards Institute/American Nuclear Society (ANSI/ANS), 1981, "Nuclear Criticality Control of Special Actinide Elements," ANSI/ANS-8.15-1981, American National Standards Institute/American Nuclear Society, Washington, D.C.

② American National Standards Institute/American Nuclear Society (ANSI/ANS), 1998, "Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors," ANSI/ANS-8.1-1998, American National Standards Institute/American Nuclear Society, Washington, D.C.

③ International Commission on Radiological Protection, 1983, "Radionuclide Transformations: Energy and Intensity of Emissions," Annals of the International Commission on Radiological Protection-38, Volumes 11-13, Pergamon Press, Oxford.

④ Walker, F.W., Kiravac, G.J., and Rourke, F.M., 1983, Chart of the Nuclides, 13th Edition, Knolls Atomic Power Laboratories, Schenectady, NY.

⑤ Not applicable. These isotopes are stable and thus have decay heats and specific activities of zero.

Ci/g = Curies per gram.
W/g = Watts per gram.

3.2 Radiation Dose Rates

3.2.1 Requirements

The external radiation dose rate of an individual payload container shall be less than or equal to 200 millirem/hour (mrem/hour) at the surface.

The external radiation dose rates of the TRUPACT-III shall be less than or equal to 200 mrem/hour) at the surface and less than or equal to 10 mrem/hour at 2 meters.

Additional payload container shielding, beyond that identified in Section 2.8, *Specification for Authorized Payloads*, as an integral component of the payload container, shall not be used to meet the above requirements. However, payload containers that meet the above radiation dose rate requirements without shielding may be shielded to levels that are ALARA.

3.2.2 Methods of Compliance and Verification

The payload container surface dose rate shall be measured and compliance recorded on the PTCD (see Section 6.2.1, *Procedure for Certification of Individual Payload Containers*). Measurements shall be made with instruments traceable to a national standard. The dose rate for the TRUPACT-III at the surface and at 2 meters shall be measured and compliance determined and documented in accordance with site procedures.

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3.3 Activity Limit

3.3.1 Requirements

As described in Section 2.7.7, *Deep Water Immersion*, of the TRUPACT-III Safety Analysis Report[1], a payload shall be acceptable for transport only if the activity plus error (i.e., one standard deviation) is less than or equal to 10^5 A_2. A_2 values are defined in 10 CFR 71[2].

3.3.2 Methods of Compliance and Verification

Compliance with the activity requirements is similar to the compliance methodology described in Section 3.1.2, *Methods of Compliance and Verification*. The activity of the payload shall be calculated from the isotopic composition and quantity of radionuclides comprising the payload. The total payload activity plus error (i.e., one standard deviation) shall be used to determine compliance with the 10^5 A_2 payload activity limit.

[1] AREVA Federal Services, LLC, *Safety Analysis Report for the TRUPACT-III Shipping Package*, current revision, USNRC Docket No. 71-9305, AREVA Federal Services, LLC, Tacoma, Washington

[2] Title 10, Code of Federal Regulations, Part 71 (10 CFR 71), *Packaging and Transportation of Radioactive Materials*, 01-01-09 Edition.

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4.0 CHEMICAL PROPERTIES REQUIREMENTS

4.1 Pyrophoric Materials

As defined by 10 CFR §61.2:

> A pyrophoric solid is any solid material, other than one classed as an explosive, which under normal conditions is liable to cause fires through friction, retained heat from manufacturing or processing, or which can be ignited readily and when ignited burns so vigorously and persistently as to create a serious transportation, handling, or disposal hazard. Included are spontaneously combustible and water-reactive materials.[1]

Examples of pyrophoric radionuclides are metallic plutonium and americium. Examples of nonradioactive pyrophorics, or materials/wastes that may cause a pyrophoric-type event, are organic peroxides, sodium metal, and chlorates.

All waste generating sites administratively control the procurement, distribution, use, and disposal of nonradioactive pyrophoric materials. In general, pyrophoric materials are not permitted in TRU waste process areas. The quantity of pyrophoric materials that does enter any process is strictly limited and controlled by site safety considerations.

4.1.1 Requirements

Radioactive pyrophoric materials shall be present only in small residual amounts (≤1 percent [weight]) in payload containers. Radioactive pyrophorics in concentrations greater than 1 percent by weight and all nonradioactive pyrophorics shall be reacted (or oxidized) and/or otherwise rendered nonreactive prior to placement in the payload container.

4.1.2 Methods of Compliance and Verification

Compliance shall be by one, or a combination, of the following methods:

- Review of records and database information, which may include knowledge of process
- Administrative and procurement controls.

[1] U.S. Nuclear Regulatory Commission (NRC), *Pyrophoric definition*, Code of Federal Regulations Title 10, Section 61.2, U.S. Nuclear Regulatory Commission, Washington, D.C.

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4.2 Explosives, Corrosives, and Compressed Gases

As defined by 49 CFR §173.50:

> ...an explosive means any substance or article, including a device, which is designed to function by explosion (i.e., an extremely rapid release of gas and heat) or which, by chemical reaction within itself, is able to function in a similar manner even if not designed to function by explosion, unless the substance or article is otherwise classed under the provisions of [49 CFR 173, Subpart C]. The term includes a pyrotechnic substance or article, unless the substance or article is otherwise classed under the provisions of [49 CFR 173, Subpart C].[1]

Examples of explosives are ammunition, dynamite, black powder, detonators, nitroglycerine, urea nitrate, and picric acid.

As defined by 40 CFR §261.22:

> (a) A solid waste exhibits the characteristic of corrosivity if a representative sample of the waste has...the following propert[y]:
>
> > (1) It is aqueous and has a pH less than or equal to 2 or greater than or equal to 12.5.
>
> (b) A solid waste that exhibits the characteristic of corrosivity has the EPA Hazardous Waste Number of D002.[2]

The physical form of the waste and waste generating procedures at the sites ensure that the waste is in a nonreactive form. All waste generating sites control the procurement, distribution, use, and disposal of explosives. Most sites have lists of restricted materials that include explosives. Typically, the TRU waste generating and storage sites do not allow explosives in the same facility as TRU waste. In addition, sampling programs for pH of inorganic sludges have shown that the sludges consistently meet the limitation on corrosives.[3]

4.2.1 Requirements

Explosives, corrosives, and compressed gases (pressurized containers) are prohibited from the payload.

Used (i.e., empty) aerosol cans are allowed as they do not impact the package internal pressure or flammability. Verification that any aerosol cans present in retrievably stored waste are empty shall be by radiography and/or process knowledge and shall be documented in site-specific compliance documents. Any aerosol cans that are not empty are prohibited.

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[1] U.S. Department of Transportation (DOT), *An Explosive; definition*, Code of Federal Regulations Title 49, Section 173.50, U.S. Department of Transportation, Washington, D.C.

[2] U.S. Environmental Protection Agency (EPA), *Characteristic of corrosivity*, Code of Federal Regulations Title 40, Section 261.22, U.S. Environmental Protection Agency, Washington, D.C.

[3] U.S. Department of Energy (DOE), *CH-TRU Waste Content Codes (CH-TRUCON)*, current revision, DOE/WIPP-3194, U.S. Department of Energy, Carlsbad Field Office, Carlsbad, New Mexico.

4.2.2 Methods of Compliance and Verification

Compliance shall be by one, or a combination, of the following methods:

- Visual examination of the waste
- Administrative and procurement controls
- Radiography
- Sampling program
- Review of records and database information, which may include knowledge of process.

4.3 Chemical Composition

The chemical constituents allowed in a given waste material type (e.g., concreted inorganic particulate waste) are restricted so that a conservative bounding G value may be established for the gas generation potential in each waste material type.

Compliance with the lists of allowable materials in Table 4.3-1 through Table 4.3-7 has been demonstrated for each chemical list corresponding to each content code. The assignment of any content code to a waste material type will also be conservative with respect to G values. For example, if an inorganic solid waste material type (II.1) at a site contains materials that do not comply with the materials listed in Table 4.3-4 (e.g., solid organics excluding packaging), it shall be classified as Waste Material Type III.1 (solid organics), which has twice the bounding G value, and the appropriate content code shall be applied. Similarly, Waste Material Type II.2 may only contain materials with no gas generation potential (G value of zero).

4.3.1 Requirements

Chemical constituents in a payload shall conform to the lists of allowable materials in Table 4.3-1 through Table 4.3-7. The total quantity of chemicals/materials not listed as allowed materials for a given waste material type in any payload container is restricted to less than 5 weight percent total. These materials, if present, are, in general, present as trace chemicals/materials (materials that occur individually in the waste in quantities less than 1 weight percent).

4.3.2 Methods of Compliance and Verification

Compliance shall be by one, or a combination, of the following methods:

- Review of records and database information, which may include knowledge of process
- Administrative and procurement controls
- Sampling program.

Content codes approved by the WIPP CH-TRU Payload Engineer comply with the chemical composition requirements. Any proposed change in process technology at a generator site for a given content code must be evaluated for compliance with the list of allowable materials in Table 4.3-1 through Table 4.3-7. This change shall be evaluated and approved by the WIPP CH-TRU Payload Engineer for compliance with existing waste material type restrictions. All changes in the chemical characteristics of the waste shall be recorded, and the date of the new process, description of the process, and list of new chemicals submitted to the WIPP CH-TRU Payload Engineer. The WIPP CH-TRU Payload Engineer may allow transport of the waste under the approved content code if none of the restrictions are violated as a result of the change. If the WIPP CH-TRU Payload Engineer determines that the old content code and corresponding waste material type(s) are no longer valid, the waste may be assigned to a new content code for shipment under the appropriate approved waste material type. The NRC shall be notified of any change not covered by the authorized contents as defined by this document (e.g., addition of a new waste form with a new G value) through an amendment to the TRUPACT-III TRAMPAC. All changes exceeding currently authorized contents shall be submitted to the NRC for review and approval prior to incorporation into a chemical list or content code.

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Table 4.3-1 — Allowable Materials for Waste Material Type I.1[a]

Absorbents/adsorbents (e.g., Celite®, diatomaceous earth, diatomite, Florco®, Oil-Dri®, perlite, vermiculite)
Acids, inorganic
Alumina cement
Aquaset® products (for aqueous solutions)
Aqueous sludges
Aqueous solutions/water
Asbestos
Ash (e.g., ash bottoms, fly ash, soot)
Batteries, dry (e.g., flashlight)
Ceramics (e.g., molds and crucibles)
Clays (e.g., bentonite)
Concrete
Envirostone® (no organic emulsifiers allowed)
Fiberglass, inorganic
Filter media, inorganic
Firebrick
Glass (e.g., borosilicate glass, labware, leaded glass, Raschig rings)
Graphite (e.g., molds and crucibles)
Grit
Heel (e.g., ash heel; soot heel; firebrick heel; sand, slag, and crucible heel)
Insulation, inorganic
Magnesia cement (e.g., Ramcote® cement)
Metal hydroxides
Metal oxides (e.g., slag)
Metals (e.g., aluminum, cadmium, copper, steel, tantalum, tungsten, zinc)
Nitrates (e.g., ammonium nitrate, sodium nitrate)
Petroset® products (for aqueous solutions)
Portland cement
Sand/soil, inorganic
Salts (e.g., calcium chloride, calcium fluoride, sodium chloride)
Other inorganic materials

[a]Other chemicals or materials not identified in this table are allowed provided that they meet the requirements of Section 4.3.1, *Requirements*. All materials in the final waste form must be inert (nonreactive), be in a nonreactive form, or have been rendered nonreactive.

Table 4.3-2 — Allowable Materials for Waste Material Type I.2[a] Soils, Solidified Particulates, or Sludges Formed from Precipitation

Absorbents/adsorbents (e.g., Celite®, diatomaceous earth, diatomite, Florco®, Oil-Dri®, perlite, vermiculite)
Alumina cement
Aquaset® products (for aqueous solutions)
Aqueous sludges
Aqueous solutions/water
Asbestos
Ash (e.g., ash bottoms, fly ash, soot)
Batteries, dry (e.g., flashlight)
Ceramics (e.g., molds and crucibles)
Clays (e.g., bentonite)
Concrete
Fiberglass, inorganic
Filter media, inorganic
Firebrick
Glass (e.g., borosilicate glass, labware, leaded glass, Raschig rings)
Graphite (e.g., molds and crucibles)
Grit
Heel (e.g., ash heel; soot heel; firebrick heel; sand, slag, and crucible heel)
Insulation, inorganic
Magnesia cement (e.g., Ramcote® cement)
Metal hydroxides
Metal oxides (e.g., slag)
Metals (e.g., aluminum, cadmium, copper, steel, tantalum, tungsten, zinc)
Nitrates (e.g., ammonium nitrate, sodium nitrate)
Petroset® products (for aqueous solutions)
Portland cement
Sand/soil, inorganic
Salts (e.g., calcium chloride, calcium fluoride, sodium chloride)
Other inorganic materials

[a]Other chemicals or materials not identified in this table are allowed provided that they meet the requirements of Section 4.3.1, *Requirements*. All materials in the final waste form must be inert (nonreactive), be in a nonreactive form, or have been rendered nonreactive.

Table 4.3-3 — Allowable Materials for Waste Material Type I.3[a] Concreted Inorganic Particulate Waste

Absorbents/adsorbents (e.g., Celite®, diatomaceous earth, diatomite, Florco®, Oil-Dri®, perlite, vermiculite)
Asbestos
Ash (e.g., ash bottoms, fly ash, soot)
Batteries, dry (e.g., flashlight)
Ceramics (e.g., molds and crucibles)
Clays (e.g., bentonite)
Concrete
Fiberglass, inorganic
Filter media, inorganic
Firebrick
Glass (e.g., borosilicate glass, labware, leaded glass, Raschig rings)
Graphite (e.g., molds and crucibles)
Grit
Heel (e.g., ash heel; soot heel; firebrick heel; sand, slag, and crucible heel)
Insulation, inorganic
Metal hydroxides
Metal oxides (e.g., slag)
Metals (e.g., aluminum, cadmium, copper, steel, tantalum, tungsten, zinc)
Nitrates (e.g., ammonium nitrate, sodium nitrate)
Portland cement
Sand/soil, inorganic
Salts (e.g., calcium chloride, calcium fluoride, sodium chloride)
Water (maximum of 30 weight percent unbound water)
Other inorganic materials

[a]Other chemicals or materials not identified in this table are allowed provided that they meet the requirements of Section 4.3.1, *Requirements*. All materials in the final waste form must be inert (nonreactive), be in a nonreactive form, or have been rendered nonreactive.

Table 4.3-4 — Allowable Materials for Waste Material Types II.1 and II.2[a] Solid Inorganic Materials

Absorbents/adsorbents (e.g., Celite®, Florco®, Oil-Dri®, diatomite, perlite, vermiculite)[b]
Asbestos
Ash (e.g., ash bottoms, fly ash, soot)
Batteries, dry (e.g., flashlight)
Ceramics (e.g., molds and crucibles)
Clays (e.g., bentonite)
Concrete/Portland cement (surface contaminated only)
Fiberglass, inorganic
Filter media, inorganic
Firebrick
Glass (e.g., borosilicate glass, labware, leaded glass, Raschig rings)
Graphite (e.g., molds and crucibles)
Grit
Heel (e.g., ash heel; soot heel; firebrick heel; sand, slag, and crucible heel)
Insulation, inorganic
Magnesium alloy
Metal oxides (e.g., slag)
Metals (e.g., aluminum, cadmium, copper, steel, tantalum, tungsten, zinc)
Nitrates (e.g., ammonium nitrate, sodium nitrate)
Salts (e.g., calcium chloride, calcium fluoride, sodium chloride)
Sand/soil, inorganic
Other inorganic materials

[a]Other chemicals or materials not identified in this table are allowed provided that they meet the requirements of Section 4.3.1, *Requirements*. All materials in the final waste form must be inert (nonreactive), be in a nonreactive form, or have been rendered nonreactive.

[b]Dry absorbents/adsorbents and other dry desiccants are allowed if they contain no absorbed or adsorbed liquids.

Table 4.3-5 — Allowable Materials for Waste Material Type II.3[a] Homogeneous Solid Inorganic Materials with Unbound Absorbed Ambient Moisture (≤6% by weight)

Any material in Waste Material Types II.1 and II.2 (Table 4.3-4) and water as unbound absorbed ambient moisture (≤6% by weight).

[a]Other chemicals or materials not identified in this table are allowed provided that they meet the requirements of Section 4.3.1, *Requirements*. All materials in the final waste form must be inert (nonreactive), be in a nonreactive form, or have been rendered nonreactive.

Table 4.3-6 — Allowable Materials for Waste Material Type III.1[a] Solid Organic Materials

Any material in Waste Types I or II (Tables 4.3-1 through 4.3-5)
Absorbent polymers, organic
Acids, solid, organic
Asphalt
Bakelite® [b]
Cellulose (e.g., Benelex®, cotton Conwed®, paper, rags, rayon, wood)
Cellulose acetate butyrate
Cellulose propionate
Chlorinated polyether
Detergent, solid (e.g., emulsifiers, surfactants)
Fiberglass, organic
Filter media, organic
Greases, commercial brands
Insulation, organic
Leaded rubber (e.g., gloves, aprons, sheet material)
Leather
Oil (e.g., petroleum, mineral)
Organophosphates (e.g., tributyl phosphate, dibutyl phosphate, monobutyl phosphite)
Paint, dry (e.g., floor/wall paint, ALARA)
Plastics [e.g., polycarbonate, polyethylene, polymethyl methacrylate (Plexiglas®, Lucite®), polysulfone, polytetrafluoroethylene (Teflon®), polyvinyl acetate, polyvinyl chloride, polyvinylidene chloride (saran)]
Polyamides (nylon)
Polychlorotrifluoroethylene (e.g., Kel-F®)
Polyesters (e.g., Dacron®, Mylar®)
Polyethylene glycol (e.g., Carbowax®)
Polyimides
Polyphenyl methacrylate
Polypropylene (e.g., Ful-Flo® filters)
Polyurethane
Polyvinyl alcohol
Resins (e.g., aniline-formaldehyde, melamine-formaldehyde, organic resins, phenol-formaldehyde, phenolic resins, urea-formaldehyde)
Rubber, natural or synthetic [e.g., chlorosulfonated polyethylene (Hypalon®), ethylene-propylene rubber, EPDM, polybutadiene, polychloroprene (neoprene), polyisobutylene, polyisoprene, polystyrene, rubber hydrochloride (pliofilm®)]
Sand/Soil
Waxes, commercial brands

[a]Other chemicals or materials not identified in this table are allowed provided that they meet the requirements of Section 4.3.1, *Requirements*. All materials in the final waste form must be inert (nonreactive), be in a nonreactive form, or have been rendered nonreactive.

[b]Bakelite is a trademark for materials that can be composed of several different polymers, including polyethylene, polypropylene, epoxy, phenolic, polystyrene, phenoxy, perylene, polysulfone, ethylene copolymers, ABS, acrylics, and vinyl resins and compounds.

Table 4.3-7 — Allowable Materials for Waste Material Types III.2 and III.3[a] Homogeneous Mixed Organic (10% by weight) and Inorganic (90% by weight) Materials

Any material in Waste Material Types I.1, I.2, I.3, II.1, II.2, II.3, or III.1 (Tables 4.3-1 through 4.3-6), provided that the total amount of solid organic material and/or absorbed or adsorbed water is less than or equal to 10 weight percent of the total waste.

[a]Other chemicals or materials not identified in this table are allowed provided that they meet the requirements of Section 4.3.1, *Requirements*. All materials in the final waste form must be inert (nonreactive), be in a nonreactive form, or have been rendered nonreactive.

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4.4 Chemical Compatibility

The lists of allowable materials in Table 4.3-1 through Table 4.3-7 restrict the chemical composition of the payload. The basis for evaluating chemical compatibility is the U.S. Environmental Protection Agency (EPA) document "A Method for Determining the Compatibility of Hazardous Wastes" (EPA-600/2-80-076).[1] This method provides a systematic means of analyzing the chemical compatibility for specific combinations of chemical compounds and materials. Any incompatibilities between the payload and the packaging shall be evaluated separately if not covered by the EPA method.[1] As described in Appendix 6.1 of the CH-TRU Payload Appendices[2], the EPA method classifies individual chemical compounds into chemical groups and identifies the potential adverse reactions resulting from incompatible combinations of the groups.

4.4.1 Requirements

Chemical compatibility shall be ensured for the following three conditions:

- Chemical compatibility of the waste form with the payload container
- Chemical compatibility of the waste form with the TRUPACT-III payload cavity
- Chemical compatibility of the waste form with the TRUPACT-III O-ring seals.

4.4.2 Methods of Compliance and Verification

Compatibility of all waste material types has been demonstrated for transport in the TRUPACT-III using the chemicals listed in Table 4.3-1 through Table 4.3-7. The Section 4.3, *Chemical Composition*, restrictions imposed on the chemical constituents of the content codes approved by the WIPP CH-TRU Payload Engineer ensure compliance with the compatibility requirements (see also Appendices 6.1, 6.2, 6.3, and 6.4 of the CH-TRU Payload Appendices).[2] The chemical list for each content code is formally documented by the site.

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[1] Hatayama, H.K., Chen, J.J., de Vera, E.R., Stephens, R.D., and Storm, D.L., 1980, *A Method for Determining the Compatibility of Hazardous Wastes*, EPA-600/2-80-076, U.S. Environmental Protection Agency, Cincinnati, Ohio.

[2] U.S. Department of Energy (DOE), *CH-TRU Payload Appendices*, current revision, U.S. Department of Energy, Carlsbad Field Office, Carlsbad, New Mexico.

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5.0 GAS GENERATION PROPERTIES REQUIREMENTS

Gas generation, concentrations, and pressures during transport of CH-TRU wastes in a TRUPACT-III payload are restricted as follows:

- For any package containing water and/or organic substances that could radiolytically generate combustible gases, determination must be made by tests and measurements or by analysis of a representative package such that the following criterion is met over a period of time that is twice the expected shipment time (defined in Appendix 8.1.2, *Shipping Period – General Case*, and Appendix 8.1.3, *Shipping Period – Controlled Shipments*): The hydrogen generated must be limited to a molar quantity that would be no more than 5% by volume of the innermost layer of confinement (or equivalent limits for other inflammable gases) if present at standard temperature and pressure (STP) (i.e., no more than 0.063 gram-moles/cubic foot at 14.7 pounds per square inch absolute (psia) and 32°F).
- The gases generated in the payload and released into the cavity shall be controlled to maintain the pressure within the TRUPACT-III containment vessel below the acceptable design pressure of 25 pounds per square inch gauge (psig).

The analysis presented in Section 5.4, *Compliance with Design Pressure and Total Gas Generation Rate Limits*, shows that all payloads authorized for transport in the TRUPACT-III will comply with the design pressure limit.

The design decay heat limit for the TRUPACT-III is 80 watts. Specific requirements associated with the restrictions on gas generation during transport of a payload are described in detail below.

5.1 Payload Shipping Category

The CH-TRU waste at the DOE sites has been classified into "payload shipping categories" to evaluate and ensure compliance with the gas generation requirements. As shown in Appendices 6.1, 6.5, and 6.6 of the CH-TRU Payload Appendices[1], gas generation due to chemical, biological, and thermal mechanisms is insignificant during transport, and radiolysis is the primary mechanism for potential flammable gas generation.

Appendix 8.1.6, *Procedure for Determining TRUPACT-III Payload Shipping Categories*, defines the methodology for determining a payload shipping category. A shipping category is defined by the following parameters:

- Chemical composition of the waste (waste type).
- Gas generation potential of the waste material type (quantified by the "G value" for hydrogen, which is the number of molecules of hydrogen generated per 100 electron volts (eV) of energy absorbed). Table 5.1-1 lists the G values associated with the various waste material types for CH-TRU waste.

[1] U.S. Department of Energy (DOE), *CH-TRU Payload Appendices*, U.S. Department of Energy, Carlsbad Field Office, Carlsbad, New Mexico.

Table 5.1-1 — CH TRU Waste Material Types and G Values

Waste Material Type	Typical Material Description①②	G Value③	Numeric Shipping Category Notation (G Value x 10^2)
I.1	Absorbed, adsorbed, or solidified inorganic liquid	1.6	0160
I.2	Soils, solidified particulates, or sludges formed from precipitation	1.3	0130
I.3	Concreted inorganic particulate waste	0.4	0040
II.1	Solid inorganic materials in plastic bags (watt*year ≤0.012)	1.7	0170
II.1	Solid inorganic materials in plastic bags (watt*year >0.012)	0.32	0032
II.2	Solid inorganic materials in metal cans	0	0000
II.3	Homogeneous solid inorganic materials with unbound absorbed ambient moisture (≤6% by weight) in metal cans	0.08	0008
III.1	Solid organic materials (watt*year ≤0.012)	3.4	0340
III.1	Solid organic materials (watt*year >0.012)	1.09	0109
III.2	Homogeneous mixed organic (10% by weight) and inorganic (90% by weight) materials in metal cans (watt*year ≤0.012)	0.34	0034
III.2	Homogeneous mixed organic (10% by weight) and inorganic (90% by weight) materials in metal cans (watt*year >0.012)	0.11	0011
III.3	Homogeneous mixed organic (10% by weight) and inorganic (90% by weight) materials in plastic bags (watt*year ≤0.012)	1.85	0185
III.3	Homogeneous mixed organic (10% by weight) and inorganic (90% by weight) materials in plastic bags (watt*year >0.012)	0.4	0040

Notes:

① Appendix 3.3 of the CH-TRU Payload Appendices[1] provides a complete discussion of watt*year criteria.

② Solidified organic waste is not an authorized content for the TRUPACT-III.

③ Dose-dependent G values for waste meeting the watt*year criteria (watt*year >0.012) cannot be used if absorbed, adsorbed, or solidified aqueous materials are present in the waste (see Appendix 3.3 of the CH-TRU Payload Appendices[1]). Appendices 3.1 and 3.2 of the CH-TRU Payload Appendices[1] provide a complete discussion of G values.

- Gas release resistance (type of payload container and type and maximum number of confinement layers used). Appendices 6.7 and 6.8 of the CH-TRU Payload Appendices[1] provide a complete discussion of gas release resistance.

For any given payload container, the shipping category provides a basis to determine the gas generation potential of the contents and the resistance to gas release of the packaging configuration. This enables evaluation of compliance with the gas generation requirements. The logic and procedure for determining payload shipping categories are presented in Appendix 8.1.6, *Procedure for Determining TRUPACT-III Payload Shipping Categories*.

5.1.1 Requirements

Each payload container shall be assigned to a payload shipping category, in a content code approved by the WIPP CH-TRU Payload Engineer, that has information on the following components:

- Waste type
- Waste material type, which defines the gas generation potential
- Total resistance to gas release by the packaging confinement layers. Total resistance has specific requirements associated with
  - Confinement Layers: The inner layers of confinement around the waste materials in the payload containers shall be plastic bags, and/or rigid containers (e.g., metal cans) with closures that meet the specifications outlined in Appendices 3.8, 6.7, and 6.13 of the CH-TRU Payload Appendices[1] and the resistance values summarized in Appendix 8.1.6, *Procedure for Determining TRUPACT-III Payload Shipping Categories*. Any other type of confinement layers used at the sites shall be shown, by testing or analysis, to be equivalent to one of the approved confinement layers described in Appendix 8.1.6, *Procedure for Determining TRUPACT-III Payload Shipping Categories*. "Equivalency" shall be established by demonstration of a hydrogen release rate greater than or equal to the approved confinement layers.

    The rigid liner and lid, if present, in an inner confinement layer (e.g., a 55-gallon drum) shall contain a ≥0.3-in. minimum diameter hole, or a filter with a hydrogen release rate equivalent to or greater than a 0.3-in. minimum diameter hole. Otherwise, the liner must be treated as any other confinement layer with the associated resistance of the liner hole diameter or filter calculated in accordance with Appendix 8.1.6, *Procedure for Determining TRUPACT-III Payload Shipping Categories*.
  - Shipping Period: The conditions specified in Appendix 8.1.3, *Shipping Period – Controlled Shipments*, must be met for use of the Controlled Shipment shipping period (10 days). For other shipments (not Controlled Shipments), a 60-day shipping period (Appendix 8.1.2, *Shipping Period – General Case*) shall be applied.

5.1.2 Methods of Compliance and Verification

Compliance and verification of the shipping category requirements shall be by comparison of the shipping category with the allowable shipping categories for the appropriate content code in the

TRUCON-III[2] document. The shipping category and content code information is recorded in the PTCD (Table 6.2-1).

The methods of compliance and verification for confinement layers and the shipping period are as follows.

Confinement Layers

Radiography, visual examination, administrative and procedural controls, or a combination of these methods may be used to demonstrate that the method of closure for each layer of confinement is in accordance with Appendices 3.8, 6.7, and 6.13 of the CH-TRU Payload Appendices[1]. The waste generation procedures shall specify the maximum number of confinement layers for each waste container. The maximum number of layers may be determined from the waste management practices in use at the time the waste was packaged and from available records and database information.

The requirements for the rigid liner, if present in an inner container, 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, sampling programs, or existing records may be used to verify that the liner, if present, meets the requirements.

Shipping Period

The requirements for the use of the Controlled Shipment (10 days) shipping period shall be met by administrative and procedural controls as specified in Appendix 8.1.3, *Shipping Period – Controlled Shipments*, and Section 6.2.3, *Shipments Designated as Controlled Shipments*. No specific conditions exist for the use of the 60-day shipping period defined in Appendix 8.1.2, *Shipping Period – General Case*.

[2] U.S. Department of Energy (DOE), *TRUPACT-III Content Codes*, current revision, U.S. Department of Energy, Carlsbad Field Office, Carlsbad, New Mexico.

5.2 Flammable (Gas/VOC) Concentration Limits

5.2.1 Requirements

As discussed in Appendices 6.1, 6.5, and 6.6 of the CH-TRU Payload Appendices[1], the primary mechanism for potential flammable gas generation in TRU wastes is radiolysis. TRU wastes to be transported in the TRUPACT-III are restricted so that no flammable mixtures can occur in any layer of confinement during shipment. While the predominant flammable gas of concern is hydrogen, the presence of methane and flammable volatile organic compounds (VOCs) is also limited along with hydrogen to ensure the absence of flammable (gas/VOC) mixtures in TRU waste payloads.

5.2.2 Methods of Compliance and Verification

The evaluation of compliance with flammable (gas/VOC) limits occurs under either the analytical category or the test category as illustrated in Figure 5.2-1.

Compliance with the flammable (gas/VOC) limits can be demonstrated under the analytical category if the total concentration of potentially flammable VOCs within the payload container (SLB2) headspace is less than or equal to 500 parts per million (ppm). If the payload container meets the analytical decay heat limit, compliance with the flammable (gas/VOC) limits is ensured. The analytical decay heat limit for each shipping category is described in Section 5.2.3, *Flammable Gas Generation Rate Limits and Decay Heat Limits*.

Compliance with the flammable (gas/VOC) limits can be demonstrated under the test category if the payload container falls into one or more of the following:

- The total concentration of potentially flammable VOCs within the payload container (SLB2) headspace exceeds 500 ppm.
- The total concentration of potentially flammable VOCs within the payload container (SLB2) headspace is less than or equal to 500 ppm, but the decay heat loading of the payload container exceeds the analytical limit for the shipping category of the payload container.

For test category payload containers, the compliance evaluation for flammable (gas/VOC) limits may be based on measurement of the headspace gas as described in Appendix 8.1.4, *Determination of Flammable Gas Generation Rates*.

The implementation of compliance methods summarized above for flammable (gas/VOC) limits is detailed in Section 5.2.2.1, *Analytical Category: Compliance with Flammable (Gas/VOC) Limits*, through Section 5.2.2.4, *Determine Compliance with Flammable (Gas/VOC) Concentration Limit –Figure 5.2-1 Step 3a Details*, and illustrated in Figure 5.2-1 and Figure 5.2-2.

[1] U.S. Department of Energy (DOE), *CH-TRU Payload Appendices*, U.S. Department of Energy, Carlsbad Field Office, Carlsbad, New Mexico.

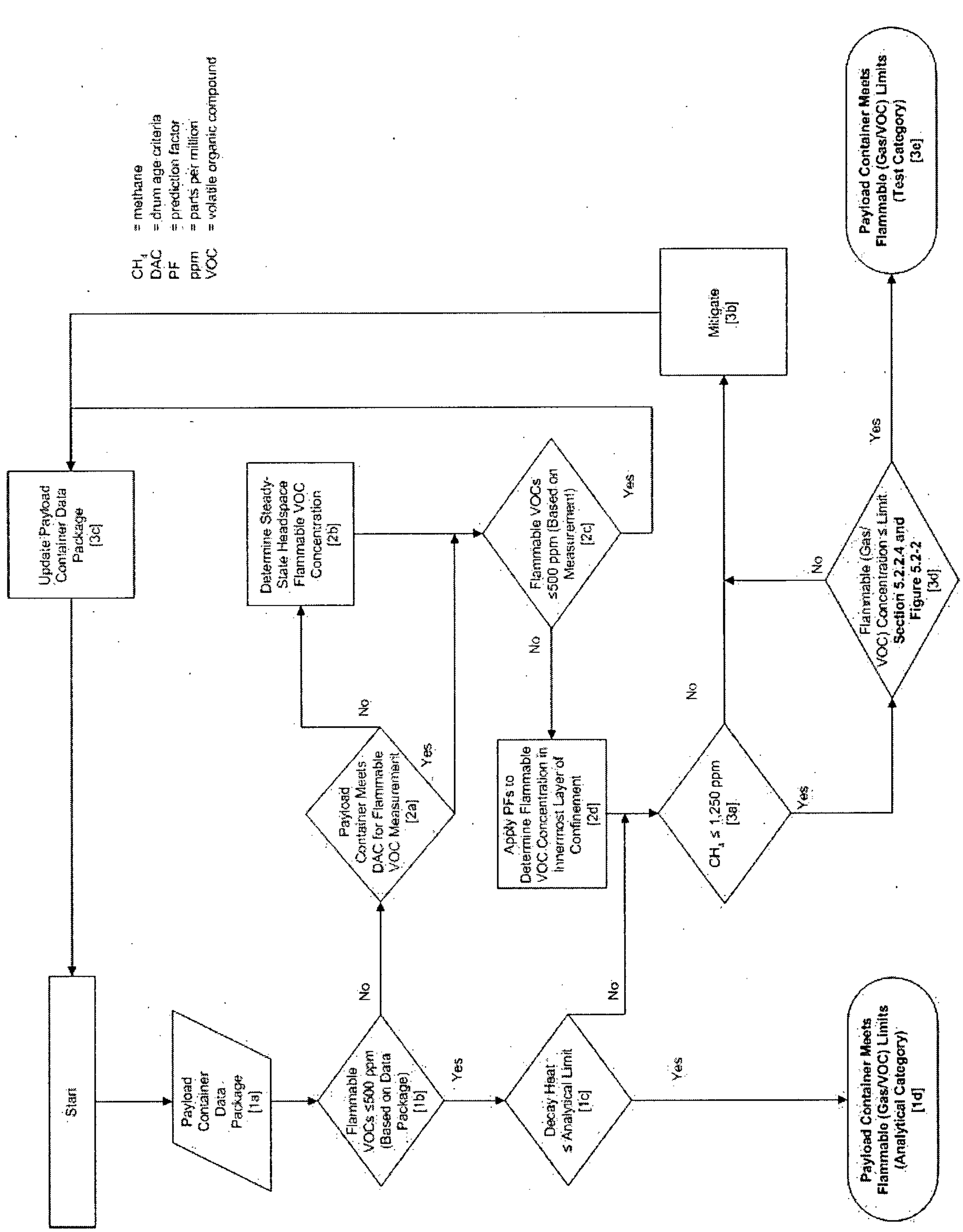

Figure 5.2-1 – Methodology for Compliance with Flammable (Gas/VOC) Concentration Limits

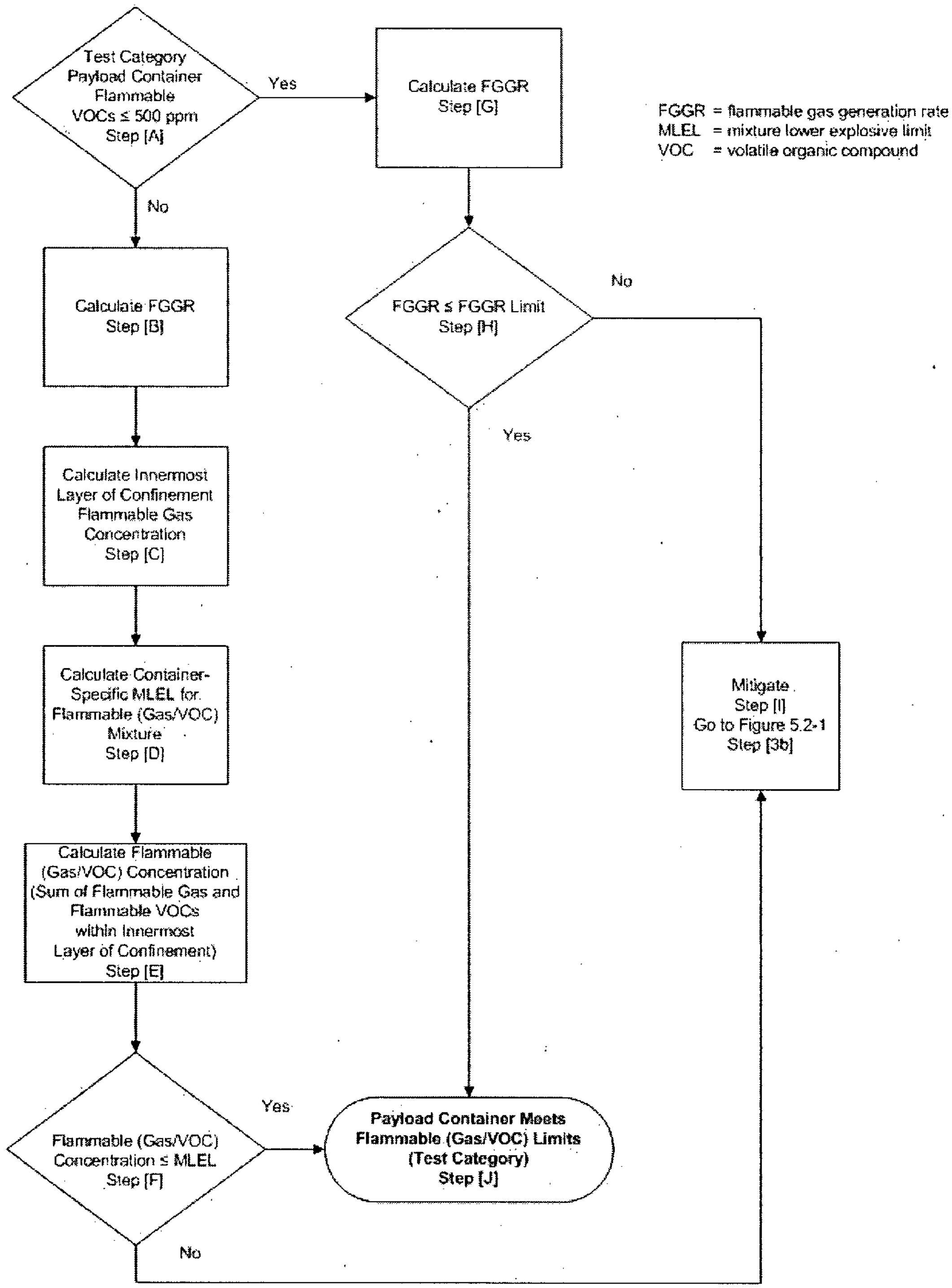

Figure 5.2-2 – Logic Diagram for Compliance with Flammable (Gas/VOC) Limits by Measurement – Step [3d] Details

5.2.2.1 Analytical Category: Compliance with Flammable (Gas/VOC) Limits

Figure 5.2-1 presents the logic for performing the compliance evaluation for flammable (gas/VOC) limits by analysis, which consists of the following steps.

Step 1a, Payload Container Data Package – The starting point for compliance evaluation by analysis is the payload container data package, which includes all data associated with the payload container. These data are gathered from one or more of the methods of payload compliance listed and defined in Section 1.5, *Methods of Compliance* (i.e., visual examination, visual inspection, NDE, records and database information, administrative and procurement controls, sampling programs, and measurement).

Step 1b, Flammable VOCs ≤ 500 ppm (Based on Data Package)? – *Can it be established that the concentration of flammable VOCs present in the headspace of the payload container is ≤ 500 ppm?* The concentration of flammable VOCs present in the headspace of the payload container is determined based on the information contained in the payload container data package. Data used to make this determination consist of process knowledge (e.g., knowledge of waste generation processes and chemical and material inputs to the process) and may include results from a headspace gas sampling program. A list of flammable VOCs is presented in Section 5.2.4, *Flammable VOCs*. If a concentration of flammable VOCs in the payload container headspace of less than or equal to 500 ppm cannot be established based on the payload container data package, the compliance evaluation shall proceed to Section 5.2.2.2, *Drum Age Criteria for Flammable VOC Measurement*, Step 2a, Payload Container Meets DAC for Flammable VOC Measurement. If it can be determined based on available data that no flammable VOCs are present in the payload container, or if it can be established that the total flammable VOC concentration in the payload container headspace is less than or equal to 500 ppm, the compliance evaluation shall proceed to Step 1c, Decay Heat ≤ Analytical Limit.

> Note: For compliance with the analytical category limit on flammable VOC concentration, VOC absorbing or adsorbing material (such as granular activated carbon to adsorb carbon tetrachloride) may be placed in a payload container provided that site personnel can verify or demonstrate the following through testing, analysis, or knowledge of the process:
>
> 1. The absorbent/adsorbent remains effective in retaining VOCs from the time of waste packaging through the end of the maximum shipping period in the TRUPACT-III,
> 2. A flammable mixture of gases does not exist in the innermost layer of confinement, and
> 3. The total concentration of potentially flammable VOCs does not exceed 500 ppm in the headspace of the payload container.

Step 1c, Decay Heat ≤ Analytical Limit? – *Does the payload container exceed the analytical decay heat limit?* For applicable payload containers (i.e., flammable VOCs less than or equal to 500 ppm in the headspace), compliance with the analytical decay heat limit may be evaluated. The derivation of decay heat limits for shipping categories is presented in Section 5.2.3, *Flammable Gas Generation Rate Limits and Decay Heat Limits*. If the payload container exceeds the analytical decay heat limit, the payload container belongs to the test category (measurement), and the compliance evaluation shall proceed to Section 5.2.2.3, *Test Category: Compliance with Flammable (Gas/VOC) Limits by Measurement*, Step 3a, $CH_4 \leq 1{,}250$ ppm. If the payload container meets the decay heat limit, the flammable (gas/VOC) limits are met and the compliance evaluation is complete [see Step 1d, Payload Container Meets Flammable (Gas/VOC) Limits (Analytical Category)].

Step 1d, Payload Container Meets Flammable (Gas/VOC) Limits (Analytical Category) – All payload containers reaching this step meet the flammable (gas/VOC) limits and are eligible for shipment if all other transportation requirements are satisfied.

5.2.2.2 Drum Age Criteria for Flammable VOC Measurement

If a payload container headspace concentration of flammable VOCs ≤ 500 ppm cannot be established based on the payload container data package (as determined in Step 1b of Figure 5.2-1), the flammable VOC concentration of the payload container headspace must be measured. Figure 5.2-1 presents the logic for the compliance evaluation for drum age criteria (DAC) and flammable VOC measurement, which consists of the following steps:

Step 2a, Payload Container Meets DAC for Flammable VOC Measurement – *Does the payload container meet the DAC for measurement of headspace flammable VOCs?* The methodology and logic for determining DAC values for payload containers is specified in Appendix 3.9 of the CH-TRU Payload Appendices[1] and Section 5.2.4, *Flammable VOCs*. If the payload container has not yet met the DAC specified for the applicable packaging configuration, the evaluation shall proceed to Step 2b, Determine Steady-State Headspace Flammable VOC Concentration. If the payload container meets the applicable DAC, the evaluation shall proceed to Step 2c, Flammable VOCs ≤ 500 ppm (Based on Measurement).

Step 2b, Determine Steady-State Headspace Flammable VOC Concentration – If the payload container has not yet met the DAC specified for the applicable packaging configuration, the 90-percent steady-state headspace flammable VOC concentration must be determined from the measured concentration as described in Appendix 3.9 of the CH-TRU Payload Appendices.[1] Following the determination of this value, the evaluation shall proceed to Step 2c, Flammable VOCs ≤ 500 ppm (Based on Measurement).

Step 2c, Flammable VOCs ≤ 500 ppm (Based on Measurement) – *Is the headspace flammable VOC concentration less than or equal to 500 ppm based on measurement?* If the measured or calculated steady-state payload container headspace flammable VOC concentration is less than or equal to 500 ppm (i.e., VOC contribution to flammability is expected to be negligible), the evaluation shall proceed to Section 5.2.2.3, *Test Category: Compliance with Flammable (Gas/VOC) Limits by Measurement*, Step 3c, Update Payload Container Data Package. If the steady-state payload container headspace flammable VOC concentration exceeds 500 ppm, the evaluation shall proceed to Step 2d, Apply PFs to Determine Flammable VOC Concentration in Innermost Layer of Confinement.

Step 2d, Apply PFs to Determine Flammable VOC Concentration in Innermost Layer of Confinement – If the steady-state payload container headspace flammable VOC concentration exceeds 500 ppm, the payload container belongs in the test category (measurement). Prediction factors (PFs) shall be applied, as described in Appendix 3.9 of the CH-TRU Payload Appendices[1], to determine flammable VOC concentration in the innermost layer of confinement.

Following the application of the PFs, the payload container data package shall be updated and the evaluation shall proceed to Section 5.2.2.3, *Test Category: Compliance with Flammable (Gas/VOC) Limits by Measurement*, Step 3a, $CH_4 \leq$ 1,250 ppm.

5.2.2.3 Test Category: Compliance with Flammable (Gas/VOC) Limits by Measurement

If the payload container under evaluation exceeds the analytical decay heat limit (as determined in Step 1c of Figure 5.2-1) or if the concentration of flammable VOCs in the payload container headspace exceeds 500 ppm (as determined in Step 2c of Figure 5.2-1), the payload container belongs in the test category (measurement). Evaluation of compliance with the flammable (gas/VOC) requirements for test category payload containers consists of evaluation based on measurement of the payload container headspace flammable (gas/VOC) concentration. Figure 5.2-1 presents the logic for performing the compliance evaluation for flammable (gas/VOC) limits by measurement, which consists of the following steps:

Step 3a, $CH_4 \leq$ 1,250 ppm – *Is the payload container headspace methane concentration less than or equal to the methane screening limit of 1,250 ppm?* The rationale for the methane screening limit is provided below.

> **Position:** A methane screening limit or concentration of 1,250 ppm in the container headspace should be used in flammability evaluations. If the container headspace methane concentration is below this screening limit, the concentration of methane should be added to the hydrogen concentration and the flammable gas generation rate (FGGR) should be determined. If the concentration is above the screening limit, the container is not eligible for shipment, and the container shall be either repackaged or mitigation measures shall be adopted.
>
> **Rationale:** Although the term "flammable gases" includes both hydrogen and methane, gas measurement data suggest methane is either not present or is present in very low concentrations in TRU waste.
>
> The 1,250 ppm methane screening limit concentration is equivalent to:
>
> - 2.5% of the methane lower explosive limit of 5 percent by volume
> - Fraction of the methane contribution to the flammable gas G value for polyethylene (i.e., [0.1 molecules methane/100 eV] / [4.1 molecules flammable gas /100 eV] or 2.4%).

The concentration of methane present in the headspace of the payload container must be measured in accordance with the headspace measurement methods discussed in Appendix 8.1.4, *Determination of Flammable Gas Generation Rates*. If the payload container headspace methane concentration exceeds 1,250 ppm, the payload container cannot be approved for shipment in its current condition. Mitigation measures must be taken under Step 3b, Mitigate. If the payload container headspace methane concentration is less than or equal to 1,250 ppm (ensuring that methane contribution to flammability is negligible), the compliance evaluation shall proceed to Step 3d, Flammable (Gas/VOC) Concentration $\leq$ Limit.

Step 3b, Mitigate – If the payload container headspace methane concentration exceeds 1,250 ppm, the payload container is not eligible for shipment and must be segregated for repackaging, treatment, or other mitigation measures. Following the completion of mitigation measures, the compliance evaluation shall proceed to Step 3c, Update Payload Container Data Package.

Step 3c, Update Payload Container Data Package – If the measured or calculated steady-state payload container headspace flammable VOC concentration is less than or equal to 500 ppm (as determined in Step 2c of Figure 5.2-1) or the payload container has undergone mitigation measures (Step 3b of Figure 5.2-1), the data package for the payload container shall be updated, and the compliance evaluation shall proceed back to "Start" in Figure 5.2-1. Following the documentation of the payload container headspace flammable VOC concentration of less than or equal to 500 ppm or completion and documentation of mitigation measures to ensure that the payload container headspace methane concentration is less than or equal to 1,250 ppm, the compliance evaluation shall start again.

Step 3d, Flammable (Gas/VOC) Concentration ≤ Limit – *Is the sum of the flammable (gas/VOC) concentrations less than or equal to the mixture lower explosive limit (MLEL)?* The flammable (gas/VOC) concentration within the innermost layer of confinement must be determined using the measured headspace flammable (gas/VOC) concentrations and the time history of the payload container, as described in Appendix 8.1.4, *Determination of Flammable Gas Generation Rates*, and Figure 5.2-2. A specific MLEL shall be calculated for the payload container, as described in Section 5.2.2.4, *Determine Compliance with Flammable (Gas/VOC) Concentration Limit –Figure 5.2-1 Step 3d Details*, and Appendix 3.10 of the CH-TRU Payload Appendices[1]. As described in Section 5.2.2.4, *Determine Compliance with Flammable (Gas/VOC) Concentration Limit –Figure 5.2-1 Step 3d Details*, and Figure 5.2-2, if the sum of the flammable (gas/VOC) concentrations in the innermost layer of confinement exceeds the MLEL, the compliance evaluation shall proceed to Step [3b], Mitigate, in Figure 5.2-1. If the sum of the flammable (gas/VOC) concentrations in the innermost layer of confinement is less than or equal to the MLEL, the flammable (gas/VOC) limits are met and the compliance evaluation is complete [see Step 3e, Payload Container Meets Flammable (Gas/VOC) Limits (Test Category)].

Step 3e, Payload Container Meets Flammable (Gas/VOC) Limits (Test Category) – All payload containers reaching this step meet the flammable (gas/VOC) limits and are eligible for shipment if all other transportation requirements are satisfied.

5.2.2.4 Determine Compliance with Flammable (Gas/VOC) Concentration Limit – Figure 5.2-1 Step 3d Details

Determination of compliance with the flammable (gas/VOC) concentration limit based on measurement consists of using a payload container headspace gas measurement along with the waste packaging configuration and history of the container to determine the gas/VOC concentrations in the innermost layer of confinement. The FGGR is determined from these measured concentrations using analytical solutions as discussed in Appendix 8.1.4, *Determination of Flammable Gas Generation Rates*. The headspace concentrations of the flammable VOCs are used to calculate the concentrations in the innermost layer of confinement using PFs determined as described in Appendix 3.9 of the CH-TRU Payload Appendices.[1]

For all containers, flammable (gas/VOC) concentrations may be measured in an inner layer of confinement or the payload container headspace. The compliance evaluation for determining if the sum of flammable (gas/VOC) concentrations is less than or equal to the MLEL is described in Figure 5.2-2 and by the following steps:

Step [A], Test Category Payload Container Flammable VOCs ≤500 ppm – The starting point for determining compliance with the flammable (gas/VOC) concentration limit based on measurement is to determine if the test category payload container contains flammable VOCs ≤500 ppm or >500 ppm based on data package information (Step $\boxed{1b}$ of Section 5.2.2.1, *Analytical Category: Compliance with Flammable (Gas/VOC) Limits*) or based on measurement data (Step $\boxed{2c}$ of Section 5.2.2.2, *Drum Age Criteria for Flammable VOC Measurement*). If a payload container contains flammable VOCs ≤500 ppm, the compliance evaluation shall begin with Step [G], Calculate FGGR. If a payload container contains flammable VOCs >500 ppm, the compliance evaluation shall begin with Step [B], Calculate FGGR.

Step [B], Calculate FGGR – Calculate the FGGR within the innermost layer of confinement using the measured flammable gas concentration in the payload container and the time history of the container (based on the methodology in Appendix 3.10 of the CH-TRU Payload Appendices[1]). The compliance evaluation shall proceed to Step [C], Calculate Innermost Layer of Confinement Flammable Gas Concentration.

Step [C], Calculate Innermost Layer of Confinement Flammable Gas Concentration – Calculate the concentration of the flammable gas within the innermost layer of confinement at the end of the shipping period inside a TRUPACT-III (X_{inner}) using the following equation:

$$X_{inner} = CG*R_T$$

where,

CG = Calculated FGGR (mole/second)

R_T = The total resistance to hydrogen release (second/mole)

The compliance evaluation shall proceed to Step [D], Calculate Container-Specific MLEL for Flammable (Gas/VOC) Mixture.

Step [D], Calculate Container-Specific MLEL for Flammable (Gas/VOC) Mixture – Calculate the container-specific MLEL within the innermost layer of confinement using the flammable group method as described in Appendix 3.10 of the CH-TRU Payload Appendices[1] using the following equation:

$$MLEL = \frac{100\%}{\sum f_i \, GCF_i}$$

where,

MLEL = Mixture lower explosive limit (volume percent)

f_i = Fraction of flammable gas *i* in mixture on an air-free and nonflammable VOC-free basis (i.e., the concentration of flammable compound *i* divided by the sum of the concentrations of flammable VOCs and flammable gas)

GCF_i = Group contribution factor for compound *i*

The group contribution factor (GCF) values for various compounds are listed in Appendix 3.10 of the CH-TRU Payload Appendices.[1] The compliance evaluation shall proceed to Step [E], Calculate Flammable (Gas/VOC) Concentration (Sum of Flammable Gas and Flammable VOCs within Innermost Layer of Confinement).

Step [E], Calculate Flammable (Gas/VOC) Concentration (Sum of Flammable Gas and Flammable VOCs within Innermost Layer of Confinement) – Calculate and record the sum of the concentrations of the flammable gas in the innermost layer of confinement and the flammable VOCs in the innermost layer of confinement. The compliance evaluation shall proceed to Step [F], Flammable (Gas/VOC) Concentration ≤ MLEL.

Step [F], Flammable (Gas/VOC) Concentration ≤ MLEL – Compare the sum of the flammable gas and flammable VOC concentrations within the innermost layer of confinement to the calculated MLEL. If the sum of the flammable (gas/VOC) concentrations in the innermost layer of confinement is less than or equal to the MLEL, the flammable (gas/VOC) limits are met and the compliance evaluation is complete [see Step [J], Payload Container Meets Flammable (Gas/VOC) Limits (Test Category)]. If the sum of the flammable gas and flammable VOC concentrations exceeds the MLEL, the compliance evaluation shall proceed to Step [I], Mitigate.

Step [G], Calculate FGGR – Calculate the FGGR within the innermost layer of confinement using the measured flammable gas concentration in the payload container and the time history of the container (based on the methodology in Appendix 3.10 of the CH-TRU Payload Appendices[1]). The compliance evaluation shall proceed to Step [H], FGGR ≤ FGGR Limit.

Step [H], FGGR ≤ FGGR Limit – Compare the calculated FGGR to the maximum allowable FGGR limit. The determination of FGGR limits for shipping categories is presented in Section 5.2.3, *Flammable Gas Generation Rate Limits and Decay Heat Limits*. If the calculated FGGR is less than or equal to the maximum allowable FGGR, the flammable (gas/VOC) limits are met and the compliance evaluation is complete [see Step [J], Payload Container Meets Flammable (Gas/VOC) Limits (Test Category)]. If the calculated FGGR exceeds the maximum allowable flammable gas generation rate, the compliance evaluation shall proceed to Step [I], Mitigate.

Step [I], Mitigate – If the payload container calculated FGGR exceeds the maximum allowable FGGR limit or the sum of the flammable gas and flammable VOC concentrations within the innermost layer of confinement exceed the calculated MLEL, the payload container is not eligible for shipment and must be segregated for repackaging, treatment, or other mitigation measures (see Step 3b of Figure 5.2-1).

Step [J], Payload Container Meets Flammable (Gas/VOC) Limits (Test Category) – All payload containers reaching this step meet the flammable (gas/VOC) limits and are eligible for shipment if all other transportation requirements are satisfied.

5.2.3 Flammable Gas Generation Rate Limits and Decay Heat Limits

The maximum allowable FGGR limit and decay heat limit, which will limit the concentration of flammable gas within any layer of confinement to less than or equal to 5% by volume, may be determined for payload shipping categories. Appendix 8.1.1, *Derivation of Flammable Gas Generation Rate Limits and Decay Heat Limits*, presents the methodology used for deriving the limits for payload shipping categories. Appendix 6.9 of the CH-TRU Payload Appendices[1] describes the temperature dependence of flammable gas generation and release rates.

The method for calculating the decay heat limit and gas generation limit for numeric shipping categories is simple and conservative to provide a direct correlation between shipping category and the limits.

The payload shipping category notation (as described in Appendix 8.1.6, *Procedure for Determining TRUPACT-III Payload Shipping Categories*) is in the form of XX YYYY ZZZZ, where XX represents the waste type, YYYY represents the G value (multiplied by 100), and ZZZZ represents the total resistance, R_T, (divided by 10,000 and rounded up). The FGGR limit per innermost layer of confinement, CG, and the decay heat limit per innermost layer of confinement, Q_i, are determined by the following equations:

$$CG = \frac{0.05}{(ZZZZ * 10{,}000)\dfrac{\text{sec}}{\text{mole}}}$$

and

$$Q_i = \frac{(4824.42)\dfrac{\text{molecules}}{\text{mole}} * \dfrac{\text{watt} * \text{sec}}{\text{eV}}}{(ZZZZ * YYYY)\dfrac{\text{sec} * \text{molecules}}{\text{mole} * \text{eV}}}$$

For example, for shipping category 30 0109 0046, substituting 0109 for YYYY and 0046 for ZZZZ yields:

$$CG = \frac{0.05}{(0046 * 10{,}000)\dfrac{\text{sec}}{\text{mole}}} = 1.086 \times 10^{-7} \text{ mole/sec}$$

$$Q_i = \frac{(4824.42)\dfrac{\text{molecules}}{\text{mole}} * \dfrac{\text{watt} * \text{sec}}{\text{eV}}}{(0046 * 0109)\dfrac{\text{sec} * \text{molecules}}{\text{mole} * \text{eV}}} = 0.9621 \text{ watts}$$

5.2.4 Flammable VOCs

A list of flammable VOCs is provided in Table 5.2-1. If a concentration of flammable VOCs in the payload container headspace of less than or equal to 500 ppm cannot be established based on waste generation procedures or records of process knowledge, headspace gas sampling for flammable VOCs is required. Prior to performing headspace sampling, a DAC needs to be met for headspace samples to be valid. DACs are estimates of time required for flammable VOCs in a payload container to reach 90 percent of the equilibrium steady-state concentration within the different layers of confinement. Alternately, the headspace sample taken before the DAC has been met can be used to determine the 90% steady-state concentration in a waste container by multiplying the measured VOC concentration by a VOC-specific and packaging-specific concentration multiplier (CM). A CM is defined as the ratio of 90 percent of the steady-state VOC concentration in the sampling headspace divided by the VOC headspace concentration at a given time. The 90% steady-state concentration can then be correlated to the VOC concentration in the innermost layer of confinement by the use of PFs, which are multipliers to be applied to the headspace concentration. DACs and CMs are determined by solving the governing mass balance and transport equations for the various VOCs. The WIPP CH-TRU Payload Engineer shall use the governing equations and methodology documented in Appendix 3.9 of the CH-TRU Payload Appendices[1], which is based on Liekhus *et al.* (October 2000)[2] to determine DACs, CMs, and PFs for each TRUPACT-III content code.

Table 5.2-1 – Flammable VOCs

Acetone
Benzene
1-Butanol
Chlorobenzene
Cyclohexane
1,1-Dichloroethane
1,2-Dichloroethane
1,1-Dichloroethene
cis-1,2-Dichloroethene
Ethyl benzene
Ethyl ether
Methanol
Methyl ethyl ketone
Methyl isobutyl ketone
Toluene
1,2,4-Trimethylbenzene
1,3,5-Trimethylbenzene
Xylenes

If additional flammable VOCs (i.e., not listed in Table 5.2-1) are identified in concentrations greater than 500 ppm total, the following process shall be used to include these VOCs in the analysis for compliance with the flammable (gas/VOC) limits:

> Each flammable VOC not listed in Table 5.2-1 will be identified by name and corresponding Chemical Abstracts Service number. A list of these VOCs shall be submitted by the shipper to the WIPP CH-TRU Payload Engineer for evaluation. For each VOC, the WIPP CH-TRU Payload Engineer will direct the evaluation of required physical and chemical properties in order to calculate DACs, CMs, and PFs using the methodology documented in Appendix 3.9 of the CH-TRU Payload Appendices[1] and the

[2] Liekhus, K.J., S.M. Djordjevic, M. Devarakonda, M.J. Connolly, October 2000, *Determination of Drum Age Criteria and Prediction Factors Based on Packaging Configurations*, INEEL/EXT-2000-01207, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho.

GCF using the methodology documented in Appendix 3.10 of the CH-TRU Payload Appendices[1].

5.3 Venting and Aspiration

5.3.1 Requirements

Containers that have been stored in an unvented condition shall be aspirated for the specific length of time to ensure equilibration of any gases that may have accumulated in the closed container. For containers with waste types in packaging configurations that do not generate any flammable gas, aspiration is not required (i.e., Waste Material Type II.2). NOTE: The aspiration requirement is applicable only to containers that have been stored in an unvented condition. The derivation of aspiration times is outlined in Appendix 3.7 of the CH-TRU Payload Appendices.[1]

5.3.2 Methods of Compliance and Verification

Aspiration times shall be determined using the methodology outlined in Appendix 3.7 of the CH-TRU Payload Appendices.[1]

[1] U.S. Department of Energy (DOE), *CH-TRU Payload Appendices*, U.S. Department of Energy, Carlsbad Field Office, Carlsbad, New Mexico.

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5.4 Compliance with Design Pressure and Total Gas Generation Rate Limits

The maximum pressure within the TRUPACT-III package under normal conditions of transport (NCT) is calculated based on bounding values. As shown in Appendices 6.1, 6.5, and 6.6 of the CH-TRU Payload Appendices[1], gas generation due to chemical, biological, and thermal mechanisms is insignificant during transport, and radiolysis is the primary mechanism for potential flammable and net (total) gas generation. The major factors affecting the internal pressure are radiolytic gas generation, thermal expansion of gases, and the vapor pressure of water within the TRUPACT-III containment vessel.

Calculation of maximum pressure in the TRUPACT-III containment vessel considers immediate release of gases from the SLB2 and any inner containers/confinement layers to the TRUPACT-III containment vessel. The TRUPACT-III containment vessel and interior void volumes are assumed to be filled with gas at 70°F (294 K) and 14.7 psia when the package is closed for transport. It is conservatively assumed that the void volume in the TRUPACT-III containment vessel outside the SLB2 container of 2,239 liters (Appendix 8.1.5, *Determination of Void Volumes for TRUPACT-III Payload*) is the only volume available in calculating pressures under NCT (no credit is taken for available void volume within the SLB2 payload container and any inner containers/confinement layers). Sufficient moisture is assumed to be present for saturated water vapor at any temperature. The pressure increase due to water vapor is obtained using the Bolton[2] equation for the saturation vapor pressure of water vapor as a function of temperature.

The maximum pressure inside the TRUPACT-III is calculated for the maximum shipping period of 60 days. The use of a 60-day shipping period in the calculation of maximum normal operating pressure is consistent with 10 CFR §71.41(c)[3]. As specified in 10 CFR §71.41(c), this section shows that the "...controls proposed to be exercised by the shipper are demonstrated to be adequate to provide equivalent safety of the shipment." The use of this shipping period is consistent with the analysis presented in Appendix 8.1.2, *Shipping Period – General Case*, which shows that the maximum normal shipping period will be less than 60 days by a large margin of safety.

The method used to calculate the maximum pressure is provided below. The number of moles per second of total gas generated by radiolysis is calculated from the following equation:

Equation 1

$$n_g = G_{eff(T)} * W * C$$

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[1] U.S. Department of Energy (DOE), *CH-TRU Payload Appendices*, current revision, U.S. Department of Energy, Carlsbad Field Office, Carlsbad, New Mexico.

[2] Bolton, D., 1980, "The Computation of Equivalent Potential Temperature," *Monthly Weather Review*, No. 108, pp. 1046-1053.

[3] Title 10, Code of Federal Regulations, Part 71 (10 CFR 71), *Packaging and Transportation of Radioactive Materials*, 01-01-09 Edition.

where,

n_g	=	Rate of radiolytic gas generation (moles/second)
$G_{eff(T)}$	=	Temperature-corrected effective G-value [the total number of molecules of gas generated per 100 eV of energy emitted (molecules/100 eV) at the temperature of the target material]
W	=	Total decay heat (watts)
C	=	Conversion constant for the units used = 1.04×10^{-5} (moles)(eV)/(molecule)(watt-second).

The effective G values are discussed in Appendix 3.2 of the CH-TRU Payload Appendices[1]. As discussed in Appendix 3.2 of the CH-TRU Payload Appendices[1], the effective G values provided at room temperature (T_{RT}) are a function of temperature based on the activation energy (E_a) for the material. They are increased, as a result of increased bulk average payload (i.e., contents) temperature, using the corresponding activation energy values obtained from Appendix 3.2 of the CH-TRU Payload Appendices[1]. The total increase in pressure for a 60-day shipping period for a bounding solid organic waste material is summarized below.

From Appendix 3.2 of the CH-TRU Payload Appendices[1] the maximum effective total (net) gas G value at room temperature is 8.4 molecules/100 eV and the activation energy is 2.1 kcal/g mole for combustible wastes.

Bounding TRUPACT-III payload temperatures are documented in Section 3.0, *Thermal Evaluation*, of the TRUPACT-III Safety Analysis Report[4] at three different payload decay heats (20 watts, 40 watts, and 80 watts). Temperatures required to calculate pressure increases include the bulk average payload temperature (T_{ap}), the bulk average void volume (gas) temperature (T_{avv}), and the minimum TRUPACT-III inner wall temperature ($T_{minwall}$). The T_{ap} is used to correct the effective G value as discussed in Section 5.4.1, *Applicable G Values*. The T_{avv} is used to correct for the thermal expansion (i.e., heat-up) of gases. The water vapor pressure contribution is calculated based on the temperature of the coolest or condensing surface on the inner wall of the TRUPACT-III, $T_{minwall}$. All three of these temperatures are approximately linear functions of the decay heat in watts. The relationships are represented by the following regression equations where all three temperatures are in units of °C and Q is payload decay heat in watts:

$$T_{ap} = 0.52214\,Q + 48.70$$

$$T_{avv} = 0.18286\,Q + 48.40$$

$$T_{minwall} = 0.05107\,Q + 46.35.$$

The calculation of decay heat limits is based on an iterative process until the previous three regression equations are met. As shown in Table 5.4-2 (at the end of this section), as a result of the iterative process a payload decay heat of 19.27 watts corresponds to the design pressure limit (25 psig) for a bounding solid organic waste material.

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[4] AREVA Federal Services, LLC, *Safety Analysis Report for the TRUPACT-III Shipping Package*, current revision, USNRC Docket No. 71-9305, AREVA Federal Services, LLC, Tacoma, Washington

5.4.1 Applicable G Values

The temperature-corrected effective G value, $G_{eff(T_{ap})}$, is calculated using the Arrhenius equation (see Appendix 3.1 of the CH-TRU Payload Appendices[1]):

Equation 2

$$G_{eff(T_{ap})} = G_{eff(RT)} \exp\left[(E_a / R)\{(T_{ap} - T_{RT}) / (T_{ap} * T_{RT})\}\right]$$

where,

$G_{eff(RT)}$	=	Effective net gas G value at 25°C (8.4 molecules/100 eV)
E_a	=	Activation energy (2.1 kcal/mole)
R	=	Gas constant (1.99×10^{-3} kcal/mole K)
T_{RT}	=	Temperature 298 K (25°C)
T_{ap}	=	Bulk average payload temperature at 19.27 watts = 331.9 K (58.8°C)

Substitution of the variables in Equation 2 results in the following expression for the net gas G value at the bulk average payload temperature:

G(331.9 K) = 8.4 molecules/100 eV exp[(2.1 kcal/mole/1.99 x 10^{-3} kcal/mole K) {(331.9 K – 298 K) / (331.9 K x 298 K)}]

G(331.9 K) = 12.04 molecules/100 eV.

5.4.2 Total Gas Generation Analysis

Using these temperature-corrected effective G values, the radiolytic gas generation rate from Equation 1 is calculated as follows:

n_g = (12.04 molecules/100 eV) x (19.27 watts) x 1.04 x 10^{-5} (moles)(eV)/ [(molecule)(watt-second)]

= 2.413 x 10^{-5} moles/second.

The total liters of radiolytic gases generated at STP at the end of 60 days would be:

V_R = (2.413 x 10^{-5} mole/second) x (60 days) x (86,400 seconds/day) x (22.4 liters/mole)

= 2,802 liters at STP.

The generated volume of radiolytic gases is heated to the bulk average void volume gas temperature (T_{avv}) at 19.27 watts of 51.9°C (325.1 K). The corresponding volume occupied is:

= (2,802 liters at STP) x (325.1 K / 273.15 K) = 3,335 liters at 51.9°C (325.1 K).

This gas contributes a pressure of:

P_{rg} = 3,335 liters / 2,239 liters total void volume * 14.7 psia = 21.89 psia at 51.9°C (325.1 K).

The initial pressure of gas present inside the TRUPACT-III at 70°F (294.3 K) is 14.7 psia. This gas is also heated to 51.9°C (325.1 K). The increased pressure associated with this increase in temperature is:

P_{hu} = (14.7 psia) x (325.1 K / 294.3 K) = 16.24 psia.

The water vapor pressure is based on the temperature of the coolest, or condensing, surface on the inner wall of the container, $T_{minwall}$.

$T_{minwall}$ = 0.05107 Q + 46.35

where,

Q = 19.27 watts

Therefore,

$T_{minwall}$ = 47.3°C (320.5 K).

The water vapor pressure, P_{wv}, from the water vapor pressure equation [2] is 1.57 psia.

Thus, the maximum pressure inside the TRUPACT-III at the end of 60 days is:

P_{max} = $P_{rg} + P_{hu} + P_{wv} - P_{atm}$ = 21.89 + 16.24 +1.57 -14.7 = 25 psig.

5.4.3 Bounding Analysis

As documented in Section 5.4.2, *Total Gas Generation Analysis*, compliance with the TRUPACT-III design pressure limit of 25 psig can be demonstrated by conservative theoretical analysis up to the wattage limits shown in Table 5.4-1.

Table 5.4-1 – Wattage Limits for Theoretical Analysis of Design Pressure

Waste Type	Container Type	Wattage Limit per SLB2 and per TRUPACT-III
I	SLB2	80
II	SLB2	80
III	SLB2	19.27

For the case of Waste Type III where the wattage limit of 19.27 watts is exceeded but the packaging design limit of 80 watts per TRUPACT-III is met, compliance with the container flammable gas generation rate limit by the methodology described in Section 5.4.2, *Total Gas Generation Analysis*, can be used to evaluate compliance with the total gas generation rate limit. Because the primary mechanism for gas generation for both flammable and total gas for Waste Types I, II, and III is radiolysis, compliance with the flammable gas generation rate limit implies actual G values (both flammable and total) that are much lower than those used to derive the limits in Table 5.4-1. Therefore, compliance with the flammable gas generation rate limits will ensure compliance with the total gas generation rate limits for the case of Waste Type III SLB2s greater than 19.27 watts in a TRUPACT-III. An example calculation is provided below.

Example Calculation

Assuming an SLB2 of Waste Material Type III.1 with no layers of confinement and a decay heat loading of 60 watts, compliance with the total gas generation rate limit is ensured if compliance with the flammable gas generation rate limit can be demonstrated by measurement. Using the equations in Section 5.2.3, *Flammable Gas Generation Rate Limits and Decay Heat Limits*, the maximum allowed FGGR for the test category SLB2 can be calculated as 8.33E-07 moles/second. The maximum possible FGGR limit per SLB2 was determined by assuming zero confinement layers and no resistance to gas release from the SLB2 filter(s). These assumptions allow the calculation of the FGGR limit using only the load type resistance value specified in Appendix 8.1.6, *Procedure for Determining TRUPACT-III Payload Shipping Categories*. The resulting 60-day shipping period payload shipping category is 30 0109 0006, corresponding to an FGGR limit of 8.33E-07 moles/second. Based on the 60-watt decay heat loading of the SLB2 and the requirement for the SLB2 FGGR to be less than or equal to 8.33E-07 moles/second, the actual G value (flammable gas) for this container can be calculated as 0.134. This compares to a theoretical G value (flammable gas) of 1.09 used to derive the analytical category limits. Because the mechanism for both hydrogen and total gas generation is radiolysis, a similar ratio exists between the actual and theoretical gas generation rates for hydrogen and total gas. This means that if the SLB2 passes the FGGR limit of 8.33E-07 moles/second, the actual G value (total gas) for this container will be lower than the theoretical G value used to derive the limit in Table 5.4-1 by a factor of 1.09/0.134 = 8. Therefore, the actual total gas generation from this container will be extremely low and will easily comply with the packaging design pressure limits.

In order to more clearly illustrate this fact and directly address the purpose of the above example, an alternate pressure increase calculation for Waste Material Type III.1 is provided below. This calculation is based on the maximum possible FGGR limit.

Alternate Pressure Increase Calculation for Waste Material Type III.1 Based on FGGR Limit

A pressure increase calculation that corresponds to the FGGR limit provides a bounding assessment of the pressure increase value. As shown above, the maximum possible FGGR limit per SLB2 is 8.33E-07 moles/second.

Using this maximum possible SLB2-specific FGGR limit, the maximum possible "radiolytic gas generation rate" was calculated using the following formula:

$$CG_{total} = \left(\frac{G_{eff(T)}}{G} \right) x \ FGGR$$

Where,

CG_{total} = Rate of total radiolytic gas generation (moles/second)

$G_{eff(T)}$ = Temperature-corrected effective total G value [the total number of molecules of gas generated per 100 eV of energy absorbed (molecules/100 eV)]

G = Flammable gas G value

FGGR = Flammable gas generation rate

Assuming the maximum TRUPACT-III design decay heat limit of 80 watts, corresponding to an average waste contents temperature of 194.8°F (363.6K), the temperature corrected effective G value (total gas) ($G_{eff(T)}$) is 15.9. The product of the $G_{eff(T)}/G$ ratio of 15.9/1.09 or 14.6 and the maximum possible container FGGR limit of 8.33E-07 moles/second yields a maximum possible total radiolytic gas generation rate of 1.21E-05 moles/second. This gas generation rate was used to calculate the maximum possible FGGR limited pressure of 14.75 psig at the end of the 60-day shipping period. The pressure of 14.75 psig is well below the 25-psig pressure design limit.

Table 5.4-2 - TRUPACT-III Pressure Increase, 60-Day Duration

Waste Material Type	Decay Heat per SLB and per Package (watts)	Average Contents Temperature (°F)	Total Gas Value, G_{eff} (molecules/ 100ev)	Activation Energy (kcal/g-mole)	Temperature Correlation Value, G_{eff} (molecules/ 100ev)	Radiolytic Gas Generation Rate (moles/sec)	Radiolytic Gas Generation STP/60 days (liters)	Average Void Gas Temperature (°F)	Radiolytic Gas Pressure Increase (psia)	Initial Gas Pressure Increase (psia)	Minimum Wall Temperature (°F)	Water Vapor Pressure (psia)	Pressure Increase @ 60 days (psig)
I.1	80.00	194.8	2.40	0	2.40	1.997E-05	2319	145.5	18.73	16.79	122.8	1.83	22.65
II.1	80.00	194.8	1.70	0.8	2.17	1.803E-05	2094	145.5	16.92	16.79	122.8	1.83	20.84
III.1	19.27	137.8	8.40	2.1	12.04	2.413E-05	2802	125.5	21.89	16.24	117.2	1.57	25.00

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6.0 PAYLOAD ASSEMBLY REQUIREMENTS

This section presents an overview of the control procedures that shall be used by the sites in order to assemble a payload qualified for transport in the TRUPACT-III. The parameters described in previous sections shall be evaluated for selection of the payload. The SLB2 identification (ID) number shall uniquely identify the SLB2. Each SLB2 shall be assigned an approved content code. Wherever applicable, the parameters shall be checked against the limits after addition of the measurement error, as detailed in previous sections. If any of the limits are not met by the SLB2, it shall be rejected from transport (subject to mitigation or repackaging), marked, and segregated.

6.1 Requirements

The TRUPACT-III payload shall be authorized for shipment by the site TCO by completing and signing the PTCD.

The shipping records shall be maintained by the shipper for a minimum period of three years after the shipment is made.

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6.2 Methods of Compliance and Verification

6.2.1 Procedure for Certification of Individual Payload Containers

Generating and storage sites shall qualify an SLB2 for transport in the TRUPACT-III by verifying that the container meets the parameter requirements/limits specified by this document and summarized in Table 6.2-1 – *Payload Transportation Certification Document (PTCD)* (at the end of this section). The information in Table 6.2-1 must be completed for each SLB2. Table 6.2-1 may be reformatted for site use. All parameters noted on the form must be included in modified versions. Data on the parameters shall be obtained by methods outlined in this document. Table 6.2-1 shall be completed as follows (section numbers in parentheses refer to sections in the TRUPACT-III TRAMPAC that provide requirement information for the transportation parameter described).

Identification Parameters

- SLB2 ID # (Section 2.3): The site-specific ID number is unique to each container of waste and provides a means for tracking data records and package history. These records on the properties of the container are referred to as the data package. The container ID number assigned to the container appears on a label affixed to the payload container and can be read for visual verification or for electronic retrieval (i.e., bar codes). This ID number may be used to track data necessary for payload container compliance determinations.
- Certification Site: This is the location at which transportation certification takes place.
- Container Designated for Controlled Shipment? (Section 5.1.2): Indicate if the container is designated for controlled shipment in accordance with the controls specified in Appendix 8.1.3, *Shipping Period – Controlled Shipments*. If the container is designated for controlled shipment, Table 6.2-2 – *Shipping Site Control Checklist for Controlled Shipments*, must also be completed as described in Section 6.2.3, *Shipments Designated as Controlled Shipments*.
- Content Code (Section 1.6): The site Transportation Certification Official shall ensure that the proper content code is assigned to the SLB2.
- Payload Shipping Category (Section 5.1): The payload shipping category shall be assigned to the payload container by looking up the shipping category from the appropriate content code in the TRUCON-III document.
- Payload Container Specifications are Met (Section 2.8.1): Compliance with the payload container specifications of Section 2.8.1, *Specification for Authorized Payload Container*, shall be ensured.
- Filter Specifications of Section 2.4 are Met: Compliance with the filter specifications in Section 2.4, *Filter Vents*, shall be ensured.

Transportation Parameters

Compliance information for the transportation parameters shall be obtained from the data package for the container. The following criteria shall be met:

- Criteria:
  - Residual liquids are <1% of the payload container volume. (Section 2.5)
  - Sharp/heavy objects are blocked/braced/suitably packaged (Section 2.6). This requirement is met if blocking, bracing, or packaging is ensured within the payload container or if sharp/heavy objects are not present.
  - Radioactive pyrophorics are ≤1% (weight). (Section 4.1)
  - Nonradioactive pyrophorics are not present or have been reacted. (Section 4.1)
  - Explosives are not present. (Section 4.2)
  - Corrosives are not present. (Section 4.2)
  - Pressurized containers and compressed gases are not present. (Section 4.2)
  - Sealed containers >4 liters (nominal) are not present (except for solid inorganic waste packaged in metal). (Section 2.7)
  - Beryllium and/or beryllium oxide are ≤1% of waste weight. (Section 3.1)
  - Machine-compacted waste is not present. (Section 3.1)
- Weight Limit (Section 2.2): The loaded weight of each SLB2 is obtained from its data package. The SLB2 weight plus error shall be compared to the maximum allowable weight limit of 10,500 pounds.
- Fissile Mass Limit (Section 3.1): The Pu-239 FGE of the payload container shall be recorded. The Pu-239 FGE plus two times the error (i.e., two standard deviations) of the payload container shall be compared to the applicable FGE limit per payload.
- Package Design Decay Heat Limit (Section 5.0): The decay heat of the payload container shall be determined as described in Section 3.1, *Nuclear Criticality*. The decay heat plus error (i.e., one standard deviation) shall be compared to the package design decay heat limit of 80 watts.
- Flammable (Gas/VOC) Concentration Limits (Section 5.2): Compliance with the 5% limit on hydrogen concentration shall be by one of two methods:
  - Compliance with Decay Heat Limit (Section 5.2.2.1): Flammable VOCs are ≤500 ppm in the container headspace. The maximum allowable decay heat limit per payload container for the applicable payload shipping category shall be recorded from the determination made pursuant to Section 5.2.3, *Flammable Gas Generation Rate Limits and Decay Heat Limits*. The measured decay heat plus the measurement error (one standard deviation) of the payload container may be obtained from its data package. Measured decay heats are determined from the isotopic composition and quantity of radionuclides, as described in Section 3.1. The measured decay heat plus the measurement error shall be compared to the maximum allowable decay heat limit per payload container for the appropriate shipping category.
  - Compliance with FGGR Limit (Section 5.2.2.3 and Section 5.2.2.4): The FGGR limit per payload container for the applicable payload shipping category shall be recorded from the determination made pursuant to Section 5.2.3, *Flammable Gas Generation*

Rate Limits and Decay Heat Limits. If this method is used, the FGGR for the payload container shall be determined according to the procedures described in Appendix 8.1.4, *Determination of Flammable Gas Generation Rates*. This FGGR shall be compared to the FGGR limit.

- Activity Limit (Section 3.3): The total payload container activity shall be less than or equal to 10^5 A_2 (curies).
- Radiation Dose Rate Limit (Section 3.2): The measured radiation dose rate at the surface of the payload container shall be ≤200 mrem/hour.

If the above requirements are met, proceed to Section 6.2.2, *Procedure for Certification of a TRUPACT-III Package*.

6.2.2 Procedure for Certification of a TRUPACT-III Package

Compliance with the SLB2 requirements ensures compliance with the TRUPACT-III package requirements, except for the weight and dose rate measurements for the loaded package. No additional controls, other than certifying the SLB2 and meeting the weight and dose rate requirements of Section 2.2, *Container/Assembly Weight*, and Section 3.2, *Radiation Dose Rates*, are needed for certifying the package for shipment. Compliance with the dose rate limits for the loaded package shall be documented in accordance with site-specific procedures.

- TRUPACT-III Body ID No.: Record the ID number shown on the TRUPACT-III body.
- Shipment No.: Record the shipment number of the trailer.
- Date TRUPACT-III Closed: The date that the TRUPACT-III is closed (i.e., closure lid installed) shall be recorded.
- Time TRUPACT-III Closed: For containers designated for controlled shipment only, the time that the TRUPACT-III is closed (i.e., closure lid installed) shall be recorded. For containers not designated for controlled shipment, the time that the TRUPACT-III is closed need not be recorded (e.g., enter "NA" for time).
- Weight of Payload Loading System (Section 2.2): The total weight of the payload loading system is recorded. If the weight is determined through a single measurement of the payload assembly, indicate the weight of the payload loading system is not applicable (e.g., "NA").
- Total Weight (Section 2.2): The sum of the payload container weight plus the weight of the payload loading system shall be recorded.
- Total Weight Plus Error Less Than or Equal to Payload Assembly Limit (Section 2.2): The payload container weight plus the weight of the payload loading system plus the weight error shall be less than or equal to 11,486 pounds.
- Transportation Certification Official: The site Transportation Certification Official shall verify that all of the requirements for the above transportation parameters are met as stated in this document. The site Transportation Certification Official shall sign and date the PTCD upon verifying that the TRUPACT-III TRAMPAC transportation requirements are met, thereby authorizing the payload for shipment. If the requirements are not met,

the payload is rejected (nonconformance disposition) and not qualified for shipment under this document.

6.2.3 Shipments Designated as Controlled Shipments

Compliance with the 10-day shipping period is administratively controlled in accordance with the conditions of Appendix 8.1.3, *Shipping Period – Controlled Shipments*, and through the following steps. These steps must be completed by the site Transportation Certification Official, or designee, and the designated receiving site operations personnel, as applicable.

Loading Time

The loading time begins with the closure of the TRUPACT-III containment vessel and ends with the departure of the shipment from the site. The loading time is limited to a maximum of 24 hours. The following steps must be completed to ensure compliance with the 24-hour loading time:

6.2.3.1 Review PTCD to determine date and time that the TRUPACT-III containment vessel closure was completed. Record date and time on Table 6.2-2 – *Shipping Site Control Checklist for Controlled Shipments*. Table 6.2-2 may be reformatted for site use provided that the same information is recorded.

6.2.3.2 Note date and time that the shipment containing the loaded package is scheduled to depart the site. Record date and time on Table 6.2-2.

6.2.3.3 Review dates and times recorded in Steps 6.2.3.1 and 6.2.3.2 to calculate total loading time. If total loading time is less than or equal to 24 hours, proceed to Step 6.2.3.4. If total Loading Time exceeds 24 hours, the package must be vented for a period at least as long as the period the TRUPACT-III containment vessel was sealed and the closure process must be repeated. Return to Step 6.2.3.1 above.

6.2.3.4 Indicate compliance with the 24-hour loading time by signature on Table 6.2-2.

Transport and Unloading Time

The transport and unloading time begins with the departure of the shipment from the shipping site and ends with the venting of the package at the receiving site. The maximum transport and unloading time is 9 days. The following steps must be completed to document compliance:

6.2.3.5 Review Table 6.2-2 to determine the date and time that the package was scheduled to depart from the shipping site. Record this date and time on Table 6.2-3 – *Receiving Site Control Checklist for Controlled Shipments*. Table 6.2-3 may be reformatted for site use provided that the same information is recorded.

6.2.3.6 Using the date and time recorded in Step 6.2.3.5, ensure that the package is vented within 9 days of the departure of the shipment from the shipping site by implementing the site unloading procedures specific to controlled shipments. Record the date and time to show compliance. Operational procedures must be in place for unloading at the receiving site to ensure that the controlled shipments are not unattended beyond the maximum 9-day transport and unloading time. If total transport and unloading time exceeds 9 days, the shipment is noncompliant with the Certificate of Compliance for the TRUPACT-III package and subject to the reporting requirements defined by 10 CFR §71.95.

6.2.3.7 Indicate compliance with the 9-day transport and unloading time by signature on Table 6.2-3.

Table 6.2-1 – Payload Transportation Certification Document (PTCD)

IDENTIFICATION PARAMETERS

SLB2 ID #: ______________________ Certification Site: ____________________

Container Designated for Controlled Shipment?① o Yes o No

Content Code: ______________________ Payload Shipping Category: ______________

Payload container specifications are met.

Filter specifications of Section 2.4 are met.

TRANSPORTATION PARAMETERS

Criteria:

- Residual liquids are <1% of the payload container volume
- Sharp/heavy objects are blocked/braced/suitably packaged
- Radioactive pyrophorics are ≤1% (weight)
- Nonradioactive pyrophorics are not present or have been reacted
- Explosives are not present
- Corrosives are not present
- Pressurized containers and compressed gases are not present
- Sealed containers >4 liters (nominal) are not present (except for solid inorganic waste packaged in metal)
- Beryllium and/or beryllium oxide are ≤1% of waste weight
- Machine-compacted waste is not present.

Weight Limit:

Value (pounds)	Error	Value + 1X Error (pounds)	Limit (pounds)
			10,500

Fissile Mass Limit:

Value (Pu-239 FGE)	Error	Value (Pu-239 FGE) + 2X Error	Limit
			______ Pu-239 FGE

Package Design Decay Heat Limit:

Value (watts)	Error	Value + 1X Error (watts)	Limit (watts)
			80

Flammable (Gas/VOC) Concentration Limits: ②

Compliance with Analytical Category: ②

- Flammable VOCs are ≤500 ppm in the container headspace

Decay Heat Value (watt)	Error	Value + 1X Error (watt)	Decay Heat Limit (watt)

Compliance with Test Category: ②

Test category requirements (Sections 5.2.2.3 and 5.2.2.4) are met ____________ Yes / No

Activity Limit: Activity less than or equal to 10^5 A_2 (curies)

Radiation Dose Rate Limit: ③ Payload container surface radiation dose rate is ≤200 mrem/hour

TRUPACT-III PACKAGE

TRUPACT-III Body ID No. ____________

Shipment No.: ____________

Date TRUPACT-III Closed: ____________ Time TRUPACT-III Closed: ____________ ④

Weight of Payload Loading System: ____________ pounds

Total Weight: ____________ pounds Total Weight plus Error ≤ 11,486 pounds

APPROVED FOR SHIPMENT

I certify that the above TRUPACT-III packaging and contents meet the requirements for transport.

____
Transportation Certification Official

____
Date

① If the payload container is designated for controlled shipment, Table 6.2-2 must also be completed for the shipment of this payload container as specified in Section 6.2.3, *Shipments Designated as Controlled Shipments*.

② Compliance with the flammable (gas/VOC) concentration limits shall be documented for either the analytical category or the test category.

③ In addition, compliance with the dose rate requirements for the TRUPACT-III package (Section 3.2, *Radiation Dose Rates*) shall be by survey of the loaded package.

④ Only required for payload containers designated for controlled shipment (10-day shipping period).

Table 6.2-2 – Shipping Site Control Checklist for Controlled Shipments

Shipment No. ____________________ Packaging No.____________________

To be completed by Shipping Site Transportation Certification Official, or designee, for each package designated as a controlled shipment:

TRUPACT-III TRAMPAC Section No.	Activity	Recorded Date	Recorded Time	Completion of Activity (Indicate by checkmark [√])
6.2.3.1	Record date and time of TRUPACT-III closure			
6.2.3.2	Record date and time the shipment containing the loaded package is scheduled to depart from the site			
6.2.3.3	Calculate and record total **Loading Time** [Limit = 24 hours]			
	Total Loading Time ≤1 day, proceed to No. 6.2.3.4. *Total Loading Time >1 day,* ***STOP****. Vent package and repeat closure process.*			
6.2.3.4	I certify that the above data is accurate and compliant with the Loading Time limit of 24 hours, as specified in Section 6.2.3 of the TRUPACT-III TRAMPAC. ______________________________ / __________ TRANSPORTATION CERTIFICATION OFFICIAL (OR DESIGNEE) DATE			

Note: Controlled shipments (10 days) shall be made in accordance with the conditions specified in Appendix 8.1.3, *Shipping Period – Controlled Shipments*, and Section 6.2.3, *Shipments Designated as Controlled Shipments*. This table may be reformatted for site use provided that the same information is recorded.

Table 6.2-3 – Receiving Site Control Checklist for Controlled Shipments

Shipment No. ____________________ Packaging No.____________________

To be completed by designated Receiving Site Operations Personnel for each package designated as a controlled shipment:

TRUPACT-III TRAMPAC Section No.	Activity	Recorded Date	Recorded Time	Completion of Activity (Indicate by checkmark [√])
6.2.3.5	Record date and time that the package was scheduled to depart from the shipping site			
6.2.3.6	Vent package within 9 days of date and time recorded above and record vent date and time			
6.2.3.7	I certify that the above data is accurate and compliant with the Transport and Unloading Time limit of 9 days, as specified in Section 6.2.3 of the TRUPACT-III TRAMPAC. ______________________________ / ____________ RECEIVING SITE OPERATIONS PERSONNEL DATE			

Note: Controlled shipments (10 days) shall be made in accordance with the conditions specified in Appendix 8.1.3, *Shipping Period – Controlled Shipments*, and Section 6.2.3, *Shipments Designated as Controlled Shipments*. This table may be reformatted for site use provided that the same information is recorded.

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7.0 QUALITY ASSURANCE

This section describes the QA programs applicable to the TRUPACT-III TRAMPAC.

7.1 QA Requirements for Payload Compliance

Certification of authorized contents for shipment in the TRUPACT-III shall be performed under a written QA program that provides confidence, for both the shipper and receiver, that the TRUPACT-III TRAMPAC requirements have been met. All waste shall be described in an approved content code.

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8.0 APPENDICES

8.1 TRUPACT-III TRAMPAC Appendices

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8.1.1 Derivation of Flammable Gas Generation Rate Limits and Decay Heat Limits

The purpose of this appendix is to provide the logic and mathematical analysis used to arrive at the flammable gas generation rate limits and decay heat limits for each payload shipping category. Limits per payload container are determined using conservative values.

When the logic and mathematical analysis requires the variable of shipment time, the conservative value of 60 days is utilized in this appendix, as described in Appendix 8.1.2, *Shipping Period – General Case*. For controlled shipments, 10 days may be assumed, as described in Appendix 8.1.3, *Shipping Period – Controlled Shipments*.

At steady state, the flow rate of hydrogen across each of the confinement layers is equivalent to the hydrogen generation rate within the innermost layer of confinement. The maximum hydrogen concentration in a payload container vented per Section 2.4, *Filter Vents*, is reached at steady state. That is, a vented container with a hydrogen generation source has increasing concentrations of hydrogen with time until steady state conditions are reached. For the purpose of these calculations, it has been assumed that the payload container is at steady state at the start of transport. As described in Section 5.3, *Venting and Aspiration*, all containers generated in an unvented condition are required to be aspirated to ensure steady-state conditions prior to transport.

The temperature dependence of decay heat limits is discussed in Appendix 6.9, *Temperature Dependence of Hydrogen Gas Generation and Release Rates*, of the CH-TRU Payload Appendices[1]. As shown in that appendix, for Waste Material Type II.1 and Waste Type III, minimum values for the decay heat limits are obtained by using the hydrogen generation and release rates at an ambient temperature of 70°F. For Waste Type I and Waste Material Type II.3, the lowest values for the decay heat limits are obtained by using the hydrogen generation and release rates at the minimum operating temperature of -20°F.

Once the payload container is sealed inside the TRUPACT-III containment vessel, concentrations of hydrogen in the different layers increase due to the accumulation of hydrogen in the containment vessel cavity. Some of the hydrogen generated during the transport period would accumulate in the payload container, with the remainder being released into the cavity. For the purpose of these calculations, the mole fraction of hydrogen in a confinement layer is set equal to the steady state value plus the mole fraction of hydrogen that has accumulated in the cavity. The containment vessel cavity mole fraction of hydrogen is obtained by assuming that all of the hydrogen generated is released into the containment vessel cavity. The maximum hydrogen concentration in the innermost layer is then limited to less than or equal to five (5) volume percent at the end of the shipping period by suitably choosing the gas generation rates. The maximum number of moles of hydrogen that can accumulate in the containment vessel cavity is:

[1] U.S. Department of Energy (DOE), *CH-TRU Payload Appendices*, current revision, U.S. Department of Energy, Carlsbad Field Office, Carlsbad, New Mexico.

Equation 1

$$N_{gen} = (CG)(t)$$

Where:

N_{gen}	=	total moles of hydrogen generated
CG	=	hydrogen gas generation rate per innermost layer of confinement (moles/second)
t	=	shipping period duration (e.g., 60 days).

The maximum mole fraction of hydrogen in the containment vessel cavity is then equal to:

Equation 2

$$X_{fh} = (N_{gen}/N_{tg}) = \{N_{gen}/[P(V_{void})/RT]\}$$

Where:

X_{fh}	=	maximum mole fraction of hydrogen in the containment vessel cavity
N_{tg}	=	total moles of gas inside the containment vessel cavity
P	=	pressure inside the TRUPACT-III, assumed to be constant at 1 atm (760 mm Hg), because the amount of gas generated is much less than the total amount of air originally in the cavity
V_{void}	=	void volume inside the containment vessel cavity (liters)
R	=	gas constant = 62.361 mm Hg-liter/mole-K
T	=	absolute temperature of air in the containment vessel cavity at the time of closure = 70°F = 294K.

The gas generation rate per innermost confinement layer that will yield a maximum hydrogen concentration of five (5) volume percent is then computed as the following:

Equation 3

$$X_{inner} = X_{fh} + (CG)(R_{eff})$$

Where:

X_{inner}	=	mole fraction of hydrogen in innermost confinement layer (a value of 0.05 has been used for this parameter since this is the maximum permissible concentration)
R_{eff}	=	the effective resistance to the release of hydrogen (sec/mole).

The effective resistance is computed by summing the individual confinement layer resistances. The resistance of a layer is equal to the reciprocal of the release rate from that layer. After substituting equations (1) and (2) into (3) and solving for the gas generation rate the following results:

Equation 4

$$CG = (X_{inner})/\left[R_{eff} + (t / N_{tg})\right]$$

where all terms are as defined previously. The decay heat per innermost confinement layer is then computed as:

Equation 5

$$Q_i = [(CG)(N_A)/(G\ \text{molecules}/100\text{eV})][1.602(10)^{-19}\ \text{watt - sec/eV}]$$

Where:

Q_i	=	decay heat per innermost confinement layer (watts)
N_A	=	Avogadro's number = $6.023(10)^{23}$ molecules/mole
G	=	G_{eff} (flam gas) = effective G value for flammable gas (molecules of hydrogen formed/100 electron volts [eV] emitted energy).

The logic for arriving at the input parameters is detailed in Appendix 6.7, *Gas Release Assessment*, of the CH-TRU Payload Appendices[1]. As described in Appendix 8.1.6, *Procedure for Determining TRUPACT-III Payload Shipping Categories*, the last four digits of the numeric shipping category is a notation for the total resistance to hydrogen release. From equation (4) above, the total resistance (R_T) can be defined as the combination of the effective resistance (R_{eff}), the resistance provided by the moles of gas in the void volume within the packaging (N_{tg}), and the shipping period (t).

Equation 6

$$R_T = R_{eff} + [t / N_{tg}]$$

Substituting equation (6) into equation (4) yields:

Equation 7

$$Q_i = \frac{(0.05 * 6.023\,(10)^{23}\ molecules / mole * 1.602\,(10)^{-19}\ watt - \text{sec}/ eV)}{(R_T\ \text{sec}/ mole * G\, value / 100\, eV)}$$

Simplifying and using the shipping category notation form of XX YYYY ZZZZ (described in Appendix 8.1.6, *Procedure for Determining TRUPACT-III Payload Shipping Categories*) where YYYY represents the G value (multiplied by 100) and ZZZZ represents the total resistance, R_T, (divided by 10,000 and rounded up) yields:

Equation 8

$$CG = \frac{0.05}{(ZZZZ * 10{,}000)\ \mathrm{sec}/mole}$$

and

Equation 9

$$Q_i = \frac{(4824.42\ molecules/mole * watt - \mathrm{sec}/eV)}{(ZZZZ * YYYY)\ \mathrm{sec} - molecules/mole - eV}$$

Because the total resistance, R_T, is rounded up to the nearest 10,000 sec/mole, the calculated FGGR limit and decay heat limit using this simplified method is conservative.

8.1.2 Shipping Period — General Case

8.1.2.1 Introduction

The purpose of this appendix is to develop, on a conservative basis, the time for the shipping period (from closure of the TRUPACT-III containment vessel until venting during removal of the closure lid) that should be considered for the analysis of gas generation in the TRUPACT-III package.

8.1.2.2 Background

TRUPACT-III shipments will be made by a fleet of trucks, each capable of transporting a single TRUPACT-III package, or by rail. The analysis in this appendix is presented for the case of shipments by truck. Shipments by rail shall meet the 60-day total maximum shipping period requirement for truck shipments. Using administrative controls, a 10-day shipping period is applicable for shipments to WIPP as presented in Appendix 8.1.3, *Shipping Period – Controlled Shipments.*

Each TRUPACT-III package is loaded on a specially designed trailer that travels over public highways on specified routes. Because of the large number of trips and because of the agreements for notification to the states through which these shipments will pass on their way to the WIPP or other receiving site, a state-of-the-art satellite tracking system will be employed to monitor the progress and position of each shipment. This monitoring capability will be available to authorities in the affected states as well as to the transportation management staff at the WIPP site and other receiving sites.

8.1.2.3 Approach

The approach to be taken in establishing the shipping period will be to develop a normal or expected shipment time based on the planned loading, transport, and unloading times. Then, a maximum shipment time will be based on adding to the normal shipment time delays caused by a number of factors. This maximum shipment time will assume that all possible delays occur. The probability of each of these delays occurring is small. The joint probability of all of these delays occurring would be extremely small. Thus, the development of a maximum shipment time based on the sum of extended delays for each of the factors is considered to have a large margin of error. In the event that a particular shipment is experiencing a delay resulting in an abnormal shipment time, close monitoring of the delay by WIPP will ensure minimal delay in the schedule.

8.1.2.3.1 Normal or Expected Shipment Time

The normal transport time is the sum of the times associated with loading the TRUPACT-III package, the normal transit time, and the unloading of the package. The loading time is the time interval from closing (sealing) the TRUPACT-III containment vessel until the truck leaves the waste shipper's facility. The transit time is the time interval beginning with departure from the shipper's facility and ending with the arrival at the WIPP site or other receiving site. The unloading time is that time interval beginning with the arrival at the receiving site and ending with the venting during removal of the TRUPACT-III closure lid. This total time defines the expected shipment time.

8.1.2.3.2 Off-Normal or Maximum Shipment Time

The maximum shipment time includes those delays that could extend the shipment time. These delays are:

- Delays in loading or releasing the truck at the shipper's facility.
- Delays in transit caused by adverse weather conditions leading to road closures, or road closures due to accidents involving other vehicles.
- Accidents involving the shipment vehicle. These delays would include the time required for notification of appropriate authorities (including the DOE Emergency Response Team) and the time to take corrective action. This corrective action may involve transfer of the TRUPACT-III package to a back-up truck, which would require the services of heavy equipment.
- Delays in transit caused by mechanical problems with the truck. This factor would include such things as tire problems, broken belts and hoses, and any other such minor problems.
- Delays caused by one or both of the drivers becoming ill.
- Delays in unloading the TRUPACT-III package at the WIPP site or other receiving site. These could potentially be caused by factors such as truck arrival at the start of a long holiday weekend or equipment problems at the receiving site.

8.1.2.4 Discussion

8.1.2.4.1 Normal or Expected Shipment Time

As stated previously, the normal or expected shipment time is that time interval beginning with the sealing of the TRUPACT-III containment vessel at the shipper's facility and ending with the venting during removal of the TRUPACT-III closure lid.

TRUPACT-III Package Loading

The package is designed so that it can be loaded within a few hours.. The loading operation is facilitated by design features and contents handling methods aimed at a quick turnaround during either loading or unloading. As one example, a roller floor may be provided on the floor of the packaging to allow for loading the payload on a rolling payload pallet. For such a loading system, the contents are handled in the horizontal position and are readily rolled into or out of the packaging. All steps in the loading process (e.g., from attaching the lifting fixture to the crane until the lift fixture lift links are disconnected from the overpack cover following loading) can be accomplished in a few hours. Thus, the time associated with loading the TRUPACT-III package for shipment is expected to be less than eight hours. However, to be conservative, one day (24 hours) is allotted for this activity.

Transit Time

Specific routes have been selected for transport of waste between the DOE facilities and from each of the DOE facilities to the WIPP site. The distances from the primary DOE facilities with large box inventory to the WIPP site are given in Table 8.1.2-1.

Table 8.1.2-1 – Normal Transit Times

To WIPP From	Distance (Miles)	Transit Time in Hours (Miles per Hour)				Transit Time in Days (Miles per Hour)			
		40	45	50	55	40	45	50	55
Hanford	1808	45.2	40.2	36.2	32.9	1.8	1.7	1.5	1.4
INL	1392	34.8	30.9	27.8	25.3	1.4	1.3	1.2	1.1
Knolls-NFS	1573	39.3	35.0	31.5	28.6	1.6	1.5	1.3	1.2
LANL	342	8.6	7.6	6.8	6.2	0.3	0.3	0.3	0.3
LLNL	1463	36.6	32.5	29.3	26.6	1.5	1.4	1.2	1.1
NTS	1177	29.4	26.2	23.5	21.4	1.2	1.1	1.0	0.9
ORNL	1440	36.0	32.0	28.8	26.2	1.4	1.3	1.2	1.1
SNL	326	8.2	7.2	6.5	5.9	0.3	0.3	0.3	0.2
SRS	1540	38.5	34.2	30.8	28.0	1.5	1.4	1.3	1.2
WVDP	2391	59.8	53.1	47.8	43.5	2.4	2.2	2.0	1.8

These shipments will be made by trucks having two drivers. Regulations governing maximum driving and on-duty times are given in 49 CFR 395, "Hours of Service of Drivers."[1]

Experience at the Idaho National Laboratory has shown that shipments of this type can achieve an average speed of 45 mph. This average speed includes stops for vehicle inspections every two hours, fueling, meals, driver relief, and state vehicle inspections.

The normal transit times to WIPP range from 0.3 day for shipments from the Los Alamos National Laboratory to 2.2 days for shipments from the West Valley Demonstration Project as shown in Table 8.1.2-1. For the purpose of conservatism three days (72 hours) is assumed for a maximum normal transit time.

Unloading

Normal unloading will be accomplished in less than a day. Once the truck has undergone the health physics survey and security checks, the tractor is disconnected, and a trailer jockey is connected to the trailer. The trailer and package are cleaned, and the trailer is moved to the unloading area. The TRUPACT-III is removed from the trailer and placed into the unloading area. The overpack cover is removed to allow access to the closure lid. The closure lid is

[1] Title 49, Code of Federal Regulations, Section 395 (49 CFR 395), "Hours of Service of Drivers."

removed after the containment vessel has been vented through a facility gas-handling system, and other procedural steps are then taken.

The normal unloading of a trailer will be accomplished in less than one day. The unloading time is, thus, conservatively assigned a value of one day (24 hours).

Total Normal or Expected Shipment Time

The total normal or expected shipment time is three to five days depending on the origin of the waste. Normal loading time is one day, transit time is one to three days, and unloading time is one day.

8.1.2.4.2 Off-Normal or Maximum Shipping Time

Loading Delays

There are a number of factors that could extend the time interval between the sealing of the TRUPACT-III closure lid and the truck leaving the shipper's facility:

- Loading could begin on a day preceding a holiday weekend
- Difficulty testing the containment O-ring seals
- Handling equipment failure.

In the most severe sequence, loading could begin on a day preceding a long (holiday) weekend. If, for example, loading began on a Friday afternoon preceding a three-day weekend, loading would not be completed until the following Tuesday. This would result in a four-day loading period.

The containment O-ring seals may fail the leak test, which would generally call for some maintenance. The worst case would probably be a failure in the leak test equipment that could take up to two days to correct.

The crane or the lifting fixture could also fail, forcing a delay in any further loading until corrected. This could also take two days.

It would be very unlikely for more than two of these scenarios to happen simultaneously, so a total of six days is deemed to be a reasonable maximum time to account for delays associated with loading. If there were conditions that could cause long, unanticipated delays, the TRUPACT-III package can be vented at the shipper's facility.

Transit Time Delays

There are several factors that could extend the maximum normal transit time of three days. Adverse weather conditions could lead to delays and road closures. A telephone survey of states in the waste shipment corridor states was conducted to ascertain a reasonable time to assume for weather delays. Table 8.1.2-2 provides the results of this survey. One can conclude from this survey that weather conditions may close a major highway for two to five days. Long-term interruptions in normal traffic caused by bridge outages, etc., would result in rerouting traffic to alternate routes. Accidents involving other vehicles could also cause delays and road closures of up to a day. It is concluded that a total transit delay of five (5) days is reasonable to assume for weather delays or road closures.

Accidents involving the shipment vehicle itself could cause lengthy delays. These delays would include the accident response time for notifying appropriate authorities (including Radiological Assistance Teams, if required) and the time to take corrective action or to mitigate the accident. One day is conservatively assumed for the response to the accident. (In addition to normal accident response protocol, monitoring of the satellite tracking system would also facilitate an early response to accidents.) Corrective action may involve retrieving the TRUPACT-III package from a damaged trailer (including the possibility that the truck could be over an embankment) and transferring it to a back-up truck. Special equipment such as cranes may be required to carry out these operations. An accident mitigation time of five days will be assumed. This time includes the time for delivery of a back-up truck, and the time to move in special heavy equipment and rig special lifting fixtures to retrieve and transfer the package to the back-up vehicle.

Delays in transit could be caused by routine mechanical problems with the truck. These problems could include tire failures, broken belts and hoses, electrical failures, and similar minor problems, or more significant problems necessitating bringing a back-up truck into service. It is conservatively assumed that appropriate responses to mechanical failures of the truck can be made in four days.

Lastly, one or both of the drivers could become ill during the trip, necessitating the possibility that one driver must do all the driving or relief drivers would have to be sent to where the truck is parked. If one driver has to do all the driving, the transit time would be doubled (i.e., add three days). If relief drivers are required, a two-day delay will occur to allow for travel time of the replacement driver(s).

Table 8.1.2-2 – Survey of Weather Related Delays on Interstate Highways of the TRU Waste Shipment Corridor Sites

State/City	Office Contacted	Date Contacted	Type of Weather Related Delays	Highway
1. Alabama/Montgomery	State DOT	2/4/88	24 hrs. max.	All
2. Arizona/Phoenix	Dept. of Public Safety	2/4/88	8 hrs. maximum for any type of emergency.	All
3. Arkansas/Little Rock	State DOT Construction of Maintenance	2/17/88	1/2 day maximum.	All
4. California/Sacramento	State DOT Highway Dept.	2/18/88	2 days due to snow every 2 to 3 years. Few minutes to 2 to 3 weeks due to flood. 2 weeks due to earthquake. Detours provided.	I-5 I-15 Route 14
5. Colorado/Denver	State DOT	2/5/88	12 hrs. maximum.	
6. Georgia/Atlanta	State DOT Maintenance	2/2/88	No information available.	
7. Idaho/Boise	State DOT	2/4/88	3 to 4 hrs. due to blizzard.	
8. Illinois/Springfield	State DOT	2/7/88	10 days because a bridge pier slipped. (Trucks were off the road for 14 days). Detours provided.	Northbound I-90, I-94
9. Indiana/Indianapolis	Dept. of Highway Operations	2/5/88	2 days due to snowstorm or blizzard/wind.	I-65
10. Kentucky/Frankfort	State DOT Highway Maintenance	2/5/88	8 hrs. maximum.	
11. Louisiana/Baton Rouge	State DOT Office of Highway Traffic and Planning	2/3/88	No information available.	
12. Mississippi/Jackson	State DOT Highway Dept.	2/17/88	None.	
13. Missouri/Jefferson City	Highway Patrol	2/4/88	1/2 to 1 day due to flooding. 1 to 1-1/2 days with detours provided.	I-70
14. Nevada/Carson City	State DOT Maintenance Div.	2/4/88	4 to 8 hrs. due to snow.	I-80
15. New Mexico/Santa Fe	State DOT	2/9/88	Closed periodically due to snow and/or wind but for a very short period of time.	Interstate
16. Ohio/Columbus	State DOT	2/5/88	8 hrs. maximum.	All
17. Oklahoma/Oklahoma City	State DOT	2/5/88	1 month due to a bridge was washed out on Cimmaron River.	I-35
18. Oregon/Salem	State DOT	2/4/88	8 hrs. maximum. Generally, usage of highway stopped for trucks/oversized vehicles for up to 8 hours for icy conditions	Interstate
19. South Carolina/ Columbia	State DOT State Dept. of Health and Control	2/3/88	No information but generally 8 hrs. maximum.	

State/City	Office Contacted	Date Contacted	Type of Weather Related Delays	Highway
20. Pennsylvania/ Harrisburg	State DOT	2/22/91	No information but generally 1 day maximum	Interstate
21. Tennessee/Nashville	State DOT	2/3/88	96 hours due to rain. 72 Hours due to rain/high water level.	State Route 54 N in Haywood County State Route 188
22. Texas/Austin	State DOT	2/16/88	2 to 3 hours due to flooding. 8 hours maximum due to snow.	I-20
23. Utah/Salt Lake City	State DOT Traffic Engr.	2/4/88	4 to 5 hours due to blizzard.	I-15
24. Washington/Olympia	State DOT	2/4/88	2 days due to avalanche.	I-90
25. West Virginia/ Charleston	State DOT	2/19/91	1 day maximum	I-70
26. Wyoming/Cheyenne	State DOT Motor Vehicle Safety	2/4/88	4 to 5 days predominantly due to weather.	I-80

Unloading Delays

Delays in unloading the TRUPACT-III package at the WIPP site or other receiving site could be caused by a number of factors: A truck could arrive at the receiving site late on a Friday preceding a three-day weekend, and the normal processing and unloading would not be completed until the following Tuesday, causing a delay in unloading of approximately 5 days. There could be equipment problems at the receiving site that could cause delays in unloading the package. Venting and handling equipment could break down. A total unloading time of four days will be assumed if unloading begins just before a regular weekend or five days for a holiday weekend. This is a reasonable maximum time to account for delays associated with unloading because the package can be vented at the receiving site (using workers overtime) if an unanticipated chain of delays were to occur.

Total Off-Normal or Maximum Shipment Time

The total off-normal or maximum shipment time is summarized in Table 8.1.2-3. A maximum shipment time of 31 days is projected assuming the worst-case scenario of all off-normal occurrences happening in the same shipment.

Table 8.1.2-3 – Shipment Time Summary

Activity	Time (Days)
Normal Shipment Time	
Loading	1
Transit Time	1-3
Unloading	1
Maximum Normal Shipment Time	3-5
Off-Normal Shipment Time[①]	
Loading	6
Transit Time	
• Normal (maximum)	3
• Weather delays and road closures	5
• Accident response	1
• Accident Mitigation	5
• Truck maintenance problems	4
• Driver illness	2
Unloading	5
Maximum Off-Normal Shipment Time	31

① Adding all the times for relatively low-probability, independent delays provides a conservative value for the maximum off-normal transit time.

8.1.2.5 Summary and Conclusions

The total normal or expected shipment time from the DOE facilities to the WIPP site or other receiving site will be three to five days. The maximum or off-normal shipment time that has been postulated to occur as a consequence of a series of accidents or other off-normal events and delays is 31 days. This maximum shipment time is six times the maximum normal expected shipment time. This justifies using a 31-day period for the basis of determining potential buildup of flammable concentrations in the TRUPACT-III package under the specified normal conditions with the absence of venting or operational controls during transport. However, to add an additional margin of safety, the shipping period used for the analysis of gas generation in the TRUPACT-III package is nearly double the maximum off-normal shipment time, or 60 days, which is more than an order of magnitude longer than the maximum normal shipment time.

8.1.3 Shipping Period – Controlled Shipments

8.1.3.1 Introduction

This appendix presents the shipping period determination for shipments designated as controlled shipments. For these shipments, the TRUPACT-III packaging is loaded at the site, transported from the site to the WIPP or other receiving site, and vented within a maximum of 10 days from the closure (or sealing) of the TRUPACT-III containment vessel. The basis for the 10-day shipping period is defined in this appendix. The use of a 10-day controlled shipment is an option available to sites that elect to impose administrative controls to ensure compliance with the conditions described herein.

8.1.3.2 Approach

The shipping period is defined to begin with closure (or sealing) of the TRUPACT-III containment vessel during loading at the shipping facility and end with venting of the TRUPACT-III containment vessel during unloading. Conservative time estimates for the following activities were used in determining the shipping period for controlled shipments:

- Loading time
- Transport time
- Unloading time.

8.1.3.2.1 Loading Time

The loading time begins with the sealing of the TRUPACT-III containment vessel and ends with the departure of the shipment of the package from the site. Activities to be completed during the loading time include leak testing and handling of the loaded package. As directed by site procedures for controlled shipments, these activities must be completed within 24 hours. If these activities are delayed beyond 24 hours, the package(s) must be vented and the closure process repeated in accordance with the administrative controls described in Section 6.2.3, *Shipments Designated as Controlled Shipments*.

8.1.3.2.2 Transport Time

The transport time begins with the departure of the shipment from the site and ends with the arrival of the shipment at the receiving site. The transport time is dependent upon the distance between the two sites and capabilities for efficient response to potential transport time delays. As shown in Table 8.1.3-1, at an average speed of 40 mph, the longest travel time from a site to WIPP is 59.8 hours (corresponding to the 2,391-mile distance from the West Valley Demonstration Project to WIPP). Controlled shipments shall be made only when the shipping distance between the two sites is bound by that shown for the West Valley Demonstration Project to WIPP in Table 8.1.3-1. This average speed takes into account stops for vehicle inspections every two hours, fueling, meals, driver relief, and state vehicle inspections. Controlled shipments between sites are not allowed if the proposed travel distance exceeds 2,391 miles.

Table 8.1.3-1 – Normal Transit Times

To WIPP From	Distance (Miles)	Transit Time in Hours (Miles per Hour)				Transit Time in Days (Miles per Hour)			
		40	45	50	55	40	45	50	55
Hanford	1808	45.2	40.2	36.2	32.9	1.8	1.7	1.5	1.4
INL	1392	34.8	30.9	27.8	25.3	1.4	1.3	1.2	1.1
Knolls NFS	1573	39.3	35.0	31.5	28.6	1.6	1.5	1.3	1.2
LANL	342	8.6	7.6	6.8	6.2	0.3	0.3	0.3	0.3
LLNL	1463	36.6	32.5	29.3	26.6	1.5	1.4	1.2	1.1
NTS	1177	29.4	26.2	23.5	21.4	1.2	1.1	1.0	0.9
ORNL	1440	36.0	32.0	28.8	26.2	1.4	1.3	1.2	1.1
SNL	326	8.2	7.2	6.5	5.9	0.3	0.3	0.3	0.2
SRS	1540	38.5	34.2	30.8	28.0	1.5	1.4	1.3	1.2
WVDP	2391	59.8	53.1	47.8	43.5	2.4	2.2	2.0	1.8

The potential factors that could delay the normal transport time are as follows:

- Adverse weather
- Vehicle accidents
- Mechanical problems with the truck
- Driver illness.

Administrative controls in place at the shipping site prohibit the initiation of a controlled shipment at times when adverse weather exists or is forecasted. Any transport time delays associated with adverse weather are expected to be minimal and are, therefore, adequately covered by the margin of safety included in this analysis (see Section 8.1.3.3, *Summary and Conclusions*).

Prompt emergency response, truck maintenance, and driver or equipment replacement during the transport of controlled shipments is ensured by the application of additional resources. Administrative controls applied to all CH-TRU waste shipments regardless of destination require the designation of a shipment as a “controlled shipment” prior to initiation of the shipment from the site. This designation provides a trigger that requires additional resources to be available in order to provide accelerated response to avoid any significant delay during the transport time. This controlled shipment protocol is in addition to the routine use of the TRANSCOM system at WIPP, which provides continuous tracking of the shipment during transport regardless of its destination (i.e., to WIPP or other receiving site).

Vehicle accidents have the potential for the longest transport time delays due to the time required to respond and perform required corrective actions. Based on the training programs provided to local emergency response personnel along the transport routes, accident response time would be minimal (less than one hour). However, additional time may be required for notification and response of other appropriate authorities such as Radiological Assistance Teams (if required). Deployment of other appropriate authorities from WIPP, the shipping facility, or other intermediate site, whichever is closer, would take no more than 1 day to reach an accident scene. Prompt mitigation of any accident is ensured by the application of WIPP site protocol for controlled shipments. Due to the additional resources available during controlled shipments, up to 2 days is considered appropriate for completing accident corrective actions. This time includes deployment of a backup truck and trailer, retrieving and transferring the package(s) to the backup vehicle, and performing any necessary surveys and/or inspections to confirm the shipment is prepared for continued transport.

Truck maintenance associated with common mechanical problems could result in transport time delays. The majority of routine mechanical problems (flat tires, belt or hose failures, etc.) can be rectified in a matter of hours. A worst-case mechanical problem would result in the need for a replacement truck, which is included in the time estimated for vehicle accident mitigation as described above.

The last remaining potential scenario for delaying the transport time is driver illness. The additional resources available for controlled shipments ensure prompt replacement of an ill driver. The time required to replace a driver is conservatively estimated as 1 day.

As a result of WIPP protocols applied to shipments designated as controlled shipments, a 5-day transport time accounts for any unexpected impact to the expected transport time.

8.1.3.2.3 Unloading Time

The unloading time begins with the arrival of the shipment at the receiving site and ends with the venting of the TRUPACT-III containment vessel. Normal unloading will be accomplished in less than one day (24 hours). Section 6.2.3, *Shipments Designated as Controlled Shipments*, outlines administrative controls imposed to ensure venting of the TRUPACT-III containment vessel within 9 days of shipment departure from the shipping site.

8.1.3.3 Summary and Conclusions

Based on a loading time of 24 hours, an estimated transport time of less than 60 hours, and an unloading time of 24 hours, the normal expected shipping period for controlled shipments is 4 to 5 days. Using a conservatively estimated transport time of 5 days, the maximum expected shipping period for controlled shipments is 7 days. The additional contingency of a 3-day margin of safety results in a maximum shipping period of 10 days. Table 8.1.3-2 provides a summary of the activities comprising the shipping period.

Table 8.1.3-2 – Shipping Period Analysis Summary

Activity	Normal Expected Time (days)	Maximum Time Used in Analysis (days)
Loading Time	<1	1
Transport Time	<2.5	5
Unloading Time	<1	1
Margin of Safety	–	3
Shipment Time	4-5	10

This analysis justifies using a 10-day period as the basis for determining compliance with gas generation requirements under rigorous operational controls during loading, transport, and unloading as specified in this appendix.

Sample shipping time data based on over 4,500 shipments of CH-TRU waste to WIPP are shown in Table 8.1.3-3. As shown, all shipments have been made in well under 10 days even without the use of administrative controls specified in this appendix. The controlled shipments completed under the conditions specified in this appendix will readily comply with the 10-day shipping period.

Only shipments designated as controlled shipments and, therefore, subject to the protocol described in this appendix and the administrative controls specified in Section 6.2.3, *Shipments Designated as Controlled Shipments*, for loading and unloading are eligible for evaluation using the 10-day shipping period.

Table 8.1.3-3 – Sample Shipping Time Data

To WIPP From	Total Number of Shipments as of 06-13-06	Average Shipping Time (hours)①	% of Time Shipments are Completed within Average Time	Shipping Time Delays: Duration of Maximum Delay	Shipping Time Delays: Explanation
ANL-E	13	38	100%	N/A	N/A
ANL-W	1	34	100%	N/A	N/A
Hanford	282	45	82%	5 days	Repairs at generator site on loading equipment
INL	1,721	36	80%	5 days	Weather delay; delay occurred en route; shipment was returned to INL and delayed prior to second departure
LANL	207	9	94%	1 day	Delay occurred at LANL as the result of generator site issues prior to shipment departure
LLNL	18	33	99%	1 hour	Delay in route
NTS	48	30	99%	9 hours	Delay in departure
RFETS	2,045	18	96%	2 days	Weather delay; delay occurred at RFETS prior to shipment departure and en route following departure
SRS	675	32	86%	3.7 days	Weather delay; delay occurred at SRS prior to shipment departure

① Average shipping times are estimated based on average speeds of 50 miles per hour and include time associated with safety inspections, fuel and food stops, and driver breaks.

N/A = Not applicable.

8.1.4 Determination of Flammable Gas Generation Rates by Measurement

This appendix summarizes the logic and methodology of using headspace flammable gas/volatile organic compound (VOC) measurements for evaluating compliance with flammable gas/VOC concentrations during transport in the TRUPACT-III package. As described in Chapter 5.0, *Gas Generation Properties Requirements*, headspace gas/VOC measurement is applicable for the following test category wastes:

- Containers that could potentially exceed 500 parts per million (ppm) flammable VOCs in the innermost confinement layer
- Containers that exceed decay heat limits.

8.1.4.1 Conceptual Model

The methodology is based on sampling the waste container headspace for flammable gases to calculate the actual flammable gas generation rate.

It is assumed that the SLB2 containers will be newly packaged and vented. The conceptual model is described below:

- An vented SLB2 payload container is filled with waste within the innermost layer of confinement (multiple bag layers are conservatively classified as a single void with an equivalent resistance). The SLB2 is vented with one or more filters with a total minimum hydrogen diffusivity meeting the requirements of Section 2.4, *Filter Vents*, at the time of waste packaging.
- Flammable gas is generated within the waste.
- Flammable gas accumulates and is transported across layers of confinement.
- After some time, the headspace gas of the SLB2 may be sampled for flammable gas.
- Initially (i.e., at the time of generation) there is no flammable gas within any confinement layer.

8.1.4.2 Mathematical Model

The generation of flammable gas within the innermost confinement layer and subsequent transport across the various confinement layers of the SLB2 can be simulated by solving the differential equations that describe the unsteady-state mass balances on flammable gas within each confinement layer of the payload container. To account for various potential packaging configurations, a set of differential equations representing mass balances on hydrogen within each of the confinement volumes (i.e., layers) of the SLB2 must be solved along with the appropriate initial conditions that represent the initial state of a container. The following list defines the variables that are used in the description of the mathematical framework.

Variables

n_i = Moles of flammable gas within void (i.e., confinement) volume "*i*" (moles [mol]).

k_i	=	Effective release rate of flammable gas across the confinement layer "*i*" (mol day^{-1} atm H_2^{-1}).
X_i	=	Mole fraction hydrogen in void (i.e., confinement) volume "*i*" (dimensionless).
R_i	=	Release rate of hydrogen across the confinement layer "*i*" (Liters [L]/day).
V_i	=	Void volume within confinement layer "*i*" (L).
T	=	Time (days).
R	=	Gas law constant (0.08206 atm L mol^{-1} K^{-1}).
T	=	Absolute temperature (K).
P	=	Absolute pressure (1 atm).
P_i	=	Partial pressure hydrogen inside void (i.e., confinement) volume "*i*" (atm H_2).
CG	=	FGGR of innermost confinement layer (mol/sec).

Subscripts

I	=	Void (i.e., confinement) volume for confinement layer "*i*".
NVV	=	Number of void (i.e., confinement) volumes within the SLB2.
1	=	Innermost confinement volume or layer.
s	=	SLB2 void volume.

For brevity in subsequent discussions, a parameter C_1 is defined as:

Equation 1

$$C_1 = CG \times R \times T / P$$

The generation of flammable gas within the innermost layer of confinement, release across confinement layers, and accumulation within the confinement volumes during storage are simulated by numerically solving the system of flammable gas mass balance differential equations for each void volume. The derivation of the general system of differential equations representing flammable gas mass balances is presented below:

Innermost void (i.e., confinement) volume (i = 1)

The flammable gas mass balance within the innermost void (i.e., confinement) volume is:

Equation 2

Accumulation = Generation – Removal by transport in response to concentration gradient

In terms of parameters the flammable gas mass balance may be expressed as:

Equation 3

$$\frac{dn_1}{dt} = CG - k_1\,(P_1 - P_2)$$

Applying the ideal gas law and assuming isobaric conditions such that P is constant total system pressure, yields:

Equation 4

$$\frac{PV_1}{RT}\frac{dX_1}{dt} = CG - k_1\,P\,(X_1 - X_2)$$

Rearranging terms and defining R_1 as k_1RT yields the following equation:

Equation 5

$$\frac{dX_1}{dt} = \frac{C_1}{V_1} - \frac{R_1\,(X_1 - X_2)}{V_1}$$

<u>Void (i.e., confinement) volumes (i = 2 to NVV-1)</u>

The hydrogen mass balances in void volumes i = 2 to NVV-1 is:

Equation 6

$$\frac{dn_i}{dt} = k_{i-1}\,(P_{i-1} - P_i) - k_i(P_i - P_{i+1})\ for\ i = 2\ to\ NVV - 1$$

Applying the ideal gas law and assuming isobaric conditions such that P is constant total system pressure, yields:

Equation 7

$$\frac{PV_i}{RT}\frac{dX_i}{dt} = k_{i-1}\,P\,(X_{i-1} - X_i) - k_iP\,(X_i - X_{i+1})\ for\ i = 2\ to\ NVV - 1$$

Rearranging terms and defining R_i as k_iRT yields the following equations:

Equation 8

$$\frac{dX_i}{dt} = \frac{R_{i-1}\,(X_{i-1} - X_i)}{V_i} - \frac{R_i\,(X_i - X_{i+1})}{V_i}$$

SLB2 void volume (i.e., headspace) (i = NVV = s)

It is assumed that the concentration of flammable gas outside the SLB2 remains at zero concentration during storage such that the flammable gas mass balance in the SLB2 void volume (i.e., headspace) is given as:

Equation 9

$$\frac{dn_s}{dt} = k_{s-1}(P_{s-1} - P_s) - k_s P_s$$

Applying the ideal gas law and assuming isobaric conditions such that P is constant total system pressure, yields:

Equation 10

$$\frac{PV_s}{RT}\frac{dX_s}{dt} = k_{s-1}P(X_{s-1} - X_s) - k_s X_s P$$

Rearranging terms and defining R_s as k_sRT yields the following equation:

Equation 11

$$\frac{dX_s}{dt} = \frac{R_{s-1}(X_{s-1} - X_s)}{V_s} - \frac{R_s X_s}{V_s}$$

Initial Conditions

Initially (i.e., at the time of generation) there is no flammable gas within any confinement layer and thus the following equation provides the initial conditions:

Equation 12

$$At\ t = 0,\ X_i = 0\ for\ i = 1\ to\ NVV$$

The first step in applying the methodology is to establish the date of SLB2 packaging or generation and sampling. Next, the SLB2 measured headspace flammable gas concentration is obtained. The equations documented earlier are solved iteratively adjusting the flammable gas generation rate, CG, until the predicted flammable gas generation rate provides a headspace flammable gas concentration that matches the sampled headspace flammable gas concentration. A validated software program can be used to apply this methodology to determine compliance with the 5-percent limit on hydrogen concentration by sampling the SLB2 headspace. Numerical solution implies obtaining the mole fractions of flammable gas in each void volume as a function of time. The solution proceeds until the simulation time equals the elapsed time between SLB2 packaging (i.e., generation) and SLB2 headspace sampling.

8.1.5 Determination of Void Volumes for TRUPACT-III Payload

This appendix documents the determination of the following TRUPACT-III package void volumes:

- Empty TRUPACT-III containment vessel
- Empty SLB2
- TRUPACT-III containment vessel when loaded with one SLB2.

8.1.5.1 Void Volume Calculation for Empty TRUPACT-III Containment Vessel

The internal dimensions of the TRUPACT-III containment vessel are as follows:

Height	=	2,000 mm (200 cm)
Length	=	2,790 mm (279 cm)
Width	=	1,840 mm (184 cm).

The internal volume (in liters) of the TRUPACT-III containment vessel excluding the volumes occupied by the interior protruding features and the ancillary handling equipment is:

$$H * L * W = (200\text{cm})(279\text{cm})(184\text{cm})\left(\frac{1\text{ liter}}{1{,}000\text{cm}^3}\right) = 10{,}267\text{ liters}$$

The interior protruding features of the TRUPACT-III containment vessel consist of the rails/guide channels, the lid shear lip, the debris shield, eight full cavity length 1-inch by 3-inch guide rails, and three full cavity width 1-inch by 3-inch guide rails with bumpers bolted on to control cavity length. The external volume associated with these interior protruding features is as follows:

$$Vol_{other} = 83\ \text{liters}$$

Therefore, the internal volume of the TRUPACT-III containment vessel accounting for the total volume occupied by the interior protruding features is:

$$10{,}267\text{ liters} - 83\text{ liters} = 10{,}184\ \text{liters}$$

The total volume occupied by the ancillary handling equipment (i.e., payload loading system) is limited to the following:

$$Vol_{loadsys} = 280\text{ liters}\ \text{(corresponds to as-tested roller floor and pallet used in CTU-2)}$$

Thus, the internal volume of the TRUPACT-III containment vessel taking into account the ancillary handling equipment is:

$$IVol_{TIII} = 10{,}184\text{ liters} - Vol_{loadsys} = 9{,}904\text{ liters}$$

8.1.5.2 Void Volume Calculation for Empty SLB2

The internal dimensions of the SLB2 are as follows:

Height	=	66.5 in. (168.910 cm)

Length = 104.25 in. (264.795 cm)

Width = 65.25 in. (165.735 cm).

The internal volume (in liters) of the empty SLB2 excluding the volumes associated with the six body vertical stiffeners and the interior protruding portions of the body flange and labyrinth members is:

$$H * L * W = (168.910\text{cm})(264.795\text{cm})(165.735)\left(\frac{1\,\text{liter}}{1{,}000\text{cm}^3}\right) = 7{,}413\,\text{liters}$$

The external volumes associated with the six body vertical stiffeners and the interior protruding portions of the body flange and labyrinth members are as follows:

$$\text{Vol}_{\text{vertstiffeners}} = (6)(27\text{in}^3) = 162\text{in}^3\left(\frac{16.4\text{cm}^3}{\text{in}^3}\right)\left(\frac{1\,\text{liter}}{1{,}000\text{cm}^3}\right) = 3\,\text{liters}$$

$$\text{Vol}_{\text{iflangelabyr}} = 966\text{in}^3\left(\frac{16.4\text{cm}^3}{\text{in}^3}\right)\left(\frac{1\,\text{liter}}{1{,}000\text{cm}^3}\right) = 16\,\text{liters}$$

The internal volume of the empty SLB2 taking into account the volumes of the six body vertical stiffeners and the body flange and labyrinth members is:

$$\text{IVol}_{\text{SLB2}} = 7{,}413\,\text{liters} - \text{Vol}_{\text{vertstiffeners}} - \text{Vol}_{\text{iflangelabyr}} = 7{,}394\,\text{liters}$$

8.1.5.3 Void Volume Calculation for TRUPACT-III Containment Vessel When Loaded with One SLB2

The external volume of the SLB2 is calculated as follows:

Internal free volume of SLB2 = 7,394 liters

Additional volume corresponding to the weight of the steel SLB2 materials of construction is calculated as:

$$\frac{\text{weight}}{\text{density}} = \frac{2{,}700\text{lb}}{0.284\text{lb}\cdot(\text{in}^3)^{-1}} = 9.507\text{in}^3\left(\frac{16.4\text{cm}^3}{\text{in}^3}\right)\left(\frac{1\,\text{liter}}{1{,}000\text{cm}^3}\right) = 156\,\text{liters}$$

The trapped air volumes occupied by the skid members, body and lid bumpers, and labyrinth region are as follows:

$$\text{Vol}_{\text{bodyskid}} = 60\,\text{liters}$$

$$\text{Vol}_{\text{bumper}} = 51\,\text{liters}$$

$$\text{Vol}_{\text{oflangelabyr}} = 4\,\text{liters}$$

Additional volume occupied by trapped air within skid members, body and lid bumpers, and labyrinth region is calculated as:

$$\text{Vol}_{\text{bodyskid}} + \text{Vol}_{\text{bumper}} + \text{Vol}_{\text{oflangelabyr}} = 60\,\text{liters} + 51\,\text{liters} + 4\,\text{liters} = 115\,\text{liters}$$

Therefore, the external volume of the SLB2 is:

$$7{,}394 \text{ liters} + 156 \text{ liters} + 115 \text{ liters} = 7{,}665 \text{ liters}$$

Thus, the internal volume of the TRUPACT-III containment vessel when loaded with one SLB2 is:

$$IVol_{TIIIw/SLB2} = 9{,}904 \text{ liters} - 7{,}665 \text{ liters} = 2{,}239 \text{ liters}$$

8.1.5.4 Summary of Calculations

The TRUPACT-III package void volumes are as follows:

Empty TRUPACT-III containment vessel = 9,904 liters

Empty SLB2 = 7,394 liters

TRUPACT-III containment vessel when loaded with one SLB2 = 2,239 liters.

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8.1.6 Procedure for Determining TRUPACT-III Payload Shipping Categories

For any given SLB2, the shipping category provides a basis to determine the gas generation potential of the contents and the resistance to gas release of the packaging configuration. This enables evaluation of compliance with the gas generation requirements.

A description of the shipping category notation is presented in the following sections.

8.1.6.1 Shipping Category Notation

The shipping category notation is a ten-digit numeric code:

XX YYYY ZZZZ

where,

XX	=	The waste type, which indicates the chemical composition of the waste
YYYY	=	The G value, or gas generation potential, of the waste material type multiplied by 10^2
ZZZZ	=	The resistance to hydrogen release of the packaging configuration multiplied by 10^{-4}.

A description of each of the parameters follows.

Waste Type
Payloads are subdivided into three waste types based on physical and chemical form as shown in Table 8.1.6-1. Table 8.1.6-1 also shows the shipping category notation denoting each waste type.

Waste Material Type
The three waste types may be further subdivided into waste material types. The waste material types define the gas generation potential of the waste, and a listing of the chemicals/materials allowed in each waste material type is presented in Tables 4.3-1 through 4.3-7. An effective bounding G value quantifying the gas generation potential of each waste material type is assigned based on the chemicals allowed. Dose-dependent G values are applicable to containers of CH-TRU waste materials of Waste Material Type II.1 and Waste Type III that meet a watt*year criteria of greater than 0.012. The determination of bounding G values for each waste material type is described in Appendices 3.2 and 3.3 of the CH-TRU Payload Appendices[1].

[1] U.S. Department of Energy (DOE), *CH-TRU Payload Appendices*, U.S. Department of Energy, Carlsbad Field Office, Carlsbad, New Mexico.

Table 8.1.6-2 presents the waste material types and their respective bounding G values, along with the shipping category notation denoting the bounding G value.

Table 8.1.6-1 — Summary of Payload Waste Types

Waste Type	Waste Type (XX)	Description and Examples
I	10	Solidified Aqueous or Homogeneous Inorganic Solids (<1 percent organics - not including packaging) - absorbed, adsorbed or solidified inorganic liquid - soils, solidified particulates, or sludges formed from precipitates - concreted inorganic particulate waste
II	20	Solid Inorganics - glass, metal, crucibles - other solid inorganics
III	30	Solid Organics - plastics (e.g., polyethylene, polyvinyl chloride) - cellulose (e.g., paper, cloth, wood) - cemented organic solids - other solid organics

Table 8.1.6-2 — CH-TRU Waste Material Types and G Values

Waste Material Type	Typical Material Description[a,b]	G Value[c]	Numeric Shipping Category Notation (G Value x 10^2) (YYYY)
I.1	Absorbed, adsorbed, or solidified inorganic liquid	1.6	0160
I.2	Soils, solidified particulates, or sludges formed from precipitation	1.3	0130
I.3	Concreted inorganic particulate waste	0.4	0040
II.1	Solid inorganic materials in plastic bags (watt*year ≤0.012)	1.7	0170
II.1	Solid inorganic materials in plastic bags (watt*year >0.012)	0.32	0032
II.2	Solid inorganic materials in metal cans	0	0000
II.3	Homogeneous solid inorganic materials with unbound absorbed ambient moisture (≤6% by weight) in metal cans	0.08	0008
III.1	Solid organic materials (watt*year ≤0.012)	3.4	0340
III.1	Solid organic materials (watt*year >0.012)	1.09	0109
III.2	Homogeneous mixed organic (10% by weight) and inorganic (90% by weight) materials in metal cans (watt*year ≤0.012)	0.34	0034
III.2	Homogeneous mixed organic (10% by weight) and inorganic (90% by weight) materials in metal cans (watt*year >0.012)	0.11	0011
III.3	Homogeneous mixed organic (10% by weight) and inorganic (90% by weight) materials in plastic bags (watt*year ≤0.012)	1.85	0185
III.3	Homogeneous mixed organic (10% by weight) and inorganic (90% by weight) materials in plastic bags (watt*year >0.012)	0.4	0040

[a] Appendix 3.3 of the CH-TRU Payload Appendices[1] provides a complete discussion of watt*year criteria.

[b] Solidified organic waste is not an authorized content for the TRUPACT-III.

[c] Dose-dependent G values meeting the watt*year criteria (watt*year >0.012) cannot be used if absorbed, adsorbed, or solidified aqueous materials are present in the waste (see Appendix 3.3 of the CH-TRU Payload Appendices[1]). Appendices 3.1 and 3.2 of the CH-TRU Payload Appendices[1] provide a complete discussion of G values.

Total Resistance

The determination of the total resistance to gas release of a payload container requires knowledge of the type and maximum number of layers of confinement used to package the waste. CH-TRU materials are typically placed in a payload container within multiple layers of plastic and/or metal cans that act as layers of confinement for radionuclides during waste handling operations. The payload safety analysis considers the layers of confinement as barriers that impede, but do not preclude, the release of gases from inside the layers of confinement (e.g., plastic bags or metal cans) to the outside of the payload container. Allowable closure methods for confinement layers are specified in Appendix 3.8 of the CH-TRU Payload Appendices[1]. The plastic layers of confinement in payload containers are of three types—liner bags, inner bags, and filtered inner and liner bags. As described in Appendices 3.8, 6.7, and 6.13 of the CH-TRU Payload Appendices[1], the release rates for confinement layers have been quantified or presented as specifications. Any other type of confinement layer used at the sites shall be shown to be equivalent to one of these for purposes of minimum hydrogen release.

The numeric payload shipping category notation used to denote the total resistance to hydrogen release of the packaging configuration of a payload container is the sum of the resistances from all confinement layers (seconds/mole) multiplied by 10^{-4}, rounded up, and reported as four digits (ZZZZ). For example, the shipping category notation for a total resistance of 459,100 seconds/mole is "0046."

8.1.6.2 Procedure for Determining Numeric Payload Shipping Category

Completion of Table 8.1.6-3 and Table 8.1.6-4, at the end of this appendix, constitutes the determination of the numeric payload shipping category.

8.1.6.2.1 Instructions for Completing Table 8.1.6-3: Numeric Payload Shipping Category Worksheet

For both tables, only the blank (unshaded) boxes need to be completed. Note that there are two separate columns for determining total resistance based on waste material type. Column 1 is used to calculate resistance factors for waste material types with G values based on water [waste material types with six-digit notations (XX YYYY) 10 0160, 10 0130, 10 0040, and 20 0008]. Column 2 is used to calculate resistance factors for all other waste material types. (Appendix 6.9 of the CH-TRU Payload Appendices[1] describes the logic for using different resistances based on waste material type.)

Container ID

Record the SLB2 container ID number in the space provided.

Waste Type

Record the two-digit waste type notation (XX) of the container from Table 8.1.6-1.

G Value

- From Table 8.1.6-2, determine the waste material type to which the container belongs.
- Record the G value for this waste material type from Table 8.1.6-2.
- Record the corresponding four-digit G value notation (YYYY) from Table 8.1.6-2.

Note: If the notation entered under Waste Type (XX) and G Value (YYYY) is 20 0000, the "Total Resistance Notation" to be entered at the bottom of Table 8.1.6-3 (ZZZZ) is always 0000, and the payload shipping category to be entered in the last row of Table 8.1.6-3 (XX YYYY ZZZZ) is 20 0000 0000. For Waste Material Type II.2 (20 0000), this completes the determination of the numeric payload shipping category, and the remainder of the instructions do not apply.

Total Resistance
For each packaging configuration, a unique resistance factor exists and is determined by totaling the individual resistance factors for the confinement layers, the payload container, and the load type. Instructions for completing this portion of the worksheet are as follows:

- Confinement Layers:

  Appendix 2.2, *Procedure for Determining Numeric Payload Shipping Category*, of the CH-TRU Payload Appendices[1] provides the individual resistance factors for the confinement layers specified in Table 8.1.6-3.

  Packaging: Choose the layers of confinement that are applicable to the payload container. As specified in Appendix 3.8 of the CH-TRU Payload Appendices[1], if a confinement layer used for the payload container is not listed, but has been shown by testing or analysis to be equivalent to (i.e., hydrogen release rate equal to or greater than) one of the entries, choose the equivalent entry.

  Type: Within each applicable layer of confinement, choose the closure type and calculate the "Total Resistance Factor" as shown below. If the confinement layer is filtered or if it is a rigid drum liner, the "Total Resistance Factor" for the layer is calculated using Table 8.1.6-4.

  Number of Layers: Enter the number of layers of confinement for each type of internal packaging that is applicable to the payload container. Leave the space blank or enter zero (0) if it is not applicable.

  Resistance Factor: Choose the "Resistance Factor" from either Column 1 or Column 2 that corresponds to the six-digit notation (XX YYYY) recorded above (see footnote "a" of Table 8.1.6-3). This is a numeric value associated with the resistance to hydrogen diffusion for each layer of confinement (resistance to hydrogen diffusion in seconds/mole divided by 100). The "Resistance Factor" for filtered or punctured confinement layers is calculated using Table 8.1.6-4.

Total Resistance Factor: Multiply the "Resistance Factor" by the "Number of Layers" of confinement for each applicable type of internal packaging. The total resistance factor for each confinement layer type is equal to the number of layers of confinement times the resistance factor (e.g., 2 twist-and-tape drum liner bags would have a total resistance factor of 2 x 2,142 = 4,284). Enter the "Total Resistance Factor" for each confinement layer type in the designated column on Table 8.1.6-3. Enter zero (0) or leave the space blank for confinement layers that are not applicable.

- Payload Container: Choose the "Resistance Factor" from either Column 1 or Column 2 that corresponds to the six-digit notation (XX YYYY) recorded above (see footnote "a" of Table 8.1.6-3). These values are derived from the minimum hydrogen diffusivity specified for the SLB2 in Section 2.4, *Filter Vents.*

- Load Type: Choose the "Resistance Factor" for appropriate shipping period and enter the chosen value in the "Total Resistance Factor" column. The load type resistance factors corresponding to the selected shipping period represent the terms t/N_{tg} in Equation 4 of Appendix 8.1.1, *Derivation of Flammable Gas Generation Rate Limits and Decay Heat Limits.*

- Total Resistance Factor Sum: Sum all the values in the "Total Resistance Factor" column and record on this line.

- Total Resistance Notation: Divide the "Total Resistance Factor Sum" by 100 and round up to the nearest whole number. Record "Total Resistance Notation" as four digits (ZZZZ) (e.g., for a total resistance factor sum of 4,591, 4,591 / 100 = 45.91, rounded up to nearest whole number is 46, and reported as four digits, the total resistance notation is 0046).

The "Payload Shipping Category" on the worksheet is determined by combining the three components of the shipping category determined above. The shipping category is recorded as XX YYYY ZZZZ.

8.1.6.2.2 Instructions for Completing Table 8.1.6-4: Filtered/Punctured Confinement Layers Resistance Worksheet

Packaging Type: Choose the layers of confinement that are applicable to the payload container.

Minimum Filter Hydrogen Diffusivity/Minimum Puncture Diameter: Choose the appropriate filter based on the minimum hydrogen diffusivity applicable to the filter. Section 2.4, *Filter Vents,* lists the venting requirements for the payload container and the confinement layers. Sites shall verify and document the use of filters with greater hydrogen diffusivity values in order to take credit for the associated decrease in total resistance per packaging configuration.

For the rigid drum liner, choose the value that matches the puncture diameter or filter diffusivity in the liner.

If the hydrogen diffusivity or puncture diameter of the confinement layer falls in between the numbers listed, select the lower value. For example, if a container has a rigid liner with a puncture diameter of 0.5 inch, select "0.375" Diameter Hole."

Number of Layers: Enter the number of layers of confinement for each type of internal packaging that is applicable to the payload container. Leave the space blank or enter zero (0) if it is not applicable.

Resistance Factor: Choose the "Resistance Factor" from either Column 1 or Column 2 that corresponds to the six-digit notation (XX YYYY) recorded on Table 8.1.6-3 (see footnote "a" of Table 8.1.6-4). This is a numeric value associated with the resistance to hydrogen diffusion for each layer of confinement.

Number of Filters/Punctures per Layer: Enter the number of filters in each confinement layer or the number of punctures in the rigid liner. If the number of filters on a given type of confinement layer varies from layer to layer, enter the minimum number of filter(s) that applies to all layers of that type. For example, if a payload container holds waste packaged in two filtered inner bag layers, one bag fitted with one filter, and one bag fitted with two filters, enter "1" for the "Number of Filters/Punctures."

Total Resistance Factor: The Total Resistance Factor for each layer is obtained as follows:

$$\frac{\text{Resistance Factor * Number of Layers}}{\text{Number of Filters/Punctures per Layer}}$$

If the calculated "Total Resistance Factor" is not a whole number, round up to the nearest whole number. Enter this number in the appropriate column in Table 8.1.6-4 and Table 8.1.6-3. Enter zero (0) or leave the space blank if it is not applicable.

Table 8.1.6-3 — Numeric Payload Shipping Category Worksheet

Container ID Number:						
Two Digit **Waste Type** Notation (XX) from Table 8.1.6-1						
G Value for Waste Material Type from Table 8.1.6-2		Four Digit G Value Notation (YYYY) from Table 8.1.6-2				
	Packaging	**Type**	**Number of Layers**	**Resistance Factor (Use One Column Only)[a]** Column 1	Column 2	**Total Resistance Factor[b]**
Confinement Layers	Inner Bag Layers	Filtered	From Table 8.1.6-4			
		Twist and Tape		23,989	17,922	
		Unvented Heat-Sealed Bag		c	115,741	
	Confinement Layers (e.g., Metal Can)	Slip-Top/Unsealed		0	0	
		Filtered	From Table 8.1.6-4			
	Liner Bag Layers	Filtered Drum Liner Bag	From Table 8.1.6-4			
		Twist and Tape Drum Liner Bag		2,142	2,142	
		Filtered SWB/Bin/TDOP Liner Bag	From Table 8.1.6-4			
		Fold and Tape SWB/ Bin/TDOP Liner Bag		1,257	1,257	
	Rigid Drum Liner	Rigid Liner	From Table 8.1.6-4			
Payload Container	SLB2	Filtered (6.6×10^{-4} m/s/mf)		21	16	
Load Type	Shipping Period: **60 Days (General Case)[d]**		559			
	Shipping Period: **10 Days (Controlled Shipment)[d,e]**		94			
Total Resistance Factor Sum						
Divide Total Resistance Factor Sum by 100 and Round Up to Whole Number						÷ 100
Total Resistance Notation (ZZZZ) Report as Four Digits If Waste Material Type II.2 (20 0000), enter 0000.						
Payload Shipping Category (XX YYYY ZZZZ)						

a Use Column 1 for the following six-digit notations (XX YYYY): 10 0160, 10 0130, 10 0040, and 20 0008. Use Column 2 for all other six-digit notations.

b Multiply the "Number of Layers" by the appropriate "Resistance Factor" to obtain the "Total Resistance Factor."

c A resistance factor has not been established for this confinement layer with these waste material types (Column 1).

d See Appendices 8.1.2 and 8.1.3 regarding the selection of a shipping period.

e The 10-day shipping period may be used only if the requirements for controlled shipment are met as described in Appendix 8.1.3.

Table 8.1.6-4 — Filtered/Punctured Confinement Layers Resistance Worksheet

Packaging / Type	Minimum Filter Hydrogen Diffusivity/Minimum Puncture Diameter	Number of Layers	Resistance Factor[a] (Use One Column Only) Column 1	Column 2	Number of Filters/ Punctures per Layer	Total Resistance Factor[b]
Inner Bag Layers: Filtered[c]	1.075×10^{-5} m/s/mf Filter		1,290	931		
	2.150×10^{-5} m/s/mf Filter		645	466		
	5.375×10^{-5} m/s/mf Filter		258	187		
	2.688×10^{-4} m/s/mf Filter		52	38		
	1.075×10^{-3} m/s/mf Filter		13	10		
Filtered Confinement Layers (e.g., Metal Can)	3.7×10^{-6} m/s/mf Filter		3,746	2,703		
	7.4×10^{-6} m/s/mf Filter		1,873	1,352		
	1.85×10^{-5} m/s/mf Filter		750.5	541		
	9.25×10^{-5} m/s/mf Filter		150	109		
	3.7×10^{-4} m/s/mf Filter		38	28		
Liner Bag Layers: Filtered Drum Liner Bag[c]	1.075×10^{-5} m/s/mf Filter		933	673		
	2.150×10^{-5} m/s/mf Filter		542	391		
	5.375×10^{-5} m/s/mf Filter		240	173		
	2.688×10^{-4} m/s/mf Filter		51	37		
	1.075×10^{-3} m/s/mf Filter		13	10		
Liner Bag Layers: Filtered SWB/Bin/TDOP Liner Bag[c]	1.075×10^{-5} m/s/mf Filter		764	551		
	2.150×10^{-5} m/s/mf Filter		480	347		
	5.375×10^{-5} m/s/mf Filter		227	164		
	2.688×10^{-4} m/s/mf Filter		51	37		
	1.075×10^{-3} m/s/mf Filter		13	10		
Rigid Drum Liner	0.3" Diameter Hole		197	197		
	0.375" Diameter Hole		126	126		
	0.75" Diameter Hole		32	32		
	1" Diameter Hole		18	18		
	2" Diameter Hole		5	5		

a Use Column 1 for the following six-digit notations (XX YYYY): 10 0160, 10 0130, 10 0040, and 20 0008. Use Column 2 for all other six-digit notations.

b Multiply the "Number of Layers" by the appropriate "Resistance Factor" and divide by the "Number of Filters/Punctures per Layer" to obtain the "Total Resistance Factor."

c No credit allowed for filter if waste is directly packaged in a filtered bag and there is potential for contact of the filter with water (see Appendix 3.11 of the CH-TRU Payload Appendices[1]).

m/s/mf = Moles/second/mole fraction.

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